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HOW I DO IT - NEUROSURGICAL TECHNIQUE EVALUATION

How I do it: tapered rod placement across the cervicothoracic junction for augmented posterior constructs

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Abstract

Background Posterior instrumentation techniques are commonly employed for cervicothoracic fixation. The pedicles of the upper thoracic vertebrae can typically accommodate larger diameter screws than the subaxial cervical vertebrae. In many construct systems, this requires the use of a tapered rod, which can be technically challenging to place.

Method Using a three-dimensionally printed biomimetic spine simulator, we illustrate the stepwise process of instrumentation and tapered rod placement across the cervicothoracic junction (CTJ).

Conclusion Tapered rod systems can augment the biomechanical stability of cervicothoracic constructs. Ease of rod placement across the CTJ hinges upon a systematic method of instrumentation.

Keywords Tapered rod · Thoracic pedicle screws · Cervicothoracic junction · Spinal Biomechanics · 3D print

Relevant surgical anatomy

The bony interface of the cervicothoracic junction (CTJ) consists of the C7 inferior and the T1 superior facets bilaterally [8]. The CTJ is a transitional zone that shifts from the highly mobile cervical spine to the near immobile thoracic spine, thus placing this area at risk for iatrogenic instrumentation failure or adjacent segment disease [4].

The pedicles of the subaxial cervical vertebrae increase in size from C3 to C7 [9]. The pedicle of C7 is generally angled more medially than T1, and this anatomical difference should be considered when choosing screw starting points with respect to rod placement [1]. The C7 vertebra often possesses a transverse foramen, but very rarely contains the vertebral artery. This anatomic pearl allows for safe placement of C7 pedicle screws with less concern for neurovascular injury than the other subaxial cervical vertebrae [3]. T1 and T2 typically possess the largest upper thoracic pedicle diameters, allowing for relatively large diameter pedicle screw insertion. This is biomechanically advantageous for CTJ fixation, especially in cases of traumatic instability, poor bone quality, or severe deformity correction [9].

In cases of scaled diameter pedicle screw insertion across the CTJ, a tapered rod is often required for transitioning from cervical to thoracic instrumentation systems [6].

Description of the technique

Preoperative considerations

An MRI and CT scan are performed in patients undergoing posterior instrumentation across the CTJ. The pedicle morphologies and diameters of C7–T2 are carefully reviewed for screw placement feasibility as well as dimensional planning. If there appears to be a vertebral artery located within the C7 transverse foramen, C7 lateral mass screws are placed instead of pedicle screws to avoid potential injury [2].

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Patient positioning

The patient is positioned prone with a pinion head holder. The patient's head is placed in a neutral position with eyes level to the floor. If necessary, a preoperative fluoroscopic image is taken to check vertebral alignment before making incision. Electrophysiologic monitoring is used in cases of deformity correction or severe canal stenosis where a decompression is required.

Technique

The skin is incised with a 10-blade knife to the subcutaneous tissue. Hemostasis is achieved, and with monopolar cautery the midline plane through the nuchal ligament is identified and followed to the spinous processes. A subperiosteal exposure is performed, and the posterior elements are exposed in their entirety. If C2 is to be included in the construct, we prefer to instrument this level first. C2 pedicle screws are inserted using an anatomic freehand technique with direct pedicle visualization. After this is performed, attention is turned to the CTJ, where a systematic method is employed to ensure feasibility of tapered rod placement. The C7 pedicle screws are planned utilizing a small laminotomy with direct pedicle palpation and visualization. Before the pedicle screws are placed, the C6 lateral mass pilot holes are created with a high-speed burr slightly superior to the midpoint of the C6 lateral mass to prevent crowding of the screw heads at C6–7.

After the C7 pedicle screws are placed, the T1 and T2 pedicle screws are inserted using freehand technique. The heads of the C7 pedicle screws can be used as a guide for starting points of the thoracic screws. We prefer to use a 5.5-millimeter (mm) rod system for the upper thoracic spine to exploit the biomechanical stability through maximal bone purchase. In our experience, T1 and T2 will typically accommodate a 6.5-mm or 7.0-mm screw diameter. After these screws are placed, the CTJ is inspected for harmonious alignment of the C6, C7, T1, and T2 screw head heights and medial/lateral placement. The remainder of the lateral mass pilot holes can be drilled and tapped, aligning with the existing instrumentation. The entry point and trajectory are based upon the Roy-Camille technique [5]. If a decompression is required, we prefer to place the lateral mass screws after the decompression is completed so the screw heads do not obstruct the surgeon during bone removal.

In order to measure the proper rod length as well as tapering point, the monopolar cautery cord is inserted through the screw heads, with one clamp placed at the transition point, and the other just distal to the T2 screw head. This measurement can be used to cut the tapered rod at the appropriate points. Manual contouring should be kept to a minimum to preserve rod integrity. If screw placement has been systematically planned across the CTJ at this point, the tapered rod should easily fit by contouring slight lordosis in the cervical portion. Bailout options if rod placement is not possible across the CTJ include removal of the C7 screws, or lateral connection to two different rod systems. One rod system is preferred in our experience for ease of alignment, and a cross connector may be employed at this level to further enhance stability. Set screws can be placed sequentially, which can assist in lowering the rod into the screw heads. After the system is finally tightened, AP and lateral fluoroscopy are used to confirm instrumentation position as well as rod placement. Intraoperative CT may be used if there is a concern for screw misplacement.

Indications

Indications for tapered rod placement across the CTJ include osteoporosis, large cervical deformity correction, oncologic deformity, severe trauma, or revision surgery with previous pseudoarthrosis.

Limitations

Tapered rod systems are weakest at the transition point and have limited manipulability. If instrumentation placement is

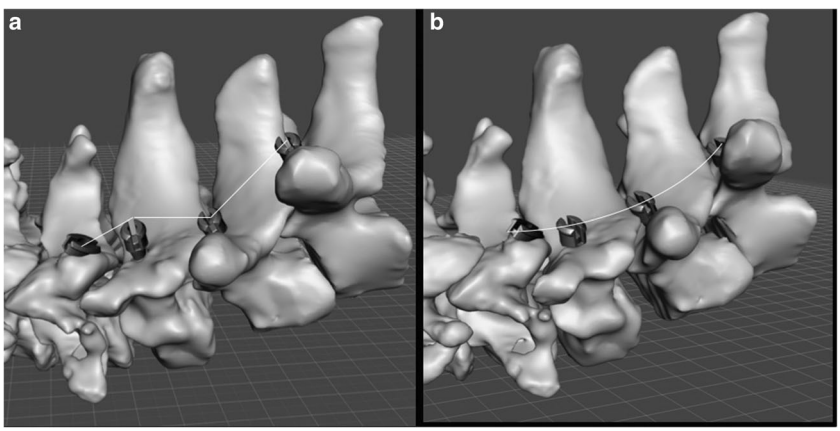

Fig. 1 **a** Three-dimensional illustration of "up-down" misalignment (white line) in adjacent screw heads that can result in excessive manipulation of the rod during placement. **b** The offending instrumentation can be replaced, slightly reversed, or slightly lowered to achieve harmonious alignment (white line). In this case, the C7 and T2 screws have been inserted slightly to achieve rod height balance

not carefully planned with future rod placement in mind, screw head misalignment may preclude usage.

How to avoid complications

The most common complication that occurs when placing a tapered rod is screw breakage or pull out with excess manipulation. It is imperative that the operator remains mindful of the manual force exerted during rod placement to prevent losing bony purchase. The most common mistake is "up-down" misposition of screw heads. If this occurs and there is excessive force required to fit the rod into the construct, then the operator may consider slightly reversing or driving in misaligned screws to achieve a neutral configuration. This is illustrated using a 3D simulation software (Meshmixer, Autodesk; 2017) in Fig. 1.

Specific perioperative considerations

Patients with prolonged surgical times or deformity correction requiring mechanical ventilation postoperatively are assessed under intensive care. A cervicothoracic orthosis is placed before leaving the operating room and is maintained for 6–12 weeks postoperatively, depending on surgical indications.

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

Preoperatively, patients are counseled about the general risks of posterior cervicothoracic surgery including major bleeding requiring a transfusion, neurovascular injury, swallowing difficulty (in cases of kyphotic deformity correction), instrumentation failure, thoracic visceral structure injury, and the possible need for additional surgery in the future [7].

Summary of ten key points

1. Patient selection is made by the requirement for enhanced biomechanical stability across the CTJ
2. Preoperative imaging is key for surgical planning and tapered rod placement feasibility
3. Neutral head position in pinions
4. C6 lateral mass pilot holes are placed before C7 pedicle screws for maximizing construct alignment and preventing crowding
5. The upper thoracic pedicle screws are placed using the C7 pedicle screw starting points as a guide
6. Two small clamps are used on the flexible cautery cord to determine tapered rod position
7. Slight lordosis is placed into the cervical portion of the tapered rod
8. Reduction devices and in-situ bending are minimized
9. Screws can be driven in or slightly reversed if heights are not harmonious
10. Intraoperative fluoroscopy is used for instrumentation and rod assessment

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent This article does not contain any studies with human participants performed by any of the authors.

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