# Cervical Spine Surgery (TECHNIQUES)

Last updated: January 28, 2021

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TONGS application → see p. TrS5 >>
HALO application → see p. TrS5 >>
Reduction of FACET SUBLUXATION / PERCH / DISLOCATION → see p. TrS9 >>

CHOICE OF APPROACH

Surgery must address two PATHOPHYSIOLOGIC COMPONENTS:

Static – surgical decompression
Dynamic – surgical fusion

DECOMPRESS + FUSE

- 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).
CERVICAL SPINE SURGERY (TECHNIQUES)

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 spilt 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**
**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 >> (including protocol for intraop spinal cord injury)

**LEVEL LOCALIZATION / WRONG LEVEL SURGERY**

Wrong level surgery

Incidence: 50% at least one wrong level surgery during career (anonymous survey of 415 spine surgeons); true incidence underreported (0.4-4.3%)

Distribution: lumbar (71%), cervical (21%), thoracic (8%)
Risk factors:
1. Difficulty visualizing reference points
2. Unusual anatomy
3. Large body habitus
4. Failure to re-localize after exposure
5. Inconsistent counting methods

Prevention measures:
- Be aware of aberrant anatomy – develop level counting plan preop.
- Avoid parallax with localization XR.

Extreme prevention measures:
1) Preop interventional radiologist injects methylene blue, places metal marker
2) Radiographic time-out
3) Intraop send localization XR to radiology and do not proceed until radiologist calls into room to discuss with attending.

CERVICAL
- 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).
- If shoulders very high (unable to see operative level on lateral XR) – use AP view or localize what you see on lateral view and count down under direct exposure.

OUTCOMES, PATIENT SELECTION
Diagnose clinical syndrome (not a radiological diagnosis*) – look for mechanical back pain (deep and agonizing, increased by loading, decreased by unloading)

*"Mankind would be better off without spine MRI" – Prof. Edward Benzel

Rule out non-mechanical pain:

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<thead>
<tr>
<th></th>
<th>True</th>
<th>False</th>
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<tr>
<td>I have low energy most days.</td>
<td></td>
<td></td>
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<tr>
<td>Most of the times I do not get restful sleep.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I spend more than 12 hours a day resting and/or sleeping.</td>
<td></td>
<td></td>
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<tr>
<td>My pain causes me a great deal of suffering.</td>
<td></td>
<td></td>
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<tr>
<td>I have pain in two or more parts of my body.</td>
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Make sure patient exhausted all conservative measures:
1. Weight loss
2. Smoking cessation
3. Increase activity
4. Core strengthening
5. Core flexibility
6. Wean opioids (opiate-induced hyperalgesia)

Explain to patient that pain is not harmful – enough for some patients to get a peace of mind to continue conservative treatment.

**Importance of preoperative opioids on pain outcomes**


- 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!

Preoperative Opioid Use and Clinical Outcomes in Spine Surgery

In patients undergoing surgery for lumbar degenerative disease, preoperative opioid use was significantly associated with: higher inpatient narcotic consumption,13 higher postoperative opioid use,10-1222-23-25-27-29-31-34-41-44 decreased opioid independence at 12 mo postoperatively,22 an increased chance of function failure postoperatively,14 worse patient-reported outcomes (12-Item Short Form Health Survey [SF-12], EuroQol-5D [EQ-5D], Oswestry Disability Index [ODI], Neck Disability Index [NDI], Numeric Rating Scale [NRS] scores),11-20 higher visual analog scale (VAS) scores for low back pain,46 lower physical component score (PCS) and mental component summary (MCS) scores,46 greater disability postoperatively,46 higher preoperative Modified Somatic Perception Questionnaire [MSPQ] scores,21 decreased frequency of urinary retention,42 increased hospital length of stay,3-26303233 higher medical costs,3-103633 gastrointestinal and urinary problems,26 higher odds of not achieving meaningful improvements in function,34 quality of life,34 dissatisfaction,34 90-d complications,34 extremity pain,34 axial pain,34 higher pain diagnoses,10 emergency department (ED) visits,10 readmission,10 90-d wound complications,10 worse functional outcomes postoperatively,29 increased patient mortality,30 aggregate morbidity,30 induced mental disorder,30 respiratory failure,30 surgical site infection,3-30 mechanical ventilation,30 pneumonia,30 myocardial infarction,30 postoperative ileus,30 nonroutine discharge,30 failure to rescue,30 device-related complications,3 hematoma- or seroma-related complications,3 acute posthemorrhagic anemia,3 and pulmonary insufficiency.3

In patients undergoing surgery for cervical degenerative disease, preoperative opioid use was significantly associated with: elevated inpatient narcotic consumption,13 higher postoperative opioid use,22-2934-40-41 reduced overall clinical success,47 higher hospitalization duration,30-33 higher medical costs,33 worse patient-reported outcomes (SF-12, EQ-5D, ODI, NDI, NRS scores),11-20 worse functional outcomes after surgery,29 increased donor site pain at 1 and 2 wk after harvest of tricortical anterior iliac crest bone graft (AICBG) for ACDF,48 higher preoperative MSPQ scores,21 decreased opioid independence at 12-mo postoperatively,22 decreased frequency of urinary retention,42 higher odds of not achieving meaningful improvements in function,34 quality of life,34 dissatisfaction,34 increased likelihood of 90-d complications,34-39 extremity pain,34 axial pain,34 higher risk of all-cause 90-d ED visits, higher pain-related ED visits, reoperation,39 receiving epidural or facet joint injections within 1 yr postoperatively,39 increased patient mortality,30 aggregate morbidity,30 induced mental disorder, respiratory failure, surgical site infection,3-30 mechanical ventilation,30 pneumonia,30 myocardial infarction,30 postoperative ileus,30 nonroutine discharge,30 and failure to rescue.

VERTEBRAL ARTERY
Anticipate need to mobilize in:
1) nerve sheath tumors with paraspinal extension:

2) en bloc cervical resections:
• analyze preop imaging – see where VA is displaced, which VA is dominant.
• benign tumors rarely have adhesions to artery (can be aggressive around tumor capsule).
• malignant tumors (see for signs of vertebral bone erosion, tumor enveloping rather than displacing artery) often invade artery.

VA pushed anteriorly by schwannoma (posterior view):

VA visible after tumor resection:

Posterior localization (e.g. for large paraspinal lesions):
• identify nerve and follow laterally (artery is more medial than most surgeons think – it is right at the lateral edge of vertebral body)
• resect pedicle if needed
• encounter robust venous plexus (easy hemostasis with injectable foam)
• stay within tumor margin.
• leave thin cuff of tissue around VA.

Anterior localization (e.g. for spondylectomy lateral mobilization)
• mobilize longus colli up and down over many levels to mobilize muscle laterally (do not cut muscle transversely – risk of Horner’s syndrome)
• go with curette laterally at upper level of vertebral body – to encounter transverse process.
• VA is directly under transverse process (dissect fibrous adhesions to nerve root)
• very little epidural bleeding
• remove transverse process with Kerrison:
C1-2 NERVE SHEATH TUMOR

Two types:
A. **Do not extend laterally to VA** – done in single stage posterior approach;
- debulk tumor centrally
- locate C2 pars and C1 lateral mass – transect tumor along this line
- mobilize tumor medially, away from VA
- work within tumor capsule laterally then develop plane around VA

B. **Extend laterally to VA** along ansa cervicalis – approach in 2 stages
transect tumor at the VA level - leave anterior tumor portion for anterior cervical approach:
### VA Injury

Study MRI / CT carefully before ACDF (VA medial to pedicle is a contraindication for anterior discectomy)

- majority of patients do not get strokes so calm down.
- let it bleed and find out where exactly injury is, then control bleeding with cottonoid.
- prepare patch of Surgicel with new cottonoid; remove old cottonoid and place Surgicel over injury; ideally, may add muscle plug over Surgicel.
- if injury inside bone (e.g. ponticulus posticus) – place bone wax.
- if injury during screw placement, place shorter screw (do not want to see screw in the artery on postop CTA) to tamponade and do not place screw on opposite side.
- keep working and do not check injury site; at the end, lift cottonoid off, may encase the whole area with bioglue.
- at the end, transfer patient to angiography suite – VA open, occluded, dissection.
- postop CTA before patient discharge – look for delayed pseudoaneurysm formation.
- incidence 0.07%.


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 VAIs. 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).

### 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 bag¹ longitudinally** underneath neck*** not shoulders²).
  *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
  ¹Dr. Mathern prefers folded towels
  ²Dr. Day places roll longitudinally between scapulae - allows shoulders fall backwards.
- Drs. Graham, Ward, Simon, Cameron, Mathern use 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.
INCISION

- some experts always use **left-sided approach** - lower chances of recurrent laryngeal nerve injury.
- transverse skin incision along skin crease; may **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 **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

**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.
**DISSECTION**

- 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**
- see above

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**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.

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**COMPLICATIONS**

(11-13.6%)

1) **dysphagia** (2-67%)
2) **esophageal injury** (0.02-4%) – usually only big hole is visible; 60% cases present > 30 days after surgery (usually due to migrated hardware); mortality 19%.
   - area of the esophagus most vulnerable to injury, known as Killian's Triangle, is formed by the junction of the paired inferior constrictor pharyngeal and cricopharyngeal muscles - anterior to
CERVICAL SPINE SURGERY (TECHNIQUES)

the C5-C6 disc (occasionally found more caudally), particularly susceptible to injury since the posterior esophageal mucosa lacks muscle protection (only thin buccopharyngeal fascia separates the esophagus from the retroesophageal space).

- dysphagia and odynophagia, followed by fever and cervical edema
- classic triad of vomiting, chest pain, and subcutaneous emphysema (Mackler’s triad) is seen in only 25% of cases and is more common in thoracic esophageal lesions.
- diagnosis: contrast esophagogram + CT with contrast
- treatment:
  a) conservative management - indicated in young patients with lesions smaller than 1 cm, who are asymptomatic and without infectious signs.
  b) surgical treatment – for suspected infection, fistula, or pseudocyst identified by contrast tests: primary repair (in delayed-presentation cases, defect is larger – add reinforcement with pedicled muscle).

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 overdistort.
9) vertebral artery injury – study MRI / CT carefully (VA medial to pedicle is a contraindication for anterior discectomy) see above >>

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 retractors are 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 discectomy (with pituitary rongeur).
- two different techniques for deep discectomy:
SMITH-ROBINSON TECHNIQUE
(Dr. Ward, Broaddus, Mathern, Simon)

**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 discectomy 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)

Interbody Graft:

- **Distraction Posts**
  - Inserted divergent
  - Distraction creates lordosis

- **Interbody graft**
  - Lordotic shape
  - Slightly oversized
    - Increase disc/foramenal 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):
CERVICAL SPINE SURGERY (TECHNIQUES)
• **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 – do not oversize graft! (easy to do it in trauma cases with disrupted posterior elements)
- 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):

**ILIAC CREST**

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

**I-FACTOR™ BONE GRAFT (CERAPEDICS)**

- 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.

**Plates 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

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- 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.

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**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
CERVICAL SPINE SURGERY (TECHNIQUES)

Op210 (30)

- 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:

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

*N.B. 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 caudad 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)

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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):

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,
CERVICAL SPINE SURGERY (TECHNIQUES)

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 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:
CERVICAL SPINE SURGERY (TECHNIQUES)

DIVERGENCE stand-alone interbody cage (MEDTRONIC)
CERVICAL SPINE SURGERY (TECHNIQUES)

AERO-C (STRYKER)
Stryker Aero-C (cervical zero profile) >>

ZERO-P AND ZERO-P VA (SYTHES)
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 “crosståreading”

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
**CERVICAL SPINE SURGERY (TECHNIQUES)\(^{\text{Op210 (47)}}\)**

**Zero P Natural**
- it has bone allograft instead of PEEK

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**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 each 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 decompresion 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 corpectomy 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):

  ![Image of corpectomy](https://via.placeholder.com/150)

- 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 – gives more lordosis and is more elastic than titanium 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.
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!

if one wants to avoid plate, may cut titanium cage the way that anterior edge is longer and overlaps anterior cortex of vertebrae above and below – may place screws through mesh holes.

**ANTERIOR PLATE**

**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)

**COMPLICATIONS**
• can lead to catastrophic sequela: neurological injury, airway compromise, or esophageal injury.
• prophylaxis – anterior plating.

Cervical Spine Surgery (Techniques)

Op210 (55)

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

Suggested reading:

Rhoton collection – Anterior Skull Base, part 2 >>

Very morbid operation – check if occiput-C2 fusion is not better alternative (degenerative retrodental pannus involutes after stabilization)

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
CERVICAL SPINE SURGERY (TECHNIQUES)

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 180º 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**
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

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 electrocautery 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.
  - 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).

**COMPLICATIONS**

(16.4-19%)
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:

![Witwer et al. (2007)](image)

**LAMINOPLASTY (S. EXPANSIVE LAMINOPLASTY)**

Catalogs
Medtronic - CENTERPIECE (laminoplasty) >>

References:
R. Jandial “Core Techniques in Operative Neurosurgery” (2011) – 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
   N.B. to qualify for laminoplasty, *patient needs to have lordosis*
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 (bicortical) 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 (unicortical) V-shaped longitudinal troughs** are drilled on the laminae with a matchstick drill bit on the other side.
  - aim 3 mm medially from the junction of the facet joint and lamina.
  - 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.

- Kim CH et al 2020 in RCT compared **regular drill bit vs. ultrasonic bone scalpel (UBS)**: hinge union rate was inferior in the UBS group at 6 mo postoperatively, but UBS was efficacious in reducing dural injuries and bleeding.
- 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:
DePuy Synthes ARCH laminoplasty system

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 (optional):
**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

At 6 months:
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; too much flexion – difficulty swallowing; too much extension – difficulty walking).
- 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

ALIGNMENT PARAMETERS

1) cervical lordosis
2) cervical sagittal vertical axis (SVA)
3) T1 slope

ARTHRODESIS

- look at flexion-extension films – try to create extension with fusion (improve sagittal balance to minimize persistent chronic pain).
- facet joints are exposed and the joint cartilage is denuded with curettes or small rasps or drill.
- 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)
- see below >>
- addition to posterior cervical fusion
- allograft technology to provide indirect neuroforaminal decompression while simultaneously enhancing fusion by placing the allograft in compression.
**CERVICOThoracic Junction**

- posterior approaches (vs. ACDF):
  - disrupt posterior tension band (muscle dissection, laminectomies, violation of ligamentous structures and facets).
  - lack anterior column support.
  - provide less restoration of cervical lordosis.
- constructs ending at the cervicothoracic junction (CTJ) may lead to higher rates of adjacent segment disease (prevalence of clinical adjacent segment disease (ASD) after cervical fusion ending at C6 or C7 is quoted from 16.0% to 38.1% at 10 yrs).
- if stopping short of the CTJ, do not disrupt the facets and interspinous ligaments.
- as of May 2020, there are 5 retrospective clinical studies: 3 recommend crossing the CTJ and 2 found no difference in outcomes.
  
  Crossing CTJ is recommended in smokers and osteoporosis (and others with increased risk of pseudoarthrosis); not recommended in frail patients

**Case series**


- retrospective review of 149 multilevel (≥ 3 levels) PCF adult patients with a mean follow-up of 18.9 mo.
- 79 (53.0%) constructs ended in the cervical spine and 70 (47.0%) constructs ended in the thoracic spine.
- 15 (10.1%) early revisions, 7 (4.7%) were related to the construct.
- C6 → T2:
  
  - 5 (8.3%) revisions were performed for constructs ending at C6, 1 (5.3%) at C7, 1 (2.6%) at T1, and none (0%) at T2 (P = .035).
  
  Extending fusion to T1-1 decreases revision risk 5-fold
  
  - mean procedure duration: 215 min at C6, 214 min at C7, 239 min at T1, and 343 min at T2 (P = .001).
  
  - mean estimated blood loss: 224 mL at C6, 178 mL at C7, 308 mL at T1, and 575 mL at T2 (P = .001).
  
  - no difference in length of stay, disposition, surgical site infection, or radiographic parameters.

T1 may be the optimal end level when taking revision rate, procedure duration, and EBL into consideration
### 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 and at steep angle; options:
  - a) *use C7 pedicle screw* (screw head may or may not collide with C6 screw head so may need to skip C6)
  - b) **C7** fixation is *skipped* to facilitate screw fixation into T1.
  - c) **C7** lateral mass screw is placed using the “*down and out*” technique
- 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; main indication – trauma, when stronger posterior purchase is needed.

  **T1 pedicle screw:**
CERVICAL SPINE SURGERY (TECHNIQUES)

Op210 (78)
C3-C7 Pedicle Screw Fixation

**Entry Point**

**Drilling Trajectory**

**Final Screw Placement**

**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.

Lee A Tan, MD K Daniel Riew, MD Vincent C Traynelis, MD Neurosurgery, Volume 81, Issue 6, 1 December 2017, Pages 893–898, https://doi.org/10.1093/neuros/nyx477 Published: 31 October 2017

FUSION EXTENSION
Globus
ELLIPSE® ADDITION®-C:

POSTERIOR FORAMINOTOMY, DISCECTOMY

Used literature:
Benzel “Spine Surgery: Techniques, Complication Avoidance, And Management“ 3rd ed.– chapter 76

Pending reading
Greenberg 469-470

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.

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

**Percutaneous Foraminal Decompression & Fusion (s. Cervical Interfacet Spacer)**

**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

**OCCIPITOCERVICAL FUSION**

DePuy Synthes
SYNAPSE system >>
DePuy
MOUNTAINEER (Occipito-Cervico-Thoracic Spinal System) >>

**Stryker**
Stryker Oasys (occipito-cervico-thoracic system) >>

**Medtronic**
Medtronic Vertex system >>

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

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.

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!

**Occipito-cervical angle**

> The occipitocervical angle (OCCA) is currently the gold standard radiographic measurement that helps clinicians estimate neutral craniocervical (CC) alignment in patients.

> The OCCa is useful due to its high interobserver reliability and because of the correlation of its angular value with surgical outcomes.
**OCC Angle**

The OCC angle is measured between the McGregor line (A) and a line parallel to the inferior endplate of C2 (B).

**C2-Mandible angle**

**C2-Mandible Angle**

Fig 2: The C2 Mangle is defined as the angle measured between a line parallel to the anterior C2-body/dens complex and a line parallel to the posterior mandible line of the mandibular ramus.
CERVICAL SPINE SURGERY (TECHNIQUES)

**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.
- consider placing a graft into C1-2 joint space after reaming it (e.g. using instruments from intrafacet spacer toolkit).

**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)

Interfacet fusion site

Laminar interposition graft

©1993, S. Harrison
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

N.B. 3.5 mm screws (4.0 mm are used for rescue), Dr. Graham uses lag screw for C1
- 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 foramen transversarium of C2

N.B. always can place C2 pars screws but not always pedicle screws!
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!
C2 Pedicle and Pars Interarticularis Screw Fixation

- C2 Pedicle Screw
- C2 Pars Screw

Entry Point

Drilling Trajectory

Final Screw Placement
Aiming **target** for pars screws:

- **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: