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  - HALO application → see p. TrS5 >>
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**CHOICE OF APPROACH**

Surgery must address two PATHOPHYSIOLOGIC COMPONENTS:

- **Static** – surgical decompression
- **Dynamic** – surgical fusion
• when choosing which levels to operate, always attempt to correct kyphosis (← puts lots of stress on cervical facets).
• ventral fusion surgery has been shown to yield better quality of life (QOL) outcomes than dorsal fusion surgery.
• complication rates (for rates of specific complications see specific approaches – anterior or posterior).
  a) ventral fusion surgery (11-13.6%) – dysphagia, esophageal injury, cardiopulmonary events, hoarseness (n. laryngeus recurrent injury due to traction), vertebral artery injury.
  b) dorsal fusion surgery (16.4-19%) - significant postoperative muscular pain, nerve (C5) palsies, pulmonary complications, hematomas, higher operative blood loss, wound infection.

N.B. complication rates and costs are significantly greater for dorsal fusion compared with ventral fusion!

**Posterior approach** – for multilevel disease:
1. **Laminectomy ± medial facetectomy ± fusion**
   • laminectomy is fastest way to decompress poor surgical candidates.
   • allows foraminotomy (root compression due to osteophytes).
   • not suitable in pronounced cervical kyphosis (kyphosis may be exaggerated by taking MRI with pillow under occiput).
   • wide laminectomy (over at least 3-5 levels) – standard for diffuse spinal stenosis; may be complicated in later years by:
     1) swan neck deformity owing to loss of posterior support;
     2) increased cervical mobility → increased risk of further spondylosis progression.
     H: lateral mass fusion.
     N.B. posterior approach is limited to patients who have either neutral or lordotic alignment!
2. **Laminoplasty** – preserves posterior tension band but still 40% patients need fusion; more suitable for young patients with oncologic indications.

**Anterior approach** – for more focal disease with less neurological deficits:
1. **Discectomy with interbody fusion (ACDF)** – especially suitable for vertebral osteophytic ridges or chronic disc herniations; best decompression for radiculopathies. see p. Spin11 >>

2. **Corpectomy with graft:**
   a) autograft (iliac crest) – very rapid fusion (advantageous in trauma cases)
   b) allograft – no postoperative iliac pain (advantageous in spondylosis cases)
   • minimal postoperative pain because the only muscle cut is platysma (patients tolerate anterior approach much better than posterior; plus, posterior approach caries higher rate of infection); other muscles are split apart (don’t hesitate split muscles higher and lower → less traction force required → less postoperative dysphagia and pain).

**360° (circumferential) approach** – combination of anterior and posterior approaches.

Global sagittal plane deformity may go unnoticed if only regional spinal imaging is assessed → unfavorable outcomes.
- maintain a low threshold for obtaining LCRs (long cassette standing XR, s. scoliosis film, s. spine survey film) as part of preoperative evaluation for cervical spine pathology – may significantly influence surgical decision-making.

### MOTION SEGMENTS

<table>
<thead>
<tr>
<th></th>
<th>Bifid Spinous Process</th>
<th>Transverse Foramen / Vert?</th>
<th>Flexion/Extension</th>
<th>Rotation</th>
<th>Lateral Bend</th>
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<tbody>
<tr>
<td>Occiput-C1</td>
<td></td>
<td></td>
<td>50</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>C1 (Atlas)</td>
<td>None</td>
<td>Yes / Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2 (Ax/s)</td>
<td>Yes</td>
<td>Yes / Yes</td>
<td>10</td>
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<td>Yes / Yes</td>
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<td>Yes</td>
<td>Yes / Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>Yes</td>
<td>Yes / Yes</td>
<td>50 (10/level)</td>
<td>50 (10/level)</td>
<td>60 (12/level)</td>
</tr>
<tr>
<td>C6</td>
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<td>Yes / Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C7 (VP)</td>
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<td>Yes / No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Motion</td>
<td></td>
<td></td>
<td>110</td>
<td>100</td>
<td>68</td>
</tr>
</tbody>
</table>

### HARDWARE

- some of the instrumentation systems are currently categorized as class III devices by FDA.
- most internal fixation devices are classified as temporary devices - intended to be implanted for > 30 days but *not intended to be implanted permanently*:
  - Orthopedic Surgical Manufacturer’s Association recommends that, whenever possible and practical, bone fixation devices should be removed when their service as an aid to healing is completed
  - general clinical opinion is that cervical instrumentation that leads to successful fusion without complication does not need to be removed.
  - each patient should receive preoperative counseling concerning this difference of opinion.
  - when patients understand the risks of repeat surgery yet request removal of hardware after bone fusion has occurred, every attempt should be made to comply with their wishes.

### INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING

See p. D25 >>
OUTCOMES

Importance of preoperative opioids on pain outcomes

JB Wick et al. “Is There a Preoperative Morphine Equianalgesic Dose that Predicts Ability to Achieve a Clinically Meaningful Improvement Following Spine Surgery?” Neurosurgery 83:245–251, 2018

- 543 cervical and 1293 lumbar patients (26% cases were revision surgeries)
- 55.5% patients used preoperative opioids.
- 50.3% of cervical and 61.9% of lumbar patients achieved MCID (minimum clinically important difference - 17.3% improvement for neck disability index for cervical patients / 14.9% improvement for Oswestry disability index for lumbar patients) at 12 mos postop.
- the best fit curve representing mean percentage of patients achieving minimum clinically important difference (MCID) on the Oswestry Disability Index or Neck Disability Index at 12 mo after lumbar or cervical surgery, respectively, vs preoperative morphine equianalgesic (MEA) dose in mg/d.
  — the change point occurred at an MEA dose of 47.8 mg/d (with a 95% credible interval of 29.0 to 60.0 mg/d) – for such patients, it may be appropriate to withhold surgery and instead refer to a pain management specialist or psychiatrist for preoperative opioid weaning; authors recommend as a cutoff to use 29 mg/d because it is roughly equivalent to commonly used regimens, such as oxycodone 10 mg TID.

Patients with preoperative MEA dose exceeding 47.8 mg/d are significantly less likely to achieve MCID

- preoperative opioid use is associated with decreased scores on postoperative patient-reported outcome (PRO) measures in spine surgery (worse outcomes are likely multifactorial, including concurrent psychiatric distress in those on opioids; plus, opioid-dependent individuals experience hyperalgesia due to altered cellular physiology and an abnormal pain response).
- total 30% of all spine surgery candidates use > 29 mg MEA/d preop!

VARIOUS UNDERLYING PATHOLOGIES

OSTEOPOROTIC SPINE
See p. Op220 >>
**CARROT-STICK FRACTURE (ANKYLOSING SPONDYLITIS)**

- routine use of CT and MR is recommended even after minor trauma.
- fractures are very unstable until healed – typically require surgical stabilization: Fixed-angle screws!!
  
  a) long segment rigid PCF – might preferable, esp. to achieve reduction (reduction under live fluoro using Mayfield, then long segment fusion, e.g. C2-Th2).
  
  b) ACDF + PCF
  
  c) ACDF with 3-level plate (so 4 screws above and 4 screws below fractured level)

  N.B. stand-alone anterior fusion → 50% failure rate; it might be difficult to achieve reduction (esp. of large distractions) via anterior approach

- very high (up to 30%) mortality regardless of treatment offered or surgical approach used; most important risk factor – age.

**ANTERIOR NECK APPROACH**

BMP is contraindicated in neck anteriorly!

**INDICATIONS**

Cervical spondylosis with myelopathy / radiculopathy – see p. Spin13 >>

**CONTRAINDICATIONS**

Patients whose careers prohibit any risk for voice alterations may best be treated with posterior foraminotomies or laminectomies (left-sided approach has lower risk of recurrent laryngeal injury).

**PREOP**

- check vocal cords if going to operate on someone who had anterior neck surgery on opposite side; alternative – use vocal cord EMG (commercially available ET tube with mounted electrodes).
- Dr. Cameron and Dr. Broaddus give 10 mg of DEXAMETHASONE to everybody – decreases postop dysphagia from 72.5% to 40%; slows down fusion (from 57% to 31% at 6 months) but final fusion rates are the same (74% vs. 72% at 12 months).

  “Dexamethasone Improves Outcomes in Spinal Fusion” Congress of Neurological Surgeons (CNS) 2013 Annual Meeting. Abstract #158. >>

  Dr. Kazemi sprays DepoMedrol on esophagus at the end of case.
- Dr. Rivet uses fluoro and microscope (80% of the time). N.B. fluoro shot for incision planning and leave in (drape together with field draping).

**POSITIONING**

- slight reverse Trendelenburg position.
- Rick doesn’t use esophageal tubes (temperature probe, OG tube) – increases risk of esophageal damage; but orogastric tube can help with identification of esophagus in reoperative cases.
- arms tucked and padded at sides; wrap arms in gel pads to protect ulnar nerve.
- head on padded horseshoe head holder
- head in extended* position (IV saline bag\(^1\) longitudinally** underneath neck*** not shoulders\(^2\)).
  
  *if myelopathic, keeping neck in neutral position without additional manipulation
  ** Dr. Graham - transversely
  ***to support neck from behind during procedure (not for extension); therefore,
  shoulders and neck should be above table

\(^1\)Dr. Mathern prefers folded towels
\(^2\)Dr. Day places roll longitudinally between scapulae - allows shoulders fall backwards.

- Drs. Graham, Ward, Simon, Cameron, Mathern use \textbf{5-10 pounds of in-line cervical traction} (not always necessary); pad straps over cheeks to avoid pressure ulcers.
  
  Dr. Broaddus does not use – due to risk of pressure sores on chin.
  Dr. Cameron does not use – no benefit (unless need to move away “second chin”).

- optional - place hemostat on skin (along natural skin crease) → preoperative fluoroscopy shot - to plan skin incision over desired vertebral body.

\textbf{INCISION}

- some experts always use \textbf{left-sided approach} - lower chances of recurrent laryngeal nerve injury.
- transverse skin incision along skin crease; may \textit{palpate carotid tubercle on C6} to select incision height (also look at MRI – what levels skin folds correspond).
  
  Dr. Rivet uses incision across midline!
  Dr. Cameron uses “carotid” skin incision along anterior sternocleidomastoid border for 4-level ACDF; opens platysma along fibers

For \textit{trauma cases}, try to use “carotid” skin incision (transverse incision may interfere with tracheostomy if patient will need one)

C1-3—1 cm below angle of the jaw
C3-4—hyoid bone
C4-5—top of the thyroid cartilage
C5-6—bottom of thyroid cartilage
C6-7—top of cricoid cartilage
Chassaignac’s tubercle on the transverse process of C6
C7-T1—bottom of cricoid cartilage

\textbf{Landmarks for levels:}

- Hyoid bone: C3
- Thyroid cartilage: C4-5
- Cricoid: C6
- Carotid tubercle: C6
• Left incision:
  - *LEFT* recurrent laryngeal n. has more predictable course than *RIGHT*
• Right incision:
  - Easier for right handed surgeon

- if it is difficult to ascertain level accurately, mark incision slightly superior to estimated level of pathology; it is easier to expose inferiorly than superiorly.
• dissect subcutaneous tissue down to platysma – with Metz scissors and DeBakey forceps
• split platysma – with scissors or Bovie* (over scissors placed underneath platysma).

*Dr. Graham likes scissors; Dr. Rivet uses Bovie

• use bipolar cauterization for hemostasis.
• important to mobilize tissue planes (superiorly and inferiorly) below platysma – allow to access more levels via shorter incision.
• sharply dissect avascular plane medial to SCM; if EJ is encountered dissect it from SCM and retract medially (if bleeds → vascular clip / sacrifice).
• blunt dissection with Kittner dissector and Cloward retractor medial to carotid sheath - until anterior vertebral fascia encountered which is swiped with Kittner as well.
  – avoid swiping up and down widely – creates potential space for hematoma
  – for upper cervical levels, make sure you are lateral to strap muscles (otherwise will be difficult to reach those levels).
  – for lower cervical levels, make sure you are inferior to omohyoid (practically, never needed).
• deflate and reinflate the endotracheal tube cuff following retractor placement – helps cuff to reposition (esp. important if using immobile table-mounted retractor).
**LOCALIZATION**

- XR needle localization of disk level – *always insert double-bent spinal needle at the highest accessible level* (if lower – bulky patient’s shoulders may obscure XR).
Drs. Rivet, JRC use fluoro and blunt instrument* (do not use needle! – accelerates degeneration if chose wrong level) *e.g. clamp tip of mosquito on prevertebral fascia. 

Dr. Mathern uses straight needle (with hemostat attached for depth gage) – if disc space is obscured, surgeon may judge by needle trajectory

- if disc space is covered with osteophyte (“patella”), do one XR, remove osteophytes with Leksell to see actual disc space – insert needle there and do second XR (may use fluoroscopy instead to avoid calling radiology again in 5 minutes).

**CLOSURE**

- irrigate with bacitracin-containing solution.
- inspect esophagus – repair if injured.
- drain directly overlying vertebrae, medium Hemovac. Dr. Graham likes drain to exit below incision – more comfortable when exits collar Dr. Rivet uses drain only occasionally
- platysma reapproximated with 2-0 Vicryl.
- subcutaneous layer with skin closed with rare 4-0 Vicryl in interrupted inverted manner (esp. Dr. Rivet uses thin sutures).
- Mastisol and Steri-Strips.
- Aspen cervical collar for 6 weeks (apply while still intubated); Dr. Simon may not use collar; Dr. Cameron does not use collar for any ACDFs; Dr. Broaddus does not use collar for 1-level ACDFs.

**COMPLICATIONS**

(11-13.6%)

1) dysphagia (3-10%)
2) esophageal injury – usually only big hole is visible.
3) hematoma (6%)
4) hoarseness (0.21%)
5) n. laryngeus recurrent injury due to traction (≈ 2.4-3 %); H: deflate ET cuff; for lower cervical levels choose right side! — before performing reoperative surgery on opposite side, direct laryngoscopy should be performed to identify existing vocal cord paralysis.
— do not use Bovie below C6
6) cardiopulmonary events
7) thoracic duct, which if injured results in chylothorax, is present only on the left side.
8) injury to sympathetic chain H: do not dissect lateral to longus colli muscles and elevate muscle subperiosteally, do not overdistract.
9) vertebral artery injury – study MRI / CT carefully (VA medial to pedicle is a contraindication for anterior discectomy)


141 CSRS members responded to the survey (total of 163,324 cervical spine surgeries): the **overall incidence of VAI was 0.07%**. Posterior instrumentation of the upper cervical spine (32.4%), anterior corpectomy (23.4%), and posterior exposure of the cervical spine (11.7%) were the most common stages of the case to result in an injury to the vertebral artery. Discectomy (9%) and anterior exposure of the spine (7.2%) were also common time points for an arterial injury. One-fifth (22/111) of all VAI involved an anomalous course of the vertebral artery. The most common management of VAI was by direct tamponade. The outcomes of VAIs included no permanent sequelae in 90% of patients, permanent neurologic sequelae in 5.5%, and death in 4.5%. Surgeons at academic and
private centers had nearly identical rates of VAIIs. However, surgeons who had performed 300 or fewer cervical spine surgeries in their career had a VAI incidence of 0.33% compared with 0.06% in those with greater than 300 lifetime cases (p5.028).

**ANTERIOR DISCECTOMY**

For indications - see p. Spin11 >>

N.B. preoperatively **check vertebral artery anatomy** – at what level enters foramen transversarium, what is the course (if suspicious → order CTA – better than intraop VA injury)!

- intervertebral space is marked with double bent spinal needle → XR → keep eye on needle, take it out and immediately mark disc space with Bovie.
- bilateral longus colli muscles taken out with **protective-tip Bovie** cauterization (Rick leaves tissue line in midline for orientation; Dr. Rivet marks midline while longus colli still intact – midline is very clear) – coagulate anterior disk surface, then between muscle and vertebra (retracting muscle edge laterally with Bovie tip and staying all the time below* muscle).

*if above – risk of Horner’s syndrome

- Shadow-Line / Boss hand-free retractor (serrated blade goes laterally, smooth – medially not to injury esophagus).
  — when retractor is placed, deflate and then reinflate endotracheal tube cuff - recenters endotracheal tube within larynx and may reduce incidence of **recurrent laryngeal nerve** injury.
  — when significant retraction is needed, visual inspection of **esophageal** undersurface can identify small tears that can be primarily repaired with absorbable sutures.
- annulotomy (No. 15 blade; Dr. Rivet never uses blade – too easy to plunge down on the cord) → **superficial diskectomy** (with pituitary rongeur).
- two different techniques for **deep diskectomy**:

### SMITH-ROBINSON TECHNIQUE

**Caspar pins** screwed into centers of vertebral bodies → insert Kerrison in disk space and rotate (to loosen disk space and uncovertebral joints) → in situ distraction with Caspar distractor → deep diskectomy with 2-0 and 3-0 curved curette + 2- and 3-mm Kerrison.

- work to well expose posterior lip of vertebral body (and remove osteophytes, if needed)
- place pins in parallel (or slightly convergent at top and bottom levels – upon distraction help to open posterior portion of disc space)
- too much distraction may brake vertebral body (bad only at top and bottom levels)
**Cervical Spine Surgery (Techniques)**

- **Interbody Graft:**
  - Distraction Posts
    - Inserted divergent
    - Distraction creates lordosis
  - Interbody graft
    - Lordotic shape
    - Slightly oversized
      - Increase disc/foraminal height

- **Discectomy and Decompression:**
  - Uncinate process
    - Vertebral artery lateral
  - Decompression
    - From uncinate process - to - uncinate process

---

**Cloward Technique**

(Dr. Graham in 99% cases, Young)

- Disadvantages:
  1. More difficult to achieve lordosis than with Smith-Robinson
  2. Native bone ingrowth in center of dowel lags a lot (long distance for cells to migrate); sometimes center of dowel disintegrates
- **Disk space drilling** – tuck Cloward drill guide over center of disk space (or disk space intersecting between upper 2/3 and lower 1/3 of field seen); may use instrument in disk space while placing drill guide (helps center drill guide; mark midline with pen!!) → drill incrementally (first leave 3 threads visible and drill; after removing drill inspect disk space through lumen of drill guide – make sure disk space is in center, plus, if still bone visible; advance by 1-2 mm until no bone visible, i.e. stop within 1 mm of posterior cortical aspect);
  - if drill guide becomes dislodged, there is cylinder guide to help reposition drill guide.
  - trim cadaver bone dowel to 12 mm length; impact it while anesthesiology applies traction.
  - Dr. Mathern - prepare disc space completely in Smith-Robinson way, then use special guiding instrument to guide drill guide and do drilling; dowel has to countersink 2-3 mm.

**Other Aspects**
- posterior ligament may be removed, esp. Dr. Simon but not for Dr. Tye; Dr. Mathern, Dr. Cameron try to avoid it to decrease risk of epidural hematoma esp. not to go too lateral into foramen – does not give any benefit (foramen is mainly opened by disk height restoration) - foraminal bleeding plexus is venous – use FloSeal on both sides of graft; if vertebra is wide then blood should easily escape anteriorly along sides of graft.
- remove anterior osteophytes with Kerrison / Leksell to provide optimal bone-plate interface
- neural foraminal decompression: scrape upwards with curette, then use 2 mm Kerrison; check with blunt nerve hook (Dr. Holloway thinks it may damage nerve and discourages that):
- Drs. JRC, Rivet, Simon use microscope.
- Dr. Simon uses SSEP and motor potential monitoring.
- disc fragments behind vertebral body:
  a) use 45° curette to cut posterior vertebral body; use blunt nerve hook “to fish out” disc fragments.
  b) Cloward technique
  c) corpectomy
- hemostasis for epidural venous bleeding – inject powerfully 5-10 mL of saline into epidural space (between dura and bone) – bleeding stops:
ANTERIOR INTERBODY ARTHRODESIS

NASS Clinical Guidelines for Cervical Radiculopathy from Degenerative Disorders (2010):
The addition of an interbody graft for fusion is suggested to improve sagittal alignment following ACD. Both ACDF with and without a plate are suggested as comparable treatment strategies, producing similar clinical outcomes and fusion rates, in the treatment of single level cervical radiculopathy from degenerative disorders. The addition of a cervical plate is suggested to improve sagittal alignment following ACDF (grade of recommendation: B).

Indications for axial neck pain – see p. Spin19 >>

**SMITH-ROBINSON TECHNIQUE**

- use curette to scrape endplates; Dr. Rivet uses drill extensively!
- use rasp to make rough surface (release Caspar distraction for this).
  - Remove end plates to expose blood-rich cancellous bone!
- remove all bone distraction instruments.
- use trialer to find appropriate graft height.
- place lordotic interbody graft (e.g. Cornerstone graft); if needed, use impactor:
- mechanically, graft should extend as far posteriorly as safely possible.
- Dr. Rivet uses PEEK grafts and does not use inserter (uses fingers and impactor).
- release distraction and remove Caspar pins (bone wax – “witch hat” – into bleeding holes).
- irrigate with bacitracin-containing solution.
- if working on > 1 levels, do the same for next level (always start on worst level).

**DEPUY**

VG2® Cervical Allograft
HEALOS® Bone Graft Replacement

Ideally, graft should extend to vertebral body edges where resistance to compression is highest (“tin can” model):

- lateral to anterior superior iliac spine to avoid inadvertent damage to lateral femoral cutaneous nerve.

**ILIAC CREST**

- composite bone substitute material consisting of P-15 synthetic collagen fragment adsorbed onto anorganic bone mineral suspended in an inert biocompatible hydrogel carrier.
- results in ACDF - similar outcomes compared to local autograft bone at 2 yr following surgery.

**ENDOSKELETON® NANOLOCK (TITAN SPINE)**
Barbara Boyan, Ph.D., Dean of the School of Engineering at Virginia Commonwealth University and an investigator in various Titan Spine studies, said, “The nanoLOCK™ surface topography is far different than what is found on titanium-coated PEEK implants. In addition, the nanoLOCK™ surface is not created by applying a coating, but rather is formed by a reductive process of the titanium itself. This eliminates the potential for delamination, which is a concern for products with a PEEK-titanium interface.”

**CLOWARD TECHNIQUE**

- **Cloward dowel rod allograft** is soaked for 30 seconds in saline, trimmed (to ≈ 12 mm), and tapped into the defect.
- drill – 10 mm, dowel – 12 mm
- Caspar pins are not used, so to accomplish distraction, may insert 3 mm Kerrison through drill guide, rotate it (so disc space distracts), then tap drill guide into place (this way drill guide spikes engage and keep disc space distracted)
- Caspar pins are not used, so anesthesia pulls on Holter sling during dowel placement.
- bits of bone graft may be packed laterally.

**ANTERIOR INSTRUMENTATION**

Obsolete technique – **ACDF without instrumentation**; mainly for Cloward technique (Smith-Robinson – risk of graft migration).

**PLATE**


- select appropriate length of anterior cervical plate:
  
  When plate is properly sized and positioned:
  
  - superior screw holes align with inferior 1/3 of superior vertebral body.
- inferior screw holes align with superior 1/3 of inferior vertebral body.
- plates have oblique holes at top and bottom level, so that even fixed angle screws will go oblique.

Plate lengths:
- 1-level Cloward (Dr. Graham) – use 23 mm
- 1-level – start with 20 mm
- 2-level – start with 40 mm
- 3-levels – start with 60 mm
- 4-level – start with 75-80 mm

**DEPUY SKYLINE PLATE**

For C2 to C7 (i.e. 1-5 levels)
Thickness = 2.5 mm Width = 16 mm Waist = 14 mm
Length 12 to 105 mm

**Plate contouring:**
- SKYLINE plate is pre-lordosed, reducing need for contouring.
- additional contouring may be accomplished by inserting plate into plate bender and squeezing handles.
- SKYLINE plate is provided with bend zones and may not be bent across CAM LOC mechanism
- plates should be bent in one direction, kyphosis or lordosis only.
- never reverse bend as this may create micro fractures that will weaken plate.
- short plates of each level do not have bend zones and therefore cannot be bent.

**ATLANTIS VISION PLATE (Medtronic)**
- older; locking less robust and gives some excuse for missed screw angles.

**Atlantis Elite Plate (Medtronic)**
- newer (locking screw same driver as for screws)

**Zevo (Medtronic)**

Zevo
Anterior Cervical Plate System

**Find a New Direction**

Over 30 years of experience in the cervical market combined with current treatment trends has been designed into the new Zevo Anterior Cervical Plate System:

- Combination of short-plate options and hyper-screw angulations to avoid impingement on adjacent levels
- Low-profile plate thickness allowing for treatment of up to 5 levels of degenerative pathologies
- Cortical screw technology designed to maximize bone purchase; featuring an enhanced driver interface
- Versatile design featuring visualization windows,\* slots for additional screw fixation, and unique pre-fixation options
- Instrumentation designed in parallel with implants to take advantage of the system features
- Visual, tactile lock

**Divergence™ ACF System (Medtronic)**
• for one level ACDF - plate and interbody cage in one.
• *laterally-divergent screws* - requires less retraction compared to the traditional medially-convergent screw insertion techniques.

### SCREWS, TRAJECTORIES

*Constrained screws* provide less angulation and construct is more *rigid* (resist axial loads well) but prone to screw *cut-out*:

![Constrained screws diagram](image)

*Variable screws* provide more angulation and construct is more *dynamic* but prone to screw *pull-out*:

![Variable screws diagram](image)
• variable (v) screws go into upper levels to allow for subsidence and then constrained (c) screws into lower levels for stability (e.g. v-v-c or v-c-c).
• 3.5 mm diameter; larger for rescue screws.
• screw length (mostly 14 [women]-16 [men] mm for adults); if need to measure:
  a) use axial CT; plain XR magnification is unpredictable (if needed, use the coin taped to skin at spine plane)
  b) use vertebral body height measurer
• Dr. Cameron uses all fixed self-tapping* screws (*to avoid cost of drill): 16 mm for all men, 14 mm for all women.
• Dr. Mathern uses variable for top level (or top two levels for 4-level ACDF) and fixed for other levels; he uses longer screws for top and bottom level (because screws go oblique, i.e. plate has oblique holes at top and bottom level);
  e.g. 16v-14f-16f  OR  16v-14v-14f-16f
• Dr. Broaddus uses all fixed and same length (15 mm for males).
• Dr. Graham uses all fixed and same length (15-16 mm for males, 14 mm for women).
• Dr. Rivet, Ward uses variable for top, fixed for bottom rest, prefer self-tapping screws.
• Dr. JRC uses top variable and others fixed (all fixed for one level trauma).

Triangulation effect – see p. Op220 >>
N.B. cervical vertebral body should not be considered to be cube (A), but rather as flattened parallelogram shaped cylinder (B):
Thus, lesser angle (than otherwise optimal 45°) may provide greater triangulation effect (note difference of shaded areas). Furthermore, lesser angles (e.g. 20°), caudal dorsal corner of vertebral body may be purchased (bicortical purchase improves pullout resistance - angling screws toward endplate provides longer screw paths and improved pullout resistance):

Resistance to axial load (toe-out is better here!):
Effect of plate length:

Compression effect (Dr. Graham technique):
Two component vectors are applied when angled screw is tightened. One brings bone to plate and other moves bone along long axis of spine (compression) (A). This may be used to apply compression forces (B):
N.B. to allow this effect, screw starting points in bone must be further apart than screw holes in plate; after first hole, do not tighten first screw and let plate stick out a little bit – will allow “to reach” for another hole – then, tightening both* screws, will allow compression!

* start with topmost screws – if plate does not conform perfectly with anterior vertebral bodies, it will make plate sit flush with vertebral body superiorly (and stick out inferiorly) – theoretical advantage to prevent dysphagia from prominent plate corner.

**DePuy Screws**

- neutral angle of SKYLINE Screw is 10° rostral/caudal and 5° medial.

*Constrained screws* provide up to 5° cone of angulation in coronal (axial?) plane while maintaining sagittal trajectory (easier screw placement without affecting stability);
  — constrained screw can pivot 2.5° medial/lateral from neutral angle.

*Variable screws* provide up to 20° of angulation;
  — variable screw can pivot 10° in all directions from neutral angle (20° cone of angulation).
• place temporary fixation pins* → lateral x-ray (to check adequate length of plate).
  *into one of cephalad and one of caudal screw bores of plate

  • **unicortical screw fixation** - place variable* screws at upper level, then constrained-angle screws into other vertebral bodies.
  *will allow subsidence as time passes
  • for trauma cases – use **bicortical screw fixation**
  • break anterior vertebral body cortex with awl then drill* (may drill all way down planned screw tract)
    *self-drilling screws do not normally require predrilling, however, awl should be used to perforate cortex to provide starting point for screw insertion
  • self-centering awl can protrude into bone up to 7 mm (to penetrate dense cortical bone, strike handle of self-centering awl with mallet)

<table>
<thead>
<tr>
<th>Color Code</th>
<th>4.0mm Self-Drilling</th>
<th>4.0mm Self-Tapping</th>
<th>4.5mm Oversized</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mm Green</td>
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<td>12mm Blue</td>
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<td>13mm Violet</td>
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<td>15mm LightBlue</td>
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<td>16mm Magenta</td>
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<td>17mm LightGreen</td>
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<td>18mm Titanium</td>
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<td>26mm Titanium</td>
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• when using **constrained screw, constrained single barrel drill guide** must be used (tip of guide mimics head of constrained screw in order to ensure drilled hole is within functional range of constrained screw):
- insert tip of single barrel drill guide into bore of screw and orient as desired.

**Drill Bit Selection**
SKYLINE System provides 12 mm (blue), 14 mm (gold), and 16 mm (magenta) fixed depth drill bits:

- self retaining screw-driver may be used to remove desired screw from screw caddy.
- insert screw into screw bore and advance it into vertebral body.

**LOCK SCREWS INTO PLACE**
- all screws should be placed before beginning locking procedure.
- use fluoroscopic imaging to confirm final trajectory of screw and plate position before screws are fully tightened and secured.

**DePuy**
Tri-Lobe CAM LOC™ mechanism - provides audible, palpable, and visual confirmation of screw lock.
- rotate CAM tightener clockwise. Resistance will be felt as CAM contacts screw head.
- CAM tightener incorporates torque-limiting feature (0.78 Nm) that will release when appropriate torque level is achieved. When this occurs, audible click will be heard.
- lock is obtained when CAM tightener torque limit releases or when CAM is positioned within typical locking zone (do not rotate CAM past 270°).
- exact position of locked CAM may vary within typical locking zone depending on screw angulations:
COMPLICATIONS

ADJACENT-LEVEL OSSIFICATION DISEASE (ALOD)
- osteophytes develop at the adjacent level
  - patients with plates placed < 5 mm from the adjacent level disc have statistically significant increases in the frequency and severity of ALOD.

NONFUSION / PSEUDOARTHROSIS
- most nonunions are not a result of graft collapse but rather of failure of one of the two graft-body interfaces to ossify (i.e. due to the lack of good graft-endplate contact):

![Image of bone graft and plate]

Risk factors
1. Multilevel fusions
2. Steroid medication
3. Noncompliance with postoperative immobilization
4. Allograft
5. Older age
6. Smoking

Martin et al. studied the effect of smoking in patients after ACDF using allograft bone with instrumentation. The reported fusion rate in nonsmokers for single-level procedures was 92%, compared with 85% in smokers. The difference for two-level procedures was more pronounced; the rate of fusion was 72% and 50% for nonsmokers and smokers, respectively. Cauthen et al. reported an overall fusion rate of 85% in nonsmokers and 77% in smokers after single- or multilevel ACDF using autograft and allograft bone without instrumentation. Additionally, Hilibrand et al. showed a 50% nonunion rate among smokers who underwent multilevel anterior cervical discectomy with interbody fusion using an autograft without fixation, compared with 69% in the control group. Bose and colleagues,
however, did not find a significant effect of smoking on fusion rate in their retrospective analysis of 106 patients. They reported a 96.67% and 97.83% fusion rate in smokers and nonsmokers, respectively, after multilevel ACDF with fixation.


Clinical Features

- axial pain may or may not be present: some fibrous unions are stable and, thus, asymptomatic and do not require revision surgery; occasionally, however, enough motion will be present that axial neck pain will be present.
- if ACDF graft subsides, foramina narrow → radiculopathy

Diagnosis

Dynamic X-ray
CT
Compare with immediate postop images!

Prophylaxis

OrthoFix

Kevin T. Foley et al. Randomized, prospective, and controlled clinical trial of pulsed electromagnetic field stimulation for cervical fusion. Spine Journal, The, 2008-05-01, Volume 8, Issue 3, Pages 436-442

- randomized, controlled, prospective multicenter clinical trial, 323 patients → 163 in stim group (Cervical-Stim; Orthofix Inc., McKinney, TX), 160 in control group.
- patients were either smokers (> 1 pack per day) and/or were undergoing multilevel fusions.
- Smith–Robinson technique with allograft bone and an anterior cervical plate.
- F/U up to 12 months
- conclusions:
  - 6 months, the stim group had a higher fusion rate than the control group (83.6% vs. 68.6%, p=.0065).
  - at 12 months after surgery, the stimulated group had a fusion rate of 92.8% compared with 86.7% for the control group (p=0.1129).
  - there were no significant differences between the stim and control groups with regard to VAS pain scores, NDI, or SF-12 scores at 6 or 12 months.
  - no significant differences were found in the incidence of adverse events in the groups
  - study did not identify smoking to be a risk factor for pseudoarthrosis, as rates of fusion for smokers and nonsmokers were nearly identical in the control group.
  - strong trend toward a lower fusion rate for multilevel versus single-level ACDF in this study (64.5% vs. 84.0%, p=.0623).
  - PEMF stimulation appeared to hasten bone healing; it did not result in a significant advantage in terms of ultimate fusion rates or clinical outcomes in the overall study population.

Treatment

A) PCF (esp. for long-segment nonunions) – best solution
B) corpectomies and strut grafting.

- try to avoid going back anteriorly, esp. if done in OSH - screws might be stripped (need to drill - avoid metal shavings in esophagus by placing towels and sterile surgical lube), esophagus might be scarred to plate.

### ZERO-PROFILE

- may be implanted adjacent to prior fusion
- in general, mechanically inferior to conventional plates (zero-P was invented when BMP was still used for ACDFs).

#### ROI-C (LDR, ZIMMER BIOMET)

Technical manual >>

![Anatomic implant](image)

**Anatomic**

![Lordotic implant](image)

**Lordotic**

Anatomic implant has 6 degrees of lordosis, lordotic – 7 degrees of lordosis.

- use fluoroscopy.
- use Depth Gauge to choose cage **depth** – 12 or 14 mm (cage should leave 1 mm from anterior* and posterior vertebral edges).
  *corresponds to depth stop (on implant holder) set to 0 mm
- cage **width** – should reach uncinate processes but not ride on them.
- cage **height** – use trial – height should not exceed the height of adjacent heathy discs.
  - if trial sits straight, the hole in the center will look perfectly round
• Caspar pin must be $\geq 7$ mm* from endplate to avoid contact with locking plate.

*or remove Caspar pin before insertion

• Cage is filled with DBX putty paste before putting into disc space.
• Cage alignment is more challenging – holder obstructs view, holder holds cage straight (so holder needs to be in sagittal plane but holder abuts trachea-larynx); X-ray verification is mandatory:
  - tantalum marker is 1 mm from posterior border of PEEK cage

• Prior to plate insertion release distraction on Caspar pins.
• If plate does not go in with simple hammer (bone too sclerotic), then use awl plates.
• Insert plates in any order (e.g. cranial first, then caudal; or the opposite).
VERTEBRIDGE PLATE SELECTION

Select the plate length according to the height of the implant being used. Use the ROI-C Standard Plate (MC1005T) with heights 5-7mm and the ROI-C Long Plate (MC1006T) with 8-10mm heights.
ADVANCE FIRST PLATE

Using thumb pressure, insert the #1 Impactor (MC9092R) to advance the first plate until it touches bone.* Take a lateral radiographic image to verify the plate is touching the bone.

*Note: If the plate does not advance with thumb pressure, confirm the plate is properly loaded in the Holder and that the Holder is aligned with the PEEK.

ADVANCE FIRST PLATE CONTINUED

Use a mallet to impact the first plate into the bone. The plate is fully advanced when the:
- Mechanical stop on the Impactor meets the mechanical stop of the Implant Holder (A1/A2).

Do not proceed to the #2 Impactor until proper placement of the implant and first plate are confirmed via fluoroscopy or x-ray (C).

*Note: The impaction lines (B) will allow visualization of the plates’ advancement and the mechanical stops should make contact when the lines appear aligned.

FINALIZE FIRST PLATE POSITION

Once position is confirmed, use the #2 Impactor (MC9093R) to finalize the advancement of the first plate. Again, the plate will have advanced completely when the mechanical stop on the #2 Impactor meets the mechanical stop on the Implant Holder.

Take a lateral radiographic image to ensure proper implant and plate position.

*Note: The plates must be advanced and finalized using this sequence:

- 1st Plate: • Advance with thumb pressure
  • #1 Impactor
  • #2 Impactor

- 2nd Plate: • Advance with thumb pressure
  • #1 Impactor
  • #2 Impactor

- confirm there is tiny separation between tips of plates on X-ray:
**DIVERGENCE stand-alone interbody cage (MEDTRONIC)**
**AERO-C (STRYKER)**
Stryker Aero-C (cervical zero profile) >>

- preassembled implant (Titanium plate and PEEK spacer).
- available in multiple configurations: lordotic, parallel, and convex profiles.
- full range of heights: 5 mm to 12 mm.
- no need to rasp disk space.
- fill PEEK spacer with DBX paste ± auto bone chips.
- use either fixed drill guide or angled awl.
  - can drill all holes through fixed drill guide and can put first (lateral) screw through it
- wider screws go on the side of previous ACDF plate.

**ZERO-P AND ZERO-P VA (SYNTHES)**
Synthes - Zero Profile anterior cervical fusion >>
Synthes - Zero P Quick Reference guide >>

- preassembled implant (Titanium plate and PEEK spacer).
- available in multiple configurations: lordotic, parallel, and convex profiles.
- full range of heights: 5 mm to 12 mm.
- no need to rasp disk space.
- fill PEEK spacer with DBX paste ± auto bone chips.
- use either fixed drill guide or angled awl.
  - can drill all holes through fixed drill guide and can put first (lateral) screw through it
- wider screws go on the side of previous ACDF plate.
• screw head has smaller step thread – locks itself by “crossthreading”

**Zero-P**

**Zero-P VA** - variable angle screws offer a wide range of screw trajectories.
Posterior end of graft (screws won't go farther than this)

Anterior end of graft
Zero P Natural >>
- it has bone allograft instead of PEEK

**ARTIFICIAL DISK**
- look for Ni allergy – all implants have some nickel in alloy.
- implant height is ≥ 8 mm → postop neck pain from disc space overdistratcion.
- some implants suitable only for concave superior endplates (prevent implant slip out).
- postop administer NSAIDs – to prevent heterotopic ossification.

**INDICATIONS**
Dr. Mummaneni: "The arthroplasty is really for younger patients between the ages of, say, 20 and maybe 50 or so, patients who have good range of motion of their neck, and normal facet joints. If you
already have your facet joints with a lot of bone spurs in patients who are 60-plus, you can't restore motion to those patients, because we're not doing anything to the joints in the back. The ones who are candidates for this operation at 1 level [are people who] have normal range of motion going in, and they have neck and arm pain from a herniated disc."

NASS Clinical Guidelines for Cervical Radiculopathy from Degenerative Disorders (2010):
ACDF and total disc arthroplasty are suggested as comparable treatments, resulting in similarly successful short term outcomes, for single level degenerative cervical radiculopathy (grade of recommendation: B).

**DYNAMIC CERVICAL IMPLANT (DCI)**

- provides limited, controlled flexion-extension while limiting axial rotation and lateral bending motions, i.e. maintains index- and adjacent-level ROM, improves sagittal alignment, and may be suitable for patients with facet arthrosis who would otherwise not be candidates for cervical TDR (total disc replacement).

Shock absorption together with maintained motion in the DCI may protect adjacent levels from early degeneration in longer follow-up.

Lateral radiographs showing the shock-absorbing capabilities of the DCI implant during movement:

Preoperative (A and B) and 1-year postoperative (C and D) functional radiographs of DDD at C4–5 with retrolisthesis in extension above cage–fusion at C5–6, dynamically stabilized with an M7 DCI (12 × 14 × 7 mm):
SECURE-C (GLOBUS)
SECURE-C®
THINK BEYOND FUSION
7-YEAR FOLLOW-UP DATA

STATISTICALLY SUPERIOR REOPERATION RATE
4.2% (SECURE-C®) vs 15.3% (ACDF)
Lower rate of secondary surgery at the index level than ACDF by 7 years

FEWER ADJACENT LEVEL SURGERIES
4.7% (SECURE-C®) vs 16.0% (ACDF)
Lower rate of adjacent level surgeries than ACDF by 7 years

RANGE OF MOTION MAINTAINED
Mean 9.1° ROM and 1.1mm Translation
Range of motion maintained over 7 years

NUNEC™ (PIONEER SURGICAL TECHNOLOGY)

PRESTIGE (MEDTRONIC)

See brochures >>
Mobi-C cervical disc (LDR)

- brochure

STUDIES


- 5-year results of a prospective, randomized US FDA investigational device exemption (IDE) study
- 24 centers
- 2-level, contiguous, cervical spondylosis.
- 225 patients received the Mobi-C and 105 patients received ACDF.
- Mobi-C patients had significantly more improvement than ACDF patients in terms of Neck Disability Index score, SF-12 Physical Component Summary, and overall satisfaction with treatment at 60 months.
- reoperation rate was significantly lower with Mobi-C (4%) versus ACDF (16%).
- no significant differences in the adverse event rate between groups.

INDICATIONS & REQUIREMENTS

- FDA approved for 1 and 2 contiguous levels (C3-7).
- minimal A/P depth - 14 mm
- skeletally mature patients
- intractable radiculopathy (arm pain and/or neurological deficit) ± neck pain, or myelopathy due to abnormality localized to the level of the disc space and at least one of the following:
  a) herniated nucleus pulposus
  b) spondylosis (defined by the presence of osteophytes), and/or visible loss of disc height compared to adjacent levels.
- patients should have failed at least 6 weeks of conservative treatment.

CONTRAINDICATIONS

- allergy or sensitivity to the implant materials (cobalt, chromium, molybdenum, titanium, hydroxyapatite, or polyethylene).
- compromised vertebral bodies at the index level - previous trauma, anatomical deformity or disease (e.g., ankylosing spondylitis, rheumatoid arthritis).
- instability on resting lateral or flexion/extension radiographs (translation > 3.5 mm, and/or > 11° angular difference to that of either adjacent level)
- osteoporosis (DEXA bone mineral density T-score < -1.5) - SCORE (Simple Calculated Osteoporosis Risk Estimation), may be used to screen patients to determine if a DEXA bone mineral density measurement is necessary
- severe facet joint disease.

WARNINGS

Heterotopic Ossification (HO) is a potential complication associated with artificial cervical discs and could lead to reduced cervical motion. However, the presence of HO has not been correlated with
adverse clinical outcomes involving the Mobi-C® Cervical Disc Prosthesis in the G050212 clinical trial.

**PRECAUTIONS**

The safety and effectiveness has not been established in:
- patients < 21 or > 67 years old
- prior cervical spine surgery, including prior surgery at the index level
- > 2 diseased or immobile cervical spine levels requiring surgical intervention
- disc height < 3 mm measured from the center of the disc in a neutral position
- disc height < 20% of AP width of the inferior vertebral body
- significant kyphotic deformity / significant reversal of lordosis.
- taking medications known to potentially interfere with bone/soft tissue healing (e.g. steroids)
- diabetes mellitus requiring daily insulin
- BMI > 40
- AIDS, HIV, and Hepatitis
- prior fusion at an adjacent vertebral level
- neck pain alone
- rheumatoid arthritis, muscular dystrophy, spinal muscular atrophy, or amyotrophic lateral sclerosis;

**DEVICE**

- cobalt, chromium, molybdenum (CoCrMo per ISO 5832-12) alloy superior and inferior plates.
  N.B. no nickel – OK for patients with Ni allergy!
- ultra-high molecular weight polyethylene (UHMWPE per ISO 5834-2) mobile insert
inner contact surfaces of the superior and inferior spinal plates are spherical and flat, respectively. This allows for fully congruent contact surfaces between the spinal plates and mobile insert.

- two lateral stops of the inferior plate controls and limits the mobility of the mobile insert.
- spinal plates, both superior and inferior, feature two rows of teeth to allow for initial and long term fixation and stability.
- titanium (per ASTM F1580) and hydroxyapatite (per ISO 13779) plasma spray coating is applied to the bony interface surfaces of the superior and inferior spinal plates

Mobi-C disc has three parts:
1. Two **metal plates**:
   - plates are made of a mix of metals (cobalt, chromium, and molybdenum).
   - plates have teeth on top and bottom that help hold plates to vertebrae.
   - teeth are pressed into bone with no bone cut out - bone sparing technique.
   - outside of metal plates are sprayed with coating (hydroxyapatite) - helps vertebrae to grow and attach to metal plates for long term stability.
2. **Plastic insert** - made from polyethylene.
   - insert is flat on bottom and round on top.

Mobi-C comes preassembled on a disposable radiolucent PEEK cartridge

**PATIENT POSITION**
- maintain **neutral lordosis** to avoid hyperextension (roll can be used to support the neck’s position).
- use gel donut (instead of horseshoe headholder) – easier for C-arm
- **rotation of the head should be prevented** using tape or a strap to the bed.
- for C6/C7, the shoulders should also be taped for better visualization (footboard may be used to maintain the patient’s position).

**C-ARM**
- prepare for C-arm use that allows cephalad and caudad movement.
- set the C-arm to capture true A/P and lateral views before final draping.
as the C-arm is moved frequently, consider taping the floor to mark the best C-arm positions to eliminate variations in film view.

**DISCECTOMY**

Differences from ACDF:
- center the exposure on midline.
- **minimize soft tissue trauma** - limiting retraction ischemia, minimal dissection of the longus coli, and less electrocautery use.
- Caspar Pin no less than 5 mm from each endplate, centered on midline in the coronal plane, parallel with the vertebral endplates in order to ensure parallel distraction.

  N.B. Caspar Distraction alone may not properly distract posteriorly
  
  H: Distraction Forceps (Paddle Distractor, 15 mm in depth) - insert to back of disc space, release the Caspar Distractor, use the Paddle Distractor to create parallel distraction; when the desired height is obtained, lock the Caspar Distractor to hold distraction and then remove the Paddle Distractor.

- complete disc removal without burrs, between the unci, preserving the bony endplate.
- remove all posterior osteophytes on the superior and inferior vertebral endplates.
- as needed, address large, significant anterior osteophytes.
- release the foramen bilaterally.
- release of posterior longitudinal ligament (PLL) may help obtain parallel distraction.
- liberally cover any bleeding bone with bone wax to help prevent heterotopic ossification.

**TRIAL WIDTH**

- insert the Width Gauge ("fork") into the disc space under lateral fluoroscopy.
- Width Gauges correspond to the implant widths of 15, 17, and 19 mm.
- position the Width Gauge flat on the inferior endplate in contact with the base of the uncus bilaterally (shape uncus with drill bit as needed).
- if the Width Gauge can be moved side-to-side more than 2 mm, trial the next larger width.
- the center reference point, located on the Width Gauge, confirms location of the vertebral midline; it is **not a depth stop and should not come in contact with the anterior face of the vertebra**.
**Depth**

It is extremely important to achieve complete A/P coverage.

- Implants only come in 13 and 15 mm depths.
- Depth Gauge is available for depth measurement - place the hook of the gauge over the posterior edge of the vertebral endplates; do not include anterior osteophyte(s) in judgment of depth:

**Height**
Implant footprints include (in mm):

<table>
<thead>
<tr>
<th>Depth</th>
<th>Width</th>
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</table>

- each footprint size is color coded by width.
- heights are available in 5, 6, and 7 mm.
- trialing should begin with the smallest height first (5 mm) and should not exceed the height of healthy adjacent discs.
- 85% of implanted Mobi-Cs are 5 mm, rarely a 7 mm.
- insert Trial → release the Caspar Distractor → lateral X-ray to validate height and depth selection and an A/P X-ray to assess central placement and width; holes in the Trial, front and side, facilitate verification of position (center and rotation).
- do not overstuff height - reference healthy adjacent discs and facets.
- if the inferior endplate of the superior vertebra is flat, use a curette to prepare room for the dome of the device.
- Trial Implant Holder can be removed to take an unobstructed A/P X-ray, then re-engaged for Trial removal.
Figure 1
Contact: stop threading

No contact: continue threading
• load the preassembled implant assembly onto the Implant Inserter. Turn the impaction knob on the Implant Inserter until the cartridge screw is completely threaded onto, and just in contact with the Implant Inserter.
• visual control of contact can be confirmed using the window.
• on the Implant Inserter. The word “UP”, indicating the top of the device, becomes completely visible when the correct position is obtained.
Important: stop threading as soon as full contact is achieved - to avoid premature opening of the PEEK cartridge and releasing the implant.

**DEPTH STOP ADJUSTMENT**

- Implant Inserter has a depth stop adjustment collar, which should be set initially at zero; zero setting will place the anterior edge of the implant flush with the anterior aspect of the vertebral body.
- depth stop allows for setting the insertion depth of the device from 0 to 5 mm.
- stop adjustment is indexed, one full turn (360°) equals 1 mm.
- at each full turn of the depth stop collar, there is a tactile feel of the ball detent dropping into a groove.

**VERIFY INSERTION TRAJECTORY**
- position the Implant Inserter in the A/P axis of the disc. This position can be verified visually; the groove on the Implant Inserter should align with midline.
- in order to verify the correct position and axial rotation about the transverse plane of the Implant Inserter, use the **Inserter Level** – it should be parallel to the OR table.
- it is important to set the correct axial rotation prior to impacting the device into the disc space. Axial rotation maneuvers of the device should be avoided once the device is in the disc space.

**DEVICE INSERTION**
• under fluoroscopy, insert the device progressively into the disc space by tapping lightly on the Implant Inserter’s impaction knob with a mallet until the device is centered on the vertebrae anterior-posterior and medial-lateral.
• implant should be centered, regardless of endplate coverage.
• during and after insertion, avoid lateral and rotational movements of the implant-to-PEEK cartridge assembly.
• if at any time prior to achieving final position the implant comes apart from the PEEK cartridge, do not attempt to reassemble. Select and use a new pre-assembled implant.
• if reinsertion is needed, check implant assembly to PEEK cartridge before reinsertion.

*Note: Take care to center the device on the vertebral endplates.
- use fluoroscopy to assess implant position.
- release the Caspar Distractor to permit the vertebral endplates to align in parallel.
- from the lateral view, assess the implant’s A/P position.
- if necessary, the posterior position of the device in the intervertebral space can be adjusted. Adjust the Implant Inserter’s depth stop knob. Mallet lightly on the Implant Inserter’s impaction knob until the desired posterior position is achieved. The implant should be centered.
- alignment of the tabs* on the inferior plate is used to assess the position of the device in rotation. Two tabs can be seen if the device is rotated. If necessary to correct a rotated device or for lateral implant adjustments, distraction of the disc space is required to prevent implant-to-PEEK cartridge disassembly in situ.

*Note: Tabs are 0.5mm posterior to the device midline.

IMPLANT INSERTER REMOVAL
*Note: Never use the Unlocking Key while loading the device.
• Once optimal device position is confirmed and the Caspar Distractor is released, apply initial *Caspar Distraction compression to set lateral implant teeth into the bone*. This will help keep the device in place during PEEK cartridge disassembly and removal.

• **Turn the Implant Inserter impaction knob clockwise** with the help of the Unlocking Key (MB9073R) in order to release the cartridge screw.* **Turn Unlocking Key approximately 20 times** to fully release the screw from the PEEK cartridge (continue to turn until the cartridge screw is completely released from the PEEK cartridge).

• The removal of the cartridge screw releases the PEEK cartridge, allowing the Implant Inserter to be disengaged from the cartridge. Carefully remove the Implant Inserter in a straight line. Take care not to move the implant.

**PEEK CARTRIDGE REMOVAL**

• Using the Extraction Forceps (MB9075R), grasp the proximal ends of the two piece PEEK cartridge at the side notches. Take care not to move the implant.

• Squeeze the forceps to release the PEEK cartridge from the implant, then extract the cartridge by pulling back the forceps along the axis of the disc.* The PEEK cartridge is disposable.
*Note: If the PEEK cartridge is difficult to extract, rotate one side of the cartridge 90° caudal, then remove with forceps. Repeat on the remaining side:
**PLATE ADJUSTMENT**

- If after removing the PEEK cartridge one or both of the plates require adjustment, the **Plate Impactor (Tamp) (MB942R)** can be used to adjust the posterior position of an individual plate. Confirm position under fluoroscopy before and after plate adjustment.
- Orient the longer lip of the Tamp toward the anterior face of the mobile polyethylene insert. Gently mallet the handle of the Tamp to push the plate posterior.

**FINAL POSITION ASSESSMENT**

- **always do A/P and lateral fluoroscopy** to confirm correct positioning of the device:
N.B. for AP view, need to remove inserter but leave pin inside PEEK cartridge (in case will need to pull implant for readjustment) – undo big knob counterclockwise:

To reengage inserter, turn big knob clockwise; keep turning further with blue donut to completely disengage pin from PEEK cartridge (pin has a reverse thread).

**Final Vertebral Compression**
- Once final position is confirmed, apply firm compression using the Caspar Distractor to seat the implant teeth into the vertebrae (does not need to fully go into bone – it will subside postop over time). In a two-level case, perform compression at each level separately.
- Once the compression is achieved, remove the Caspar Distractor.
- Remove all the Caspar Pins. Place bone wax as needed in the holes created by the pins to reduce bleeding and on any anterior bone surfaces exposed during osteophyte removal.
**Removal of Cartridge Screw**

- Remove and dispose of the cartridge screw by pulling back and unscrewing **counter-clockwise** the Implant Inserter’s impaction knob. Removal of the cartridge screw is required for cleaning and in two-level cases for the attachment of a new PEEK cartridge to the Implant Inserter.

1. Pull back handle to seat screw.

2. Rotate handle counter-clockwise.

3. Separate screw from Inserter.
**Considerations for 2-level surgery**

- place Caspar Pin in the intermediate vertebral body mid-distance between endplates.
- trial and complete implantation of one level.
- Leave the Caspar Pin in the middle vertebral body and move the most inferior or superior pin to the opposite most inferior or superior vertebral body. Then repeat the steps described previously in this document for insertion of the first Mobi-C implant:
  - Attach the Caspar Distractor to the pins and distract to access the second disc.
  - Complete the discectomy.
  - Measure the width and depth.
  - Trial to determine the height and final implant size.
  - Assemble a Mobi-C to the Implant Inserter.
  - Insert the Mobi-C.
  - Verify the implant’s position via radiographic visualization.
  - Apply **light Caspar Distractor compression** and then remove the Implant Inserter and the PEEK cartridge.
  - Assess final position of both implants via radiographic visualization.
  - Apply **firm vertebral compression with the Caspar Distractor** to seat the implant teeth into the vertebrae.

**SPECIAL SITUATIONS**

Mobi-C is **not approved to be combined with ACDF**; if for some reasons one (of two level) implantation fails (e.g. too much endplate was removed), may place ROI-C in that level.

**Implant removal for revision**

- **DISTRACTION** - centrally insert Caspar Pins above and below both endplates. Attach the Caspar Distractor to the pins and distract using the knob. Take care to not over distract, when adjusting the height for implant removal.
- **IMPLANT REMOVAL** - using a Penfield #4 or thin osteotome, loosen the inferior bone to implant interface. Hook the tips of the Extraction Forceps (MB9075R) posterior to the tabs on the inferior plate. Remove the inferior plate and mobile insert together, taking care to stay in the axis of the intervertebral space.
• using a Penfield #4 or thin osteotome, loosen the superior bone to implant interface. Grab the anterior edge of the superior plate using a Needle Holder. Remove the plate from the disc space.

**Post-op management**

- ambulate the day of surgery; discharge, based on surgeon preference, often the first day post-op.
- prescribe a **soft collar**, based on surgeon preference.
- **short-term NSAID**: Dr. Hisey uses 200 mg/d **IBUPROFEN** for 6 weeks – to prevent heterotopic ossification.

_Tsung-Hsi Tu et al., Heterotopic ossification after cervical total disc replacement: determination by CT and effects on clinical outcomes, J Neurosurg Spine 14:457–465, 2011 457_  

- back to office work in 1-2 weeks.
- **PT**: isometric strengthening typically at 2 weeks.
- restrict overhead activity, repetitive neck movements, and heavy lifting for 6 weeks.
- **dynamic XR** at 6 weeks (at 12 weeks PRN).
Magnetic Resonance Imaging (MRI) Compatibility

**Safe up to 3.0 Tesla** (Mobi-C® is expected to produce a maximum temperature rise of < 3 °C after 15 minutes of continuous scanning).

- **Image artifact** caused by the device extends 29 mm from the Mobi-C® when imaged with a gradient echo pulse sequence and a 3.0 T.

## CORPECTOMY

**Used sources:**
R. Jandial “Core Techniques in Operative Neurosurgery” (2011): Procedure 60
R. Nader “Neurosurgery Tricks of the Trade – Spine and Peripheral Nerves“ (2014), Ch. 8

### INDICATIONS

- **Posterior osteophytes / ossified posterior longitudinal ligament** (PLL) that often bridges past disk spaces and cannot be adequately removed with discectomies alone
- **Osteomyelitis** that fails nonoperative management
- Vertebral body **tumor**
- Vertebral body **burst fracture**
- Part of circumferential stabilization with **fracture-dislocations**.
- If bone is good quality, no risk factors, then 2-level corpectomy may not need posterior stabilization.

**Two-level corpectomy +/- PCF**


- 21 patients, choice over the surgical procedures was exercised by every surgeon individually.
- Both groups benefitted from surgery concerning pain, disability, and myelopathy.
- While all patients of the ANT/PCF group showed no postoperative instability, one third of the patients of the ANT group exhibited instability and clinical deterioration - revision surgery with secondary posterior fusion was needed.
  
  *N.B.* Patients with a sole anterior approach demonstrated a very high rate of instability (33%) and clinical deterioration in a long-term follow-up. Therefore, we recommend to **routinely perform an additional posterior fusion after two-level cervical corpectomy**.

**Two-level corpectomy (ACCF) versus three-level discectomy (ACDF) for multilevel cervical spondylotic myelopathy**


- 20 patients underwent 2-level ACCF, 35 patients underwent 3-level ACDF; preoperative Nurick scores were higher in the ACCF group (2.1 vs 1.1, p = 0.014), and more patients underwent PSF in the 2-level ACCF group compared with patients in the 3-level ACDF group (60.0% vs 17.1%, p = 0.001).
- Two-level ACCF was associated with greater **EBL** (382.2 ml vs 117.9 ml, p < 0.001) and longer **hospital stays** (7.2 days vs 4.9 days, p = 0.048), but a subgroup comparison of patients without PSF showed no significant difference in length of stay (3.1 days vs 4.4 days for 2-level ACCF vs 3-level ACDF, respectively; p = 0.267).
- **Perioperative complication rates** were similar in the 2 groups when patients underwent anterior decompression without PSF.
— there was a trend toward more complications in the 2-level ACCF group (20.0%) than the 3-level ACDF group (5.7%; p = 0.102), but a subgroup analysis that excluded those who had second-stage PSF no longer showed the same trend (2-level ACCF, 0.0% vs 3-level ACDF, 3.4%; p = 0.594).

- both groups obtained similar postoperative cervical lordosis, operative ASD rates, radiographic pseudarthrosis rates, neurological improvement, and pain relief.
  — no significant differences (ACCF vs. ACDF) in terms of postoperative sagittal Cobb angle (7.2° vs 12.1°, p = 0.173), operative ASD (6.3% vs 3.6%, p = 0.682), and radiographic pseudarthrosis rate (6.3% vs 7.1%, p = 0.909).
  — similar improvement in mean VAS neck pain scores (3.4 vs 3.2 for ACCF vs ACDF, respectively; p = 0.860) and Nurick scores (0.8 vs 0.7, p = 0.925).

**CONTRAINDICATIONS**

- aberrant vertebral artery* is relative contraindication and requires attention to width of corpectomy trough.
  
  *i.e. aberrant vertebral artery (VA) passing medial to the pedicle precludes carpectomy at that level.
- chin on chest deformity (best treated with cervicothoracic fusion and T1 osteotomy)
- anterior bony ankylosis

**TECHNIQUE**

- recommend monitoring with MEP and SSEP.
- use fiberoptic intubation.
  - complete discectomies above and below (but do not spend time on removing PLL, decompressing foramina – easier to do once vertebral body is removed); do not destroy endplates (to avoid subsidence, telescoping)!!!
  - corpectomy is done: anterior 3/4 using Leksell (to collect bone) → deepest 1/4 using high speed drill with coarse 3-4 mm diamond burr – to drill trough just wide enough (1.5-2.2 cm; wider has risk of vertebral artery damage) to fit cage (may leave bone lips posteriorly to avoid posterior graft migration):
- width of corpectomy should not exceed 15 mm to avoid vascular injury and allow lateral walls to help with bony fusion.
- optional* - open posterior longitudinal ligament:

*PLL is removed only if torn or in the presence of sequestered disk because PLL removal may be associated with increased risk of C5 stretch injury, or CSF leak (especially in cases of infection or irradiated tumor).
- dura must be visualized (makes sure that decompression is complete):
• decompression must extend to lateral aspects:

• 1- to 2-mm posterior shelf of bone may be created in superior aspect of vertebral body below to prevent posterior graft migration.
- distraction using Caspar distraction posts or standard handheld distractor helps to correct kyphosis and facilitates graft placement.
- for strut graft reconstruction, endplates must be parallel or slightly narrower posteriorly.

**GRAFT Complications:**
1) subsidence (thus, preserve endplates)
2) kick out

- graft height is calculated under traction.

**CAGE**

A. **Titanium** mesh (e.g. Medtronic Pyramesh, DePuy Bengal) - ideal for long segments (has lots of space inside cage – accommodates plenty of autograft (i.e. bone chips); trim length to fit exactly; Dr. Cameron uses circular (vs. oval)

B. **Stackable PEEK** cage

C. **Methyl methacrylate** - as a preshaped block or inside silastic tubing (e.g. thoracic drain) - used in oncology patients with a limited life expectancy (< 6-12 months) as this construct is less expensive, resists tumor destruction, and loses its compressive support after 1 year.

D. **Expandable cage** (e.g. Medtronic STRATOSPHERE – has articulating endplates that better conform to anatomy) – can match anatomy very well but very little space inside to fill with bone graft.

**BONE**

- better fusion but more frequent dislocation:

A. **Iliac crest autograft** offers a decreased risk of infection and a better fusion rate at the cost of donor site morbidity and limitation to two-level reconstruction.

B. **Fibula strut allograft** eliminates donor site morbidity at the cost of an increased rate of infection and nonunion.
ANTERIOR PLATE

- instrumentation with anterior plate and screw fixation provides immediate stability, obviating the need for postoperative rigid external immobilization, increasing fusion rate, and acting as a buttress to prevent graft extrusion.
  
  N.B. it has no proven impact on clinical outcome!

COMPLICATIONS

Pseudoarthrosis
Adjacent level disease (e.g. 35% incidence of accelerated spondylosis rostral to the uninstrumented motion segment).
Graft dislodgement (incidence as high as 29%; 9% rate for two-level corpectomies, 50% rate for three- and four-level corpectomies)
- can lead to catastrophic sequela: neurological injury, airway compromise, or esophageal injury.
- prophylaxis – anterior plating.
Caudal graft dislodgement of a titanium cage:

Witwer et al. (2007)

TRANSPERIAL ODONTOIDECTOMY

Used sources:
R. Jandial “Core Techniques in Operative Neurosurgery” (2011): Procedure 57

Suggested reading:

Rhoton collection – Anterior Skull Base, part 2 >>

INDICATIONS
- compression of cervicomedullary junction:
  1. Irreducible atlantoaxial subluxation
  2. Unstable odontoid fractures
  3. Ventrally located pathology of the lower clivus or atlantoaxial complex
  4. Os odontoideum
CONTRAINDICATIONS
1. **Trismus** (H: splitting of mandible)
2. Oropharyngeal infection
3. Low-riding hard palate - requires a more extensive approach (e.g. palate split)
4. Certain vascular aberrations - "kissing carotids", single median vertebral artery
5. Intradural lesions - better approached from a lateral approach

PLANNING
MRI - ligamentous complex and soft tissue masses
CTA - level of hard palate, position of carotid arteries
Dynamic radiographs - to evaluate craniocervical stability

- epidural retrodental pannus causing cord compression - first thought might be to decompress posteriorly (at least as first stage) – error! – cord gets even more deformed and patient deteriorates!
  H: always decompress from compressing side!
- it is essential to know the location of carotid arteries; otherwise, catastrophic injury could result!

"kissing carotids":


- hard palate dictates rostral access (superior border and extent of exposure and resection); if visualization is inadequate:
  a) soft palate split
  b) mandibular split
  c) endonasal approach (independently or combined) for compression above hard palate
PROCEDURE

- **microscope** or **endoscope**
- **neuronavigation** or **lateral fluoroscopy**
- optional preoperative **tracheostomy** - if splitting of mandible is required to facilitate exposure.

disruption of anterior osteoligamentous complex may destabilize spine, H: dorsal arthrodesis (e.g. occipito-C3 fusion)
keep MAP > 85 mm Hg
Patients with severe cord compression may be subject to ischemic injury during positioning or intraoperative fluctuations in mean arterial pressure
antibiotics should cover mouth flora (e.g. CLINDAMYCIN)
10 mg of DEXAMETHASONE

position:
- supine
- table rotated 180° away from anesthesia (so can work with microscope and fluoroscopy)
- head in a Mayfield head holder in slight extension (alternative – halo crown attached to Mayfield via adapter)

retractor (ensure that tongue and endotracheal tube are behind the retractor!; release tongue pressure as often as you can – reduces tongue swelling but still typically need to keep intubated for 24 hrs or more):

Dingman:
advance Foley catheter through each nostril into oral cavity and then grab and secure tight both ends with hemostat – retracts soft palate
linear incision is made in pharyngeal mucosa (stick needle into superior and inferior ends of planned incision and check with lateral fluoroscopy if it is enough; may also palpate anterior C1 tubercle through mucosa):
mucosa is opened with Bovie to expose anterior ring of C1:

C1 ring is removed with high-speed bur (e.g. M8):
• odontoid is removed using combination of electric drills and hand tools:

• decompression has been completed when dura has been identified:
- to achieve successful decompression, it is important to ensure adequate lateral extension of bone removal (avoid injury to hypoglossal nerves, vertebral arteries, and carotid arteries!!!)
- close mucosa with interrupted 0 Vicryl sutures

**POSTOPERATIVELY**
- keep NPO for 7 days (to protect mucosa healing) – so place NG tube in OR and suture it to nasal septum.
- keep intubated overnight (plus, steroids for 24 hours).

**COMPLICATIONS**

1. Durotomy - risk of meningitis from oropharyngeal flora.
   - watertight dural closure with addition of fascial graft and lumbar drainage may help prevent CSF fistulas
2. Care must be taken during resection at lateral margin of exposure to avoid injury to hypoglossal nerves, vertebral arteries, and carotid arteries.
   - pathology situated lateral to hypoglossal nerves and vertebral arteries may be better accessed via anterolateral, lateral, or posterolateral approaches
3. Patients with severe canal compromise may be subject to ischemic injury during positioning or intraoperative fluctuations in mean arterial pressure.

**POSTOP OF ANTERIOR APPROACHES**
Cervical Spine Surgery (Techniques)

**Foley**
Pull at 5 am on POD#1 – may discharge home early if voids.

**C-Collar**
- For 6 weeks after fusions.
  - **No C-collar** for 1-2 level ACDF: Dr. Cameron
  - 2-weeks for 1-level: Dr. Holloway.

**Imaging**
- **No imaging** – Drs. Graham, Mathern, Holloway
- **Routine imaging** – Drs. Cameron, Broaddus, JRC, Ward

**Follow up**
1) **6 weeks** - do XR (not for fusion but for any unexpected findings) and take off C-collar.
2) **3 months** – may do flexion-extension XR
3) **6 months**
4) **12 months** – time to diagnose “nonfusion” (only if symptomatic; some people never have radiographic fusion but remain asymptomatic); H: OrthoFix.

- If patient is symptomatic, especially if with SCI (e.g. central cord syndrome), consider MRI to check for decompression and syrinx development.

**POSTERIOR NECK APPROACH**

**Technique**

**Patient Position**
- N.B. avoid neck flexion or extension in myelopathy!
- N.B. keep head neutral (look from side at positioned patient) if fusing; tendency to flex neck – unable to swallow postop.
- Gel rolls longitudinally or white Wilson frame; tuck arms at sides.
- Table is placed in a **reverse Trendelenburg position** - to decrease intraoperative bleeding and intraocular pressure.

**Approach**
- Midline skin incision is made with a full-thickness scalpel cut, down into subcutaneous fat.
- Incision is deepened with electrocautery.
- Self-retaining retractors aid in hemostasis.
- Once below subcutaneous fat, it is very important to carefully stay in midline (actual median raphe may deviate from actual physical midline by quite a bit but is visible by carefully using electrocautery on cut rather than coagulate; median raphe usually looks like a white band of fascia approximately 3 to 4 mm wide)
- Care is used to avoid dissecting into paraspinal muscles, which would lead to greatly increased bleeding and postoperative pain.
- Crossing bleeders from venous plexus can be coagulated.
separation between paraspinal muscles can sometimes be very fine when they merge centrally in raphe.

at level of spinous processes, muscles span tips and can be preserved in performing unilateral foraminotomy/discectomy without fusion.

when the plan is to fuse or dissect previously fused levels, interspinous tissue can be taken with lateral soft tissue flaps so that only bone remains - this will minimize bleeding by staying out of vascular muscle.

levels are localized:
   a) spine needles on spinous processes percutaneously prior to incision – rarely needed
   b) towel clamp on exposed spinous process with intraoperative lateral radiograph.

once subperiosteal dissection has been completed with electrosurgery down to level of lamina, Cobb elevator is used to strip soft tissues laterally with scraping technique.

only expose enough of the lateral masses to place lateral mass screws and no further, as beyond the lateral masses, one encounters venous plexuses that bleed profusely + dorsal nerves innervating the paraspinal muscles may be injured and can result in substantial muscle atrophy.

**O-ARM**

the easiest for O-arm to move is Jackson / Axis table (but Mayfield adaptor is rather bulky and patient positioning is tricky).

spin O-arm early – helps to orient to anatomy and amount of dissection needed.

spin O-arm again after screw placement (obviates the need for postop CT) but before rod placement (so can adjust screws if needed).

**CLOSING**

removal of the dorsal portion of a prominent C7 and/or T1 spinous process can be extremely helpful for limiting wound tension in slender patients.

#1 absorbable suture is used for fascia and muscle.

   o if local irradiation has been performed or is anticipated, nonabsorbable suture should be considered, at least for the fascial closure.

numerous sutures with small bites are placed in fascia of paraspinal muscles deep in attempt to bring muscles back together - this combats incision's tendency to invaginate during healing.

   N.B. some experts do not close muscles to prevent necrosis at stitches!

some experts divide the bifid spinous processes with a bone cutter during approach, keeping the paraspinal muscles attached; these are tagged, facilitating bone-to-bone closure at the conclusion of the operation - prevents having to suture into muscle, which obligates necrosing the captured muscle.

it is helpful to tag clamp sutures in same layer and then tie them before proceeding to more superficial layer.

meticulous hemostasis and closure of dead space along with drains help to prevent postoperative wound complications that are inherent to this approach.

drain is highly recommended:
   — deep subfascial drain is placed.
   — superficial subdermal drain is added if the adipose layer is > 3 cm.

skin is closed with staples (Dr. Graham prefers Steri-Strips if skin is in reasonably good condition).
1) significant postoperative muscular pain
2) nerve (C5) palsies – use intraop EMG!
3) pulmonary complications (4.6%)
4) hematomas (3.22%), operative blood loss (significantly [p < 0.01] greater in dorsal approach compared with ventral approach)
5) wound infection (4.7% vs. 0.6% with ventral surgery)

LAMINECTOMIES (CLAM)

- **indications** - see p. Spin15 >>
- CLAM is contraindicated in the kyphotic spine (loss of cervical lordosis)
- if stenosis severe, decompress several levels as cord tends to “herniate / bow” posteriorly – risk of SCI, C5 palsy (use intraop monitoring!); plus, OPLL tends to progress postoperatively.
- **complications:**
  1) delayed formation of postlaminectomy membranes → recompression of the spinal cord dorsally over the site of the laminectomy.
  2) increased cervical mobility (esp. at lower levels of CLAM) → kyphosing:

LAMINOPLASTY (S. EXPANSIVE LAMINOPLASTY)

Catalogs
Medtronic - CENTERPIECE (laminoplasty) >>

Used sources:
Jandial – procedure 61

ADVANTAGES OVER ACDF / CORPECTOMY
• much lower complication rate and greater functional recovery for long segment pathologies.  
  

**ADVANTAGES OVER CLAM**

• preserves posterior tension band – prevents loss of sagittal balance (lordosis).
• preservation of the lamina provides an anatomic barrier preventing the formation of postoperative scar over the dura mater (postlaminectomy membrane).

Controversies (laminoplasty vs. PCF)
Expansive laminoplasty (EL) or laminectomy followed by fusion (LF), are usually performed in patients with multilevel (≥ 3) cervical spondylotic myelopathy (CSM). However, the superiority of either of these techniques is still open to debate.

Seven studies comprising 302 and 290 patients treated with EL and LF, respectively, were included in the final analyses. Both groups were similarly improved in JOA grade (MD 0.09, 95% CI -0.37 to 0.54, p = 0.07) and neck pain VAS score (MD -0.33, 95% CI -1.50 to 0.84, p = 0.58). Both groups evenly lost cervical lordosis. In the LF group lordosis seemed to be preserved in long-term follow-up studies, although the difference between the 2 treatment groups was not statistically significant. Both EL and LF lead to clinical improvement and loss of lordosis evenly. There is no evidence to support EL over LF in the treatment of multilevel CSM. Any superiority between EL and LF remains in question, although the LF shows favorable long-term results.


**INDICATIONS**
(same as for laminectomy) – cervical stenosis: see also p. Spin15 >>

1. Multilevel cervical stenosis with preservation of normal lordotic curvature (laminoplasty is contraindicated in the kyphotic spine)
2. Diffuse ossification of posterior longitudinal ligament.
3. Posterior cord compression resulting from buckling of thickened ligamentum flavum
4. Posterior exposure of intraspinal pathology (tumor, vascular malformation, infection, hematoma.
5. Factors limiting anterior neck dissection, including short neck, scarring from previous anterior neck dissection or radiation).

**CONTRAINDICATIONS**

1. Straightening of normal cervical lordosis or kyphosis
2. Cervical instability (from trauma, tumor invasion, or connective tissue disorder)
3. Broad-based ventral pathology that may not be readily accessed from posterior approach

**TECHNIQUE**

• prone on chest rolls or wide Wilson frame.  
• head in pins – flexed and translated posteriorly.  
  
  *N.B. avoid neck flexion or extension in myelopathy!*
• leave interspinous ligament intact - undisturbed posture tension band.
• **exposure stops medial to facets** - this is motion-preserving procedure, and arthrodesis is to be avoided.

• **complete longitudinal troughs** are drilled on laminae on one side; if one side has more stenosis or is more symptomatic, this is the side on which we perform the opening.
  — at lamina–lateral mass junction, 3-mm cutting bur drill bit is used to make small laminotomy hole at inferior aspect of the inferiormost lamina of the levels to be addressed.
  — Medtronic B-1 bit (low-profile footed drill bit) – cut cephalad
  — caution is warranted at C7, when included, because of its unique angle.
  — it is also acceptable to drill a small trough (using the 3-mm cutting bit) on opening side and complete opening in this fashion or with 2-mm Kerrison punch.
  — use of **bone wax** is avoided!

• **partial depth troughs** are drilled on the laminae with a matchstick drill bit on the other side.
  — bone bleeding on this side can be addressed with bone wax.
  — care is taken not to breach anterior cortical bone.
  — surgeon should err on the side of leaving more bone, as fine-tuning can be done once every level is at, or close to, the desired thickness.

  ![Halfway through other side](image)

• using 2 mm Kerrison, divide ligamentum flavum at the ends of planned laminae-spinous process complex.

• laminae-spinous process complex is **hinged**.
  — controlled pressure is applied to spinous process toward hinged side to expand opening.
  — sometimes one must resect ligamentum flavum, as pressure is applied to the spinous process, to open the door.
  — of hinge fails to bend despite resection of what seems to be adequate amount of bone, check to be sure that the bone was completely divided on open side.
  — foraminotomies, if indicated, are now performed (do not to destabilize facets!); may need to use **lateral hole plate** then (as cranial-caudal diameter of lateral mass gets shortened).

• if hinge side is fractured, three simple solutions are available:
  a) often no change in operative plan is necessary because the posterior elements remain in position by wedging the graft in position and its fixation on the open side
  b) entire hinge side can be opened, in the same technique as the open side, and grafts can be placed
  c) **trough plate** can be placed across fracture line:
laminae-spinous process complex is **fixed** in new position with OD plates laid on posterior surface of facets and lateral edge of laminae;

N.B. most common reason for failure of laminoplasty has been restenosis due to hinge closure!

— screw may be placed in graft (if used) to secure it in position.

N.B. do not place any graft across interlaminar spaces to ensure no fusion occurs across levels!
Examples of plates:

**Medtronic CENTERPIECE™ Plate Fixation System**

A. **Open Door Plates** - laminar shelf on plate, available in 8 mm to 18 mm sizes in 2 mm increments

B. **Graft Plates** - available in 8 mm to 18 mm sizes in 2 mm increments
C. **Lateral Hole Plates** (in Open Door and Graft Plate Designs) – Medial/lateral orientation of the lateral mass screw holes allows for flexible screw placement

D. **Wide Mouth Plates** - wider laminar shelf to accommodate thick laminae:

E. **Trough Plates** - small, angled plates provides fixation for floppy or displaced hinge:

Examples of grafts:

**Medtronic CENTERPIECE™ System**
— all cortical graft, freeze-dried, curved edges
— predrilled center screw hole allows for immediate access for screw insertion
— available in 8 mm to 18 mm sizes in 2 mm increments

**PCF**

**Indication** – adjunct to laminectomies to prevent kyphosis (check CT – if significant anterior osteophytes are present, patient may not kyphose without PCF)

**Contraindications:** aberrant vertebral artery, fractured lateral mass.

- prone on chest rolls or wide Wilson frame.
- head in pins – translated posteriorly (but keep neck neutral for fusion).
- Dr. JRC likes fluoro – to have XR whenever needed.
  — fluoroscopy should be used to confirm proper cervical alignment if PCF is part of either occipitocervical fusion or cervicothoracic fusion

**ARTHRODESIS**

- facet joints are exposed and the joint cartilage is denuded with curettes or small rasps.
- joint space is packed with autologous bone chips; alternatively, machined interfacet allograft spacers can be used to augment posterior cervical fusion (see below).

**CERVICAL INTERFACET SPACER (CIS)**

- addition to posterior cervical fusion
- allograft technology to provide indirect neuroforaminal decompression while simultaneously enhancing fusion by placing the allograft in compression.

**INSTRUMENTATION**

- fixation at C1 can be achieved by screws placed in the lateral mass, see below >>
- fixation at C2 can be achieved by screws placed in the pars, pedicle, or lamina, see below >>
- lateral mass screws are used for fixation from C3 to C6; whereas pedicle screws are typically used for fixation at T1-2.
- C7 lateral mass is rather small, so:
  a) use C7 (and T1) pedicle screw
  b) fixation into C7 is not performed to facilitate screw fixation into T1.
- additional sublaminar hooks or translaminar screws can be used at the caudal part of the construct to reinforce the screw fixation if necessary.

**LUQUE L-RODS AND LUQUE RECTANGLES**

*Read Benzel (2012) ch. 147*
**LATERAL MASS FIXATION**

Medtronic - Vertex (older system), Infinity (newest system)

- expose entirely posterior surface of lateral masses.
- *place screws before laminectomy* to protect spinal cord from instrument passing above exposed dura.
- *screws* are 3.5 mm diameter, 14-16 mm length.
  - “favored-angle screws” - allow for fewer angulations in certain planes and a bias in the way the screw saddle sits on the screw.
- *rods* are 3.0-3.5 mm diameter.
  - lateral offset connectors can be placed if a screw is significantly outside the rod longitudinal axis, as sometimes occurs with the transition from lateral mass screws to thoracic pedicle screws.

Standard Magerl technique:
- divide mentally posterior surface of lateral masses into quadrants; drill with matchstick starting hole at medial-inferior corner of lateral mass center.
— looking globally at starting points of posterior cervical screws, particularly in a long segment fixation incorporating occiput, C1, or C2, can help prevent unnecessary contouring during rod placement

- drill hole aiming up (to avoid nerve root) and out (to avoid vertebral artery); best way to achieve trajectory is to rest drill shaft on Cn-1 spinous process tip (as Dr. JRC noticed – you always need steeper trajectory than that).
  - if vertebral artery is encountered, place bone wax in hole → insert shorter salvage screw for tamponade, avoid placement of screws on contralateral side (alternative methods of fixation should be pursued if necessary, such as laminar screws); if the bleeding is refractory to these measures, it may be necessary to expose the vertebral artery for primary repair or occlusion.
- if screw is not self-tapping, then tap but just the beginning of canal (just to engage tap); ± check with ball probe (practically not needed as bicortical fixation is considered superior to unicortical fixation; if vertebral artery is injured – will see bright red blood through hole immediately).

- options for stripped screw:
  a) larger diameter rescue screw
  b) small amount of polymethylmethacrylate placed into hole before screw
  c) trans-facet screw

- decorticate posterior surface of lateral masses and facet joint spaces

- place screws and rods.
  - for lowest levels may be difficult to achieve trajectory; options: a) extend incision, b) make a stab skin incision to pass screw driver, c) skip C7 and place T1 pedicle screws (unique trajectory – very inward and very towards feet, almost 45 degrees towards floor).
- if needed, perform laminectomies.
- place grafts into lateral gutters ± facet joint spaces.

**Pedicle Screw Fixation**

- pedicle is entered 1 mm caudal to the facet joint.
- drill aiming medially 25-30 degrees; orientation is perpendicular to the long axis of the spine at C7, T1, and T2
- use either navigation or verify the position of the pedicle by palpation through a small laminoforaminotomy prior to drilling.
- screws are 4.0 mm diameter.
- lateral mass screws are preferred for C3-6.

T1 pedicle screw:
CERVICAL SPINE SURGERY (TECHNIQUES)

Op210 (92)
C3-C7 Pedicle Screw Fixation

**INDUCING LORDOSIS**
even with lordotic rods and compression, it is not uncommon to achieve inadequate lordosis, especially if the construct includes the upper thoracic spine.

- solution - use of spinous process cables or a third rod fixed into the spinous processes of C2 and thoracic vertebrae with subsequent compression to create additional lordosis.

- spinous processes should be no more than 1 cm apart to create adequate lordosis.

  N.B. excessive neck extension may cause iatrogenic compression of the nerve roots, especially if there is radiographic foraminal stenosis preoperatively. H: prophylactic foraminotomies (if there are flexible segments with foraminal stenosis, the patient can be placed supine in the clinic and asked to maintain the neck extension for 10-15 min - if the patient develops any numbness, paresthesia, pain, or weakness in the arms, then a prophylactic foraminotomy should be performed).

- for fixed deformity cases, Smith-Petersen Osteotomy and Pedicle Subtraction Osteotomy can be used.


PERCUTANEOUS FORAMINAL DECOMPRESSION & FUSION

DTRAX facet system (Providence Medical Technology)
- minimally invasive approach - distraction of the facet joint to increase neural foraminal volume for nerve root decompression.

- titanium implant inserted percutaneously from a posterior approach under fluoroscopic guidance through 1cm working channels.

- DTRAX increases foraminal volume more than 17%

- DTRAX had minimal effect on cervical lordosis:
  Change in overall cervical lordosis = 1.9 degrees
  Change in segmental lordosis at the treated level = 1.1 degrees
INDICATIONS
Lateral disc herniations without significant uncovertebral spurring - see p. Spin11.

CONTRAINDICATIONS
Central disc herniations and "disc-osteophyte complexes".

INTRAOPERATIVE
Position
- prone in pins, neck in flexion
- Gardner-Wells tongs may be used to apply traction (10-20 pounds) via flexion vector
- maximum reverse Trendelenburg position (minimizes venous bleeding)
- shoulders may be taped down using 3-inch silk tape from around the acromioclavicular joint, down the arms (supporting them from falling downward), then around the foot of table. Overstretch with excessive force can cause a brachial plexus injury.
- Dr. Broaddus uses microscope; Drs. Cameron, Graham don’t.
- in personal observance, high risk of nerve damage – use intraop free-running EMG.

Posterior approach for C6-7 herniation on left; interrupted line - skin incision; oblique lines - area of bone removal that exposes left C7 nerve root and disc herniation.

Foraminotomy
- interlaminar V of lateral aspect is starting point (check it with ballprobe):
Dr. Broaddus uses high-speed **irrigating diamond bur** (thermal damage may be detrimental) - held like a pencil as close to the bottom of the bur as possible for better control - surgeon's fingers should point down into the wound as a result; the other hand holds a small Frazier suction tip.

**Drs. Cameron, Graham** use **matchstick drill bit**.

Drill bit is maneuvered in small, circular motions, getting gradually deeper (ventral); in-and-out motions are to be avoided.

**Inferior articular process of superior vertebra is burred away in L-shaped resection** (resect 50% of distance between interlaminar V and lateral margin of facet – this is where lateral margin of pedicle is*), leaving superior articular process of inferior vertebra:

*Foramen is bounded by pedicles; if one performs decompression lateral to pedicle, foramen will be completely free!
- if facet joints are arthritic and have large spurs, foraminotomy hole can become quite deep.
- burring is stopped once soft tissue is seen protruding through remaining bone at "floor" or on "walls" of foraminotomy or bone takes on translucent appearance from becoming so thin.
- any bone that is overlying C6 pedicle is then removed with 1 mm Kerrison (careful – don’t lever Kerrison heel against nerve root – may easily permanently damage it):

- it is preferable to complete drilling laterally first, rather than medially, because if medial cortex is perforated first, engorged vein underneath protrudes while surgeon is trying to complete lateral drilling and causes considerable bleeding and difficult visualization.
- **Cord protection**: suction tip is maintained in interspace when drilling, to protect the soft tissue overlying the cord in case of a sudden drill "kick" or movement. Alternatively, curette can be placed into interspace, hooked into foramen, to protect cord. Codman-Karlin 2B curette is ideal tool, since it can be held like a pencil, and with a pulling motion, the bone overlying the foramen can be lifted out; 1-mm Kerrison rongeur is also useful.

- **Vein that overlies nerve root tends to bleed profusely**, so it is important to understand maneuvers that can decrease bleeding. Reverse Trendelenburg positioning with the abdomen hanging freely is used to decrease venous pressure. Thrombin soaked hemostatic gelatin (Gelfoam) and cottonoid patties are packed into the bleeding foraminotomy site.

- Thoroughness of decompression is assessed by palpating superior and inferior pedicles with tip of Codman curette or nerve hook or Penfield #4 - once entire interpedicular region has been unroofed, bony decompression is done.

**Figure 76-10**

A, The arrows point to the C6 pedicle. The nerve is retracted cranially, and a right-angled ball-tipped probe is utilized to hook the herniated disc fragment. If there is no disc fragment and one is just performing a foraminotomy, after making sure that the foramen is completely open, one should recheck with the neck in full extension. This ensures that even with the patient’s neck in full extension, the foramen is still wide open. It should also be noted that the entire foraminotomy and discectomy procedure should be performed with the neck in maximal flexion, which opens up the foramen. B, The root is retracted cranially, and the small pituitary rongeurs are used to remove the disc fragment.
- resecting 50% of cervical facet does not typically require fusion or stabilization.
- at the end, adequacy of foraminal decompression can be checked with the patient's neck extended.

**Figure 76-11**

A, Postoperative CT showing a foraminotomy at C6-7. B, Three-dimensional reconstructed image of the foraminotomy.
Discectomy
- find nerve root axilla – reach for disc there; may need to bipolarize veins there.
- nerve root can be gently retracted superiorly and disc material removed with reverse angle curette.

**COMPLICATIONS**

1) neurologic deterioration
2) dural injury → pseudomeningocele (H: fibrin sealant or tissue graft and tight wound closure)
3) inadequate decompression with persistent or recurrent symptoms.
4) air embolism

**OCCIPITOCERVICAL FUSION**

DePuy Synthes
SYNAPSE system

DePuy
MOUNTAINEER (Occipito-Cervico-Thoracic Spinal System)

Stryker
Oasys (occipito-cervico-thoracic system)

Medtronic
Vertex system

K2M / Stryker
CASPIAN® Occipital Anchor – biomechanically analogous to occipital plate

N.B. take lateral XR preop with patient standing in neutral position – note the angle between C-spine and cranium – use same angle when positioned on the table (otherwise, might be hard to judge correctly); too much flexion – unable to swallow food!
N.B. Take meticulous attention not to rotate head in relation to body.

- Instrumentations along junctions (occ-C, C-T) tend to break rods - some people place 3 or even 5 rods.
- Always put crosslink at C1-2 level.

**C1-C2 INSTRUMENTED FUSIONS**

Good articles:

O-arm use >>

To reduce risk of vertebral artery injury, electrocautery is not used more than 15 mm lateral to midline when performing subperiosteal dissection of superior posterior ring of C1.

**TRANSARTICULAR SCREWS**

Risk of vertebral artery injury – check on CT how much bone is available at C2 transverse foramen level.

Technique described by Foley and Fassett and Apfelbaum – see Medtronic Vertex manual
CERVICAL SPINE SURGERY (TECHNIQUES)

C1-C2 Transarticular Screw Fixation

Entry Point

Drilling Trajectory

Final Screw Placement

TRANSLAMINAR SCREWS

Technique described by Wright – see Medtronic Vertex manual
C2 Translaminar Screw Fixation

Entry Point

Drilling Trajectory

Final Screw Placement

LATERAL MASS SCREWS (C1)
Technique described by Harms and Melcher
CERVICAL SPINE SURGERY (TECHNIQUES)


C1 Lateral Mass Screw Fixation

Entry Point

Drilling Trajectory

Final Screw Placement

IMPLANTS:
3.5 x 32-36-mm lateral mass screws into C1 (Dr. Graham uses lag screw)
3.5 x 14-16-mm lateral mass screws into C2
20-30-mm rods

N.B. 3.5 mm screws (4.0 mm are used for rescue)

- head in a 3-point Mayfield headholder in pins
- prone on chest rolls with arms tucked at sides (if using navigation – best on Jackson table with Mayfield adapter)
- reverse Trendelenburg position to minimize bleeding!
- head and neck in as neutral position as possible (but it is OK to flex slightly to open C1-2 space)
- bulk of upper torso retracted caudally with the use of wide tape attached to the skin.
- expose posterior arch of C1, laminae of C2.
- expose inferior part of posterior surface of C1 lateral mass through C1-2 interspace.
  - retract C2 root with DRG caudally (if need to sacrifice → occipital anesthesia)
  - may encounter very large engorged venous plexuses on both sides (hemostasis achieved with Gelfoam packings and bipolar) – may lose lots of blood; H: subperiosteal dissection – with small curette lift periosteum from C1 arc root
- C1 lateral mass screws:
  - entry point is the middle of the junction of the C1 posterior arch and the midpoint of the posterior inferior part of the C1 lateral mass
  - trajectory: drill bit should be angled straight or slightly convergent, approximately 5-10° medial, and parallel to the underside of the C1 posterior arch. When drilling under fluoroscopic control, additional orientation can be obtained by directing the tip of the drill bit toward the caudal half of the anterior tubercle of C1
  - palpate with curette the lateral mass → Midas Rex drill used to drill through the cortical surface of C1 lateral mass and then manual drill used to drill along the pedicle under fluoroscopic guidance to achieve bicortical purchase (ball probe used to feel the trajectory of the screw) → polyaxial screws placed on either side of C1.
    N.B. C1 needs bicortical purchase! (vs. C2; although Nader recommends bicortical for C2 as well)

Beware of arcuate foramen (foramen arcuale atlantis, ponticulus posticus or posterior ponticle, or Kimerle anomaly) - frequently encountered normal variant of the atlas - atlantic portion (V3) of the vertebral arteries pass through this foramen – can be injured if surgeon tries to drill C1 lamina to better accommodate C1 screw head.
  - incidence is ~ 8% (range 1-15%) and it is more common in females.
  - variable morphology, can be complete or incomplete and may be unilateral or bilateral.
LATERAL MASS: PEDICLE AND PARS SCREWS (C2)

- give marginally better fusion rate
- risk of vertebral artery injury – check on CTA how much bone is available at C2 transverse foramen level; artery is most vulnerable as it traverses through the foramen transversarium of C2
Technique for C2 pedicle screw fixation described by Dickman.


Technique for C2 pars interarticularis screw fixation described by Mummaneni and Foley.


C1-C2 posterior screw-rod fixation technique is reversible, and is especially applicable to active patients with healed odontoid fractures!
Cervical Spine Surgery (Techniques)

C2 Pedicle and Pars Interarticularis Screw Fixation

- C2 Pedicle Screw
- C2 Pars Screw

Entry Point

20-30°

10-15°

Drilling Trajectory

20-30°

35°

Final Screw Placement
Aiming target for pars screws:

- **C2 pars screw:**
  - **start point** (start in cortex with C1 drill bit) – posterior surface of lateral mass:
    - for pedicle screw: the entry point is 3-4 mm above the C2 inferior facet
— for pars screw: the entry point is 3 mm superior to the C2-3 facet joint line and 3 mm lateral to the lamina-lateral mass junction; N.B. do not start too high (i.e. too far from C2-3 joint) – screw will go too close to superior cortex (screw may get exposed during decortication at the end).

- **trajectory** — superomedially (to avoid vertebral artery) along medial border of pars (thus, feel with Penfield 4 or curette medial border of superior facet of C2) towards posteromedial tubercle of facet joint; use 2 mm drill bit
  — for pedicle screw: the drill bit should be angled 20°-30° medial and directed into the central axis of the C2 pedicle. In the sagittal plane, the drill bit is angled approximately 20°-30° cephalad.
  — for pars screw: the drill bit should be angled slightly medial (10°-15°). In the sagittal plane, the drill bit is angled approximately 35° cephalad, assessed fluoroscopically by aiming toward the anterior tubercle of C1.
- decorticate C1-2 joint space with small M8 bit and stuff it with bone shavings.

### VERTEX (MEDTRONIC)

- the Adjustable Drill Guide can be used for drilling the desired depths from 6 mm up to 52 mm.
- the depth of the Drill guide can be adjusted in 2mm increments to allow for desired drill depth that will correspond with the lateral mass screw length.
  — it may be impossible to use drill guide at C1-2 interspace if it is narrow – use “naked” drill.
- the drilling depth is adjusted by pressing the slide forward while adjusting the measuring tube to the desired drill depth. Once the slide reaches the desired depth, rotate the slide into the locked position and prepare the pilot hole in the desired trajectory

- Vertex screws are self-tapping, therefore this surgical step is considered optional. If tapping is desired, place the Tap Sleeve over the end of the Tap Shaft to visualize the depth of the tap in bone. The trajectory of the tap should follow the same trajectory as outlined for drilling
- gold anodized tip of the tap represents the first 10 mm of thread
- Ball-tip Pedicle Feeler may be used to gently palpate the bone of the C1 lateral mass

**SONGER® SPINAL CABLE**

- alternative to monofilament wire for spinal fixation procedures via sublaminar passage.

Double wires are the best!

- available in titanium (1.3 mm diameter) and steel (1 mm diameter).
- available in single-loop and double-loop configurations.
- can be tensioned and secured using a single instrument.
- known level of tension can be achieved using the Torque Driver

C1-2 fusion using bone graft:
HALIFAX CLAMPS

Not recommended - poor results!
ODONTOID SCREW

Outcomes (fusion rates) - see p. TrS9 >>

Contraindications
- fracture > 6 weeks old.
- disrupted transverse ligament (TL holds distal fragment in place while placing screw).
- look at apical ligament before surgery (if calcified*, aseptic necrosis will happen and odontoid screw will not work).
  *distal dens blood supply is coming through apical ligament
- difficult if patient has prominent chest (hard to achieve angle).

TECHNIQUE

Anterolateral approach – incision at C5 level.
- biplane fluoroscopy (make sure everything is visible – place bite block to keep mouth open, make sure head support is not in a way [Mayfield frame is obstructive]):
  - drill off the superior anterior corner of C3 (also violates anterior part of C2-3 disk)
  - wire pin inserted under fluoroscopy is replaced by lag screw over it (1 or 2 screws have same success):
- lag-screw effect can be obtained by drilling near bone fragment hole to diameter greater than, or equal to, outer diameter of a screw: