The Surgical Management of Cervical Myelopathy

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Disclosures

- ATEC: Consultant, Royalties, Stock, Teaching
- Globus: Teaching

Cervical Myelopathy

- Common degenerative (usually) condition caused by compression on the spinal cord that is characterized by clumsiness and difficulty with fine motor tasks in the hands and gait imbalance/ataxia



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Why I am Talking About Cervical Myelopathy?

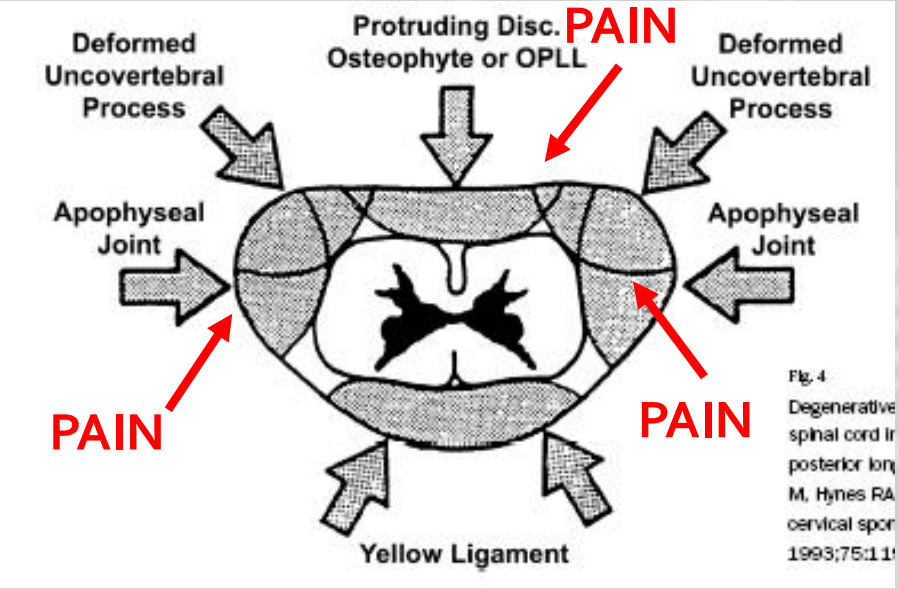
- **Isn't this a pain conference?**
  - I thought cord compression is/can be painless
- **Well….**
  - Neck & back pain are the #1 reason for PCP visits and missed days of work in the U.S.
  - Everyone here is on the front lines treating spine-related pain
  - Symptomatic Tandem (Cervical + Lumbar) stenosis occur in 25-36% of patients[1]
    - Painful lumbar stenosis can present with concurrent painful or painless CSM
    - Low back patients are at substantially increased risk of CSM
    - A complaint of pain often demands primary or all attention during a visit
- **Neck Pain is the most common CC of myelopathy**
  - Patients can adapt to (ignore) instability (cane/walker or reduce activity)
  - Unmanageable pain is frequently what ultimately brings patients in for assessment

[1]Yamada et al., JOSR 2018

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Pathophysiology

- **Cervical spondylotic myelopathy (CSM)**
  - Degenerative
  - Most common cause of cervical myelopathy





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Pathophysiology

- **Congenital Stenosis**
  - Congenitally narrowed canal → predisposed to develop myelopathy with minimal degenerative changes



- **OPLL (Ossified Posterior Longitudinal Ligament)**
  - Male > Female
  - Commonly in Asian ethnicity
  - Cause is unclear but associated w/ obesity, DM, poor calcium absorption

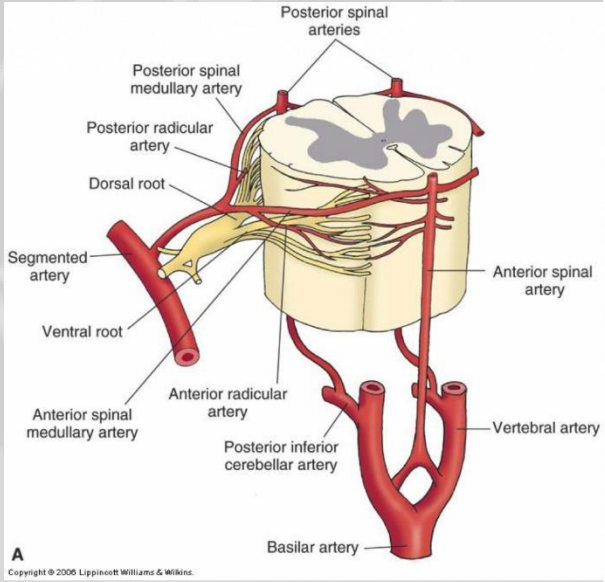


Pathophysiology

- **Less Common Causes**
  - Rheumatoid arthritis
  - MS
  - Trauma
  - Spinal cord infarction
  - Infection
  - Tumors
  - Hypermobility Syndromes

Neurologic Injury

- Direct cord compression
- Ischemic injury
  - Compression of anterior spinal a.
  - Decreased flow of pial plexus
  - Venous congestion





Rao et al, JBJS 2007

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Myelomalacia

- Severe compression results in irreversible changes in the cord
- Gray matter and lateral columns show the most changes
- Changes include: cystic cavitation, gliosis, and demyelination caudal to the compression



Rao et al, JBJS 2007

Funicular Pain

- Pain from compression of spinothalamic tract
  - Lhermittes Sign!
- Present with false-localizing signs
  - LE numbness and weakness
  - Claudicating LE pain
- Burning, tingling, or electric-shock sensation into the extremities



Funicular Pain

- **Diagnosis inherently challenging**
  - High rate of ASYMPTOMATIC tandem stenosis
  - High rate of some degree of stenosis in asymptomatic patients over 40
  - Degree of cervical stenosis does not correlate directly with likelihood of funicular pain
- **Useful adjuncts to imaging:**
  - SSEPs/MEPs with changes below effected level
  - Cervical ESIs



Pain and Cervical Myelopathy

- Schneider MM et al. 2024 (Global Spine J.)
  - Neurologic status did not differ significantly between pts w/ and w/o neck pain
- Kogl N. et al 2025 (The Spine Journal)
  - Severe neck pain linked to worse PROMs
  - Pre-op neurologic function NOT linked to PROMs
- Niu S. et al 2020 (Clinical Spine Surgery)
  - Neck pain was CC in 33% of patients with myelopathy
- Wong R. et al 2026 (Global Spine Surgery)
  - Pts with with fastest pain improvement had most severe neurologic impairment and pain at baseline
  - Pts with mild/moderate pain and disability had worst recovery

Natural History of CSM

- Slowly progressive
- Rarely improves with non-operative modalities
- Prognosis: early recognition and tx prior to permanent cord damage
- Clarke and Robinson followed the progression of 120 patients until the time of surgery
  - 5% had rapid onset of sx followed by a long period of quiescent disease
  - 20% showed gradual steady progression of S&S
  - 75% showed step-wise deterioration with variable times of quiescence

Clark and Robinson, 1956

Diagnosis

Subtle clinical findings of early myelopathy make diagnosis difficult and it is often overlooked

- **Neck pain and stiffness**
  - OFTEN the dominant complaint
- **Extremity paresthesias**
  - Diffuse non-dermatomal numbness and tingling
- **Weakness & clumsiness**
  - Dropping objects, difficulty with fine motor control
- **Gait instability**
  - Wobbly or "drunk" on feet
  - Most important clinical predictor of severity
- **Urinary retention**
  - Rate and only appears late in disease progression

Physical Exam

- **Motor**
  - LE weakness more concerning finding
  - Finger escape sign (Wartenberg's Sign)
    - Fingers extended and adducted
    - Small finger spontaneously abducts due to intrinsic m. weakness (and unopposed EDM)
  - Grip and release test
    - Should be able to make fist and release 20 times in 10 sec.
- **Sensory**
  - Proprioception dysfunction (dorsal columns)
    - Poor prognosis
  - Decreased pain sensation (lateral spinothalamic)

Physical Exam

- **Upper motor neuron signs (spasticity)**
  - Hyperreflexia
    - can be absent if concurrent radiculopathy or peripheral neuropathy
  - Inverted brachioradialis reflex
    - Tapping BR -> ipsilateral finger flexion
  - Hoffmann's sign
    - Snapping distal phalanx → spontaneous flexion of other fingers
    - More worrisome if asymmetric
  - Sustained clonus
    - > 3 beats of clonus (very low sensitivity, very high specificity)
  - Babinski
- **Gait and balance**
  - Toe-to-heel walking difficulty
  - Romberg
- **Provocative Tests**
  - Lhermitte Sign: extreme neck flexion → electric shock down spine and extremities

Needing a Cane is Not Part of Normal Aging





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Gait Analysis

- Gait can be confounded by many factors
  - PAIN
  - Age
  - Deconditioning
  - Weight/body habitus
  - Lower Extremity injuries surgeries or deformities
    - THA, TKA, ankle fracture ORIF, ankle fusion, LLD/amputations
    - Knee and/or ankle/foot valgus/varus
  - Peripheral neuropathy
  - Vision
  - Inner ear dysfunction
  - CVA
  - MS, Parkinson's, Cerebellar disorders
  - Medications

Gait Analysis

- **Watch patient walk into office and exam room**
  - Wide-based, unsteady, shorten stride, slowed paced, prolong double support, limited ankle extension
- **Foot drop**
  - L4 and/or L5 radiculopathy
  - Anterior tib injury/damage (prior surgery)
  - Peroneal neuropathy
  - Sciatic neuropathy
  - Charcot Marie Tooth
- **Trendelenburg**
  - L4 and/or L5 radiculopathy
  - Gluteus medius injury (THA)
  - Sciatic N.
- **Inability to heel-to-toe**

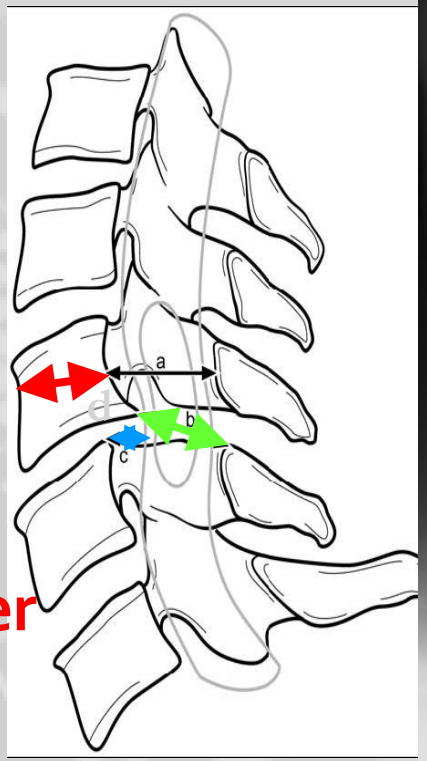


Differential Diagnosis

- Amyotrophic Lateral Sclerosis (ALS): upper and lower motor neurons are affected
- Multiple Sclerosis
- Carpal Tunnel Syndrome
- Diabetic Neuropathy
- Cerebral Issue (injury, stroke, etc.)
- Normal aging

Radiographs

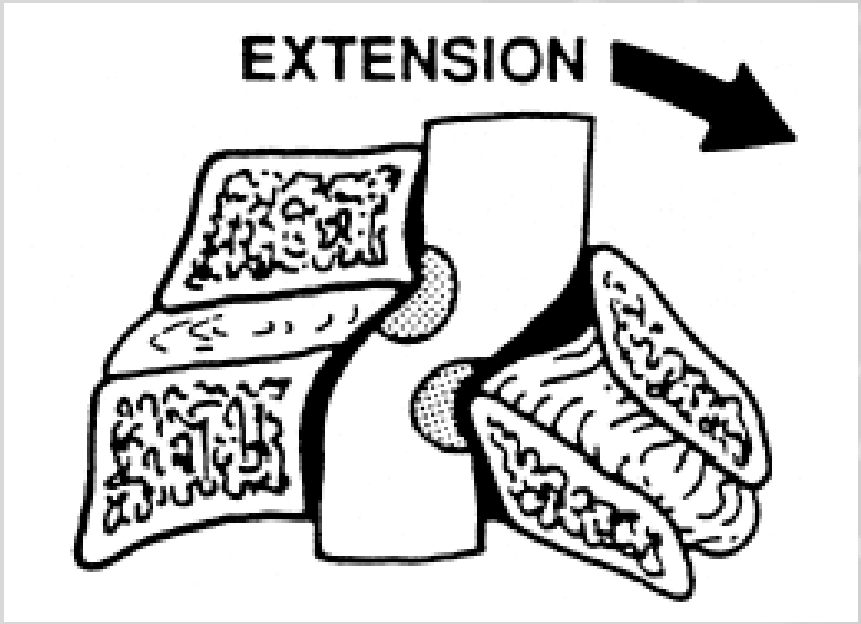
- **AP/Lateral/Flex/Ext.**
  - Degenerative changes
    - Uncovertebral and facet joint arthropathy
    - Osteophytes
    - OPLL
    - Loss of cervical lordosis
    - Spondylolisthesis (static or dynamic)
- **Decreased sagittal diameter**
  - less than 13mm on lateral XR
  - Torg ratio < 0.8 (a/d)

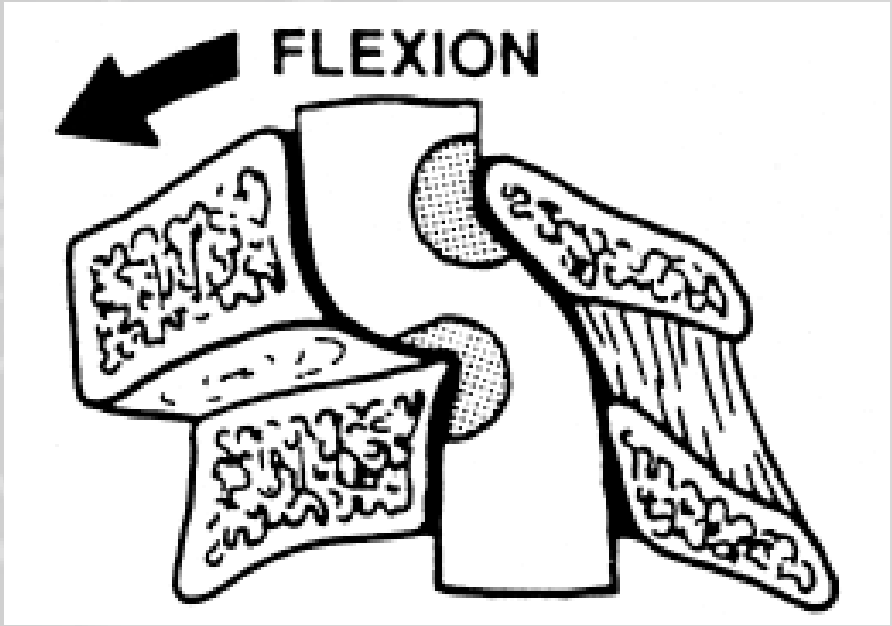




Dynamic Stenosis

- Translation or angulation between vertebrae → narrow canal space
- Get FLEX-EX imaging

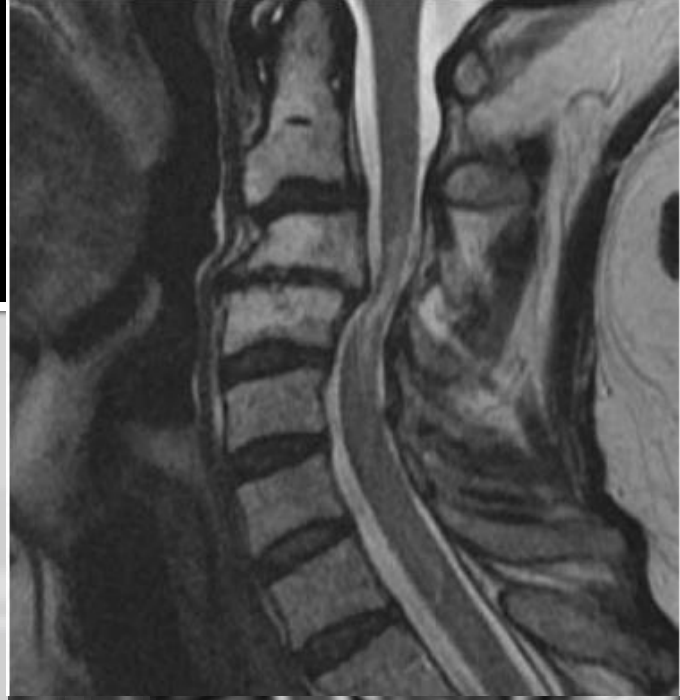


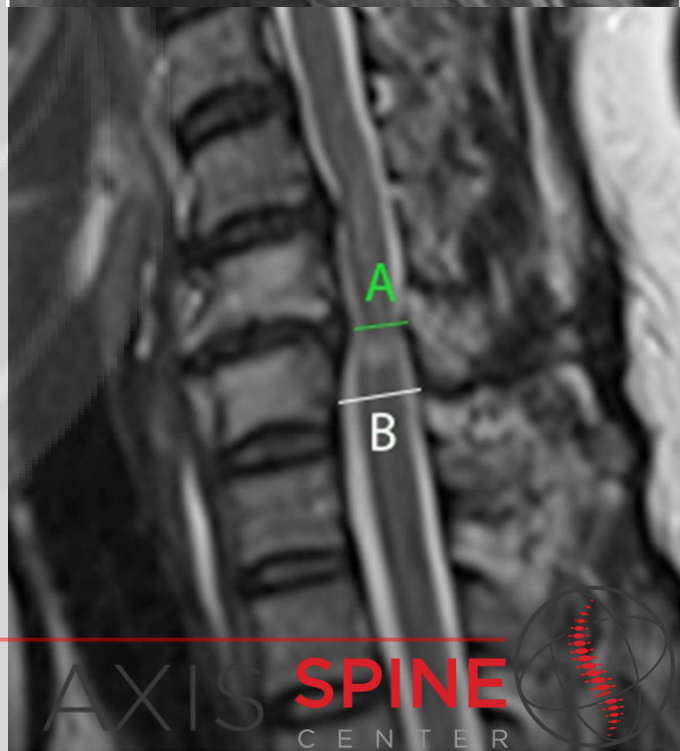


Bernhardt et al, JBJS 1993

MRI

- Study of choice to evaluate cord
- Evaluate CSF effacement
- Spinal cord changes
  - Bright T2 (myelomalacia)
  - Bright T1 (poor prognosis)
- Compression ratio < 0.4
  - Poor prognosis
- Evaluate soft tissue, discs, ligaments, and bone (to an extent)





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MRI: Incidental Findings

- **Boden et al. 1990**
  - Evaluated MRIs in asymptomatic patients
  - 20% of asymptomatic patients had abnormal findings
  - Disc degeneration/narrowing at one or more level
    - 25% of subjects less than 40
    - 60% in those older than 40

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CT

- Gold standard for bony anatomy
- Evaluate OPLL
- Myelography
  - Evaluate soft tissue vs. bony compression
  - Useful for pacemaker, previous surgery (w/ or w/o hardware), evaluate fusion status
  - Risk of spinal headache



Treatment

- **Non-operative**
  - Observation, NSAIDs, ESIs, therapy, immobilization and lifestyle modifications
    - Mild disease with **NO** functional impairment
    - Poor surgical candidates
  - CLOSE FOLLOW-UP
- **Operative**
  - Any functional impairment
  - Outcomes contingent upon pre-operative impairment
  - Procedure selection depends on:
    - Cervical alignment, number of stenotic levels, location of compression, comorbidities

Treatment

Simplified Treatment Algorithm for CSM

	1 or 2 levels of compression	3+ levels of compression
> 10 rigid Kyphosis	3 **Anterior alone (ACDF/corpectomy /hybrid)**	5 **Combined AnteroPosterior •Anterior to correct kyphosis/decompress •Posterior to Decompress**
< 10 rigid kyphosis		4 **Posterior alone Laminoplasty vs Laminectomy + Fusion**

Anterior Cervical Decompression and Fusion (ACDF)

- Mainstay of treatment for 1-3 level disease
- Fixed cervical kyphosis of > 10°
  - Lordosis restored by anterior procedure
- Pathology is anterior (discs or disc-osteophyte complexes)
- Corpectomy can be added if pathology is behind vertebral body
- Pros
  - Lower infection rate, less post-operative pain, less blood loss, faster
- Cons
  - Requires fusion → loss of motion, non-union (especially with multi-level), can be dangerous with OPLL

Anterior Cervical Decompression and Fusion (ACDF)



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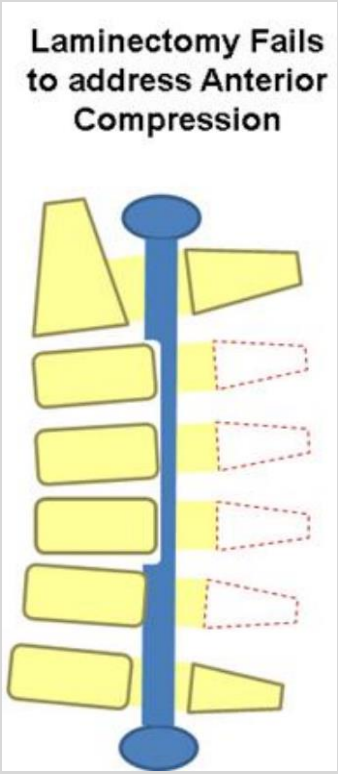
Anterior Cervical Decompression and Arthroplasty (ACDA)

- Alternative to ACDF
- Maintains motion
- Reduced rate of adjacent segment degeneration
  - Studies +/-
- Contraindications
  - Kyphosis
  - Advanced age
  - Spondylolisthesis
  - Extensive bony central stenosis

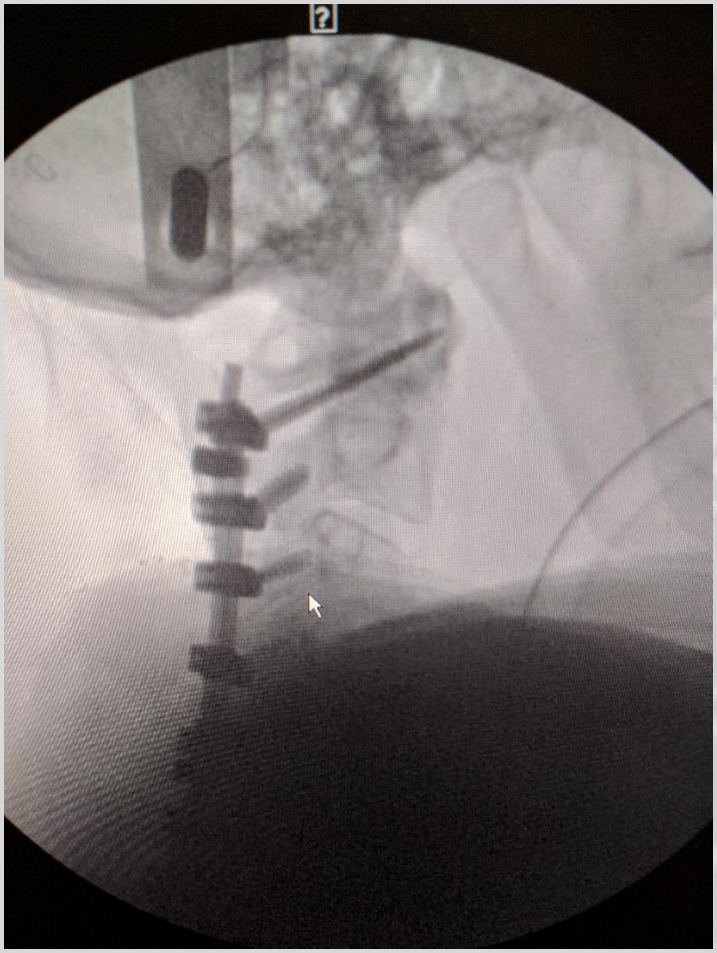


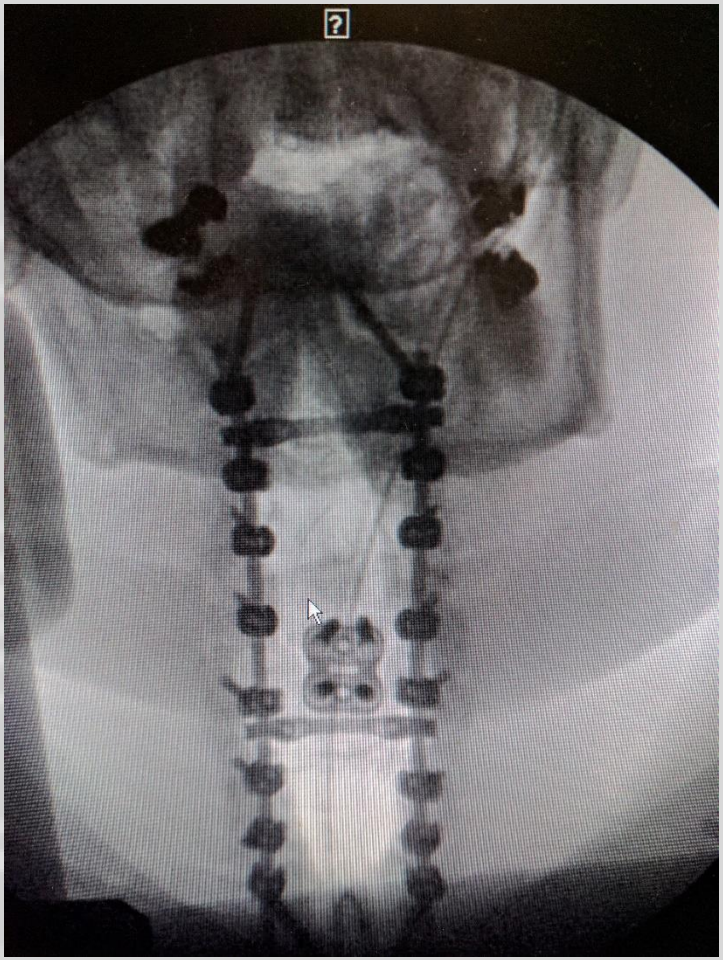
Posterior Laminectomy and Instrumented Fusion

- **Multilevel (3+) compression with fixed kyphosis < 10°**
- **Pros**
  - Able to address more levels without a disproportionate increased in non-union rate, fusion can improve neck pain from degen. facets
- **Cons**
  - Significantly more painful, longer recovery, cannot address kyphotic deformity without osteotomy



Posterior Laminectomy and Instrumented Fusion

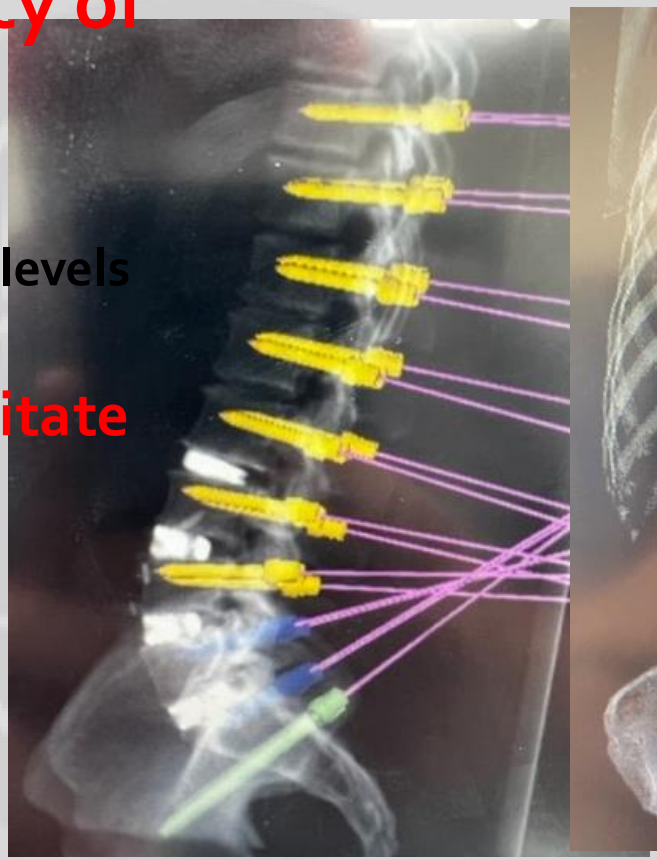




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Posterior Laminectomy and Instrumented Fusion w/ ROBOTS

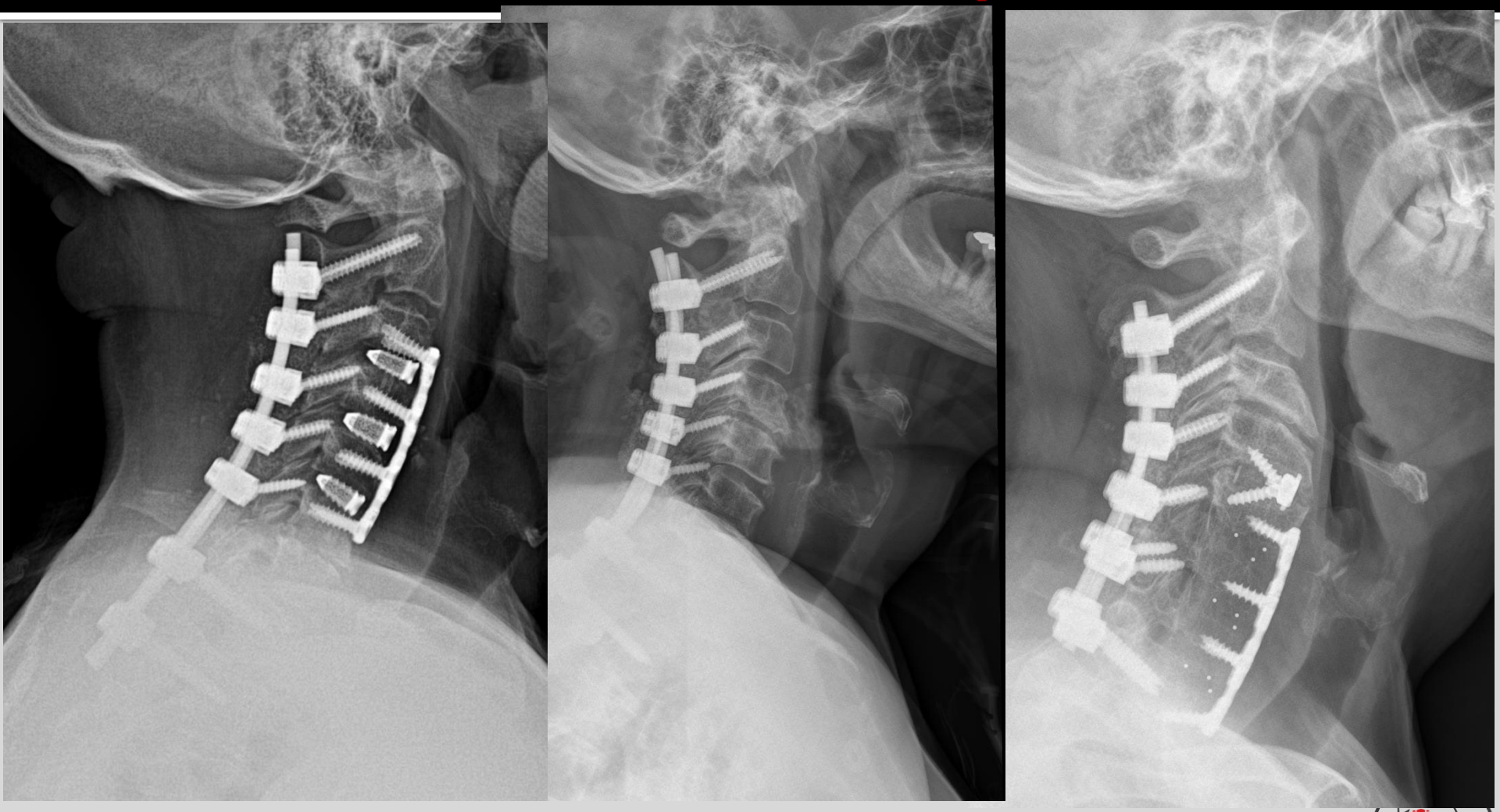
- Increased accuracy of instrumentation
  - Longer, large screws
  - Instrument diminutive levels
- Screws placed to facilitate alignment correction
- Increased speed of instrumentation





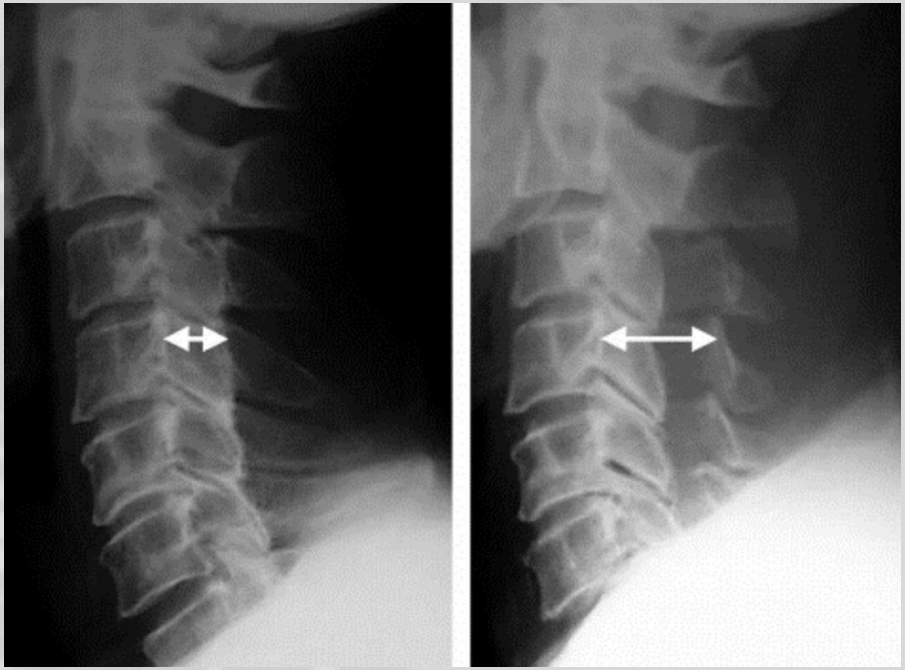
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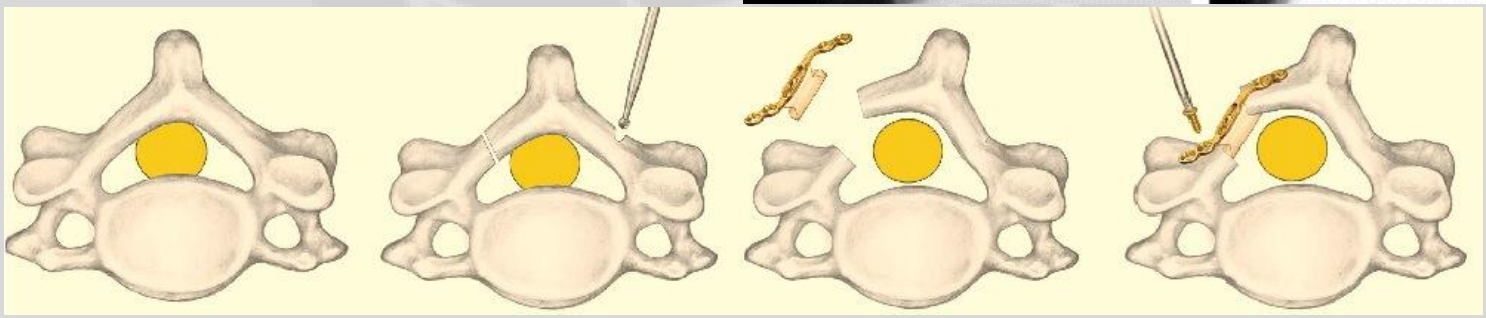
Posterior Laminectomy and Instrumented Fusion w/ ROBOTS



Cervical Laminoplasty

- Multilevel (3+) compression with fixed kyphosis < 10°
- Volume of canal is expanded by creating a "hinged-door" laminectomy

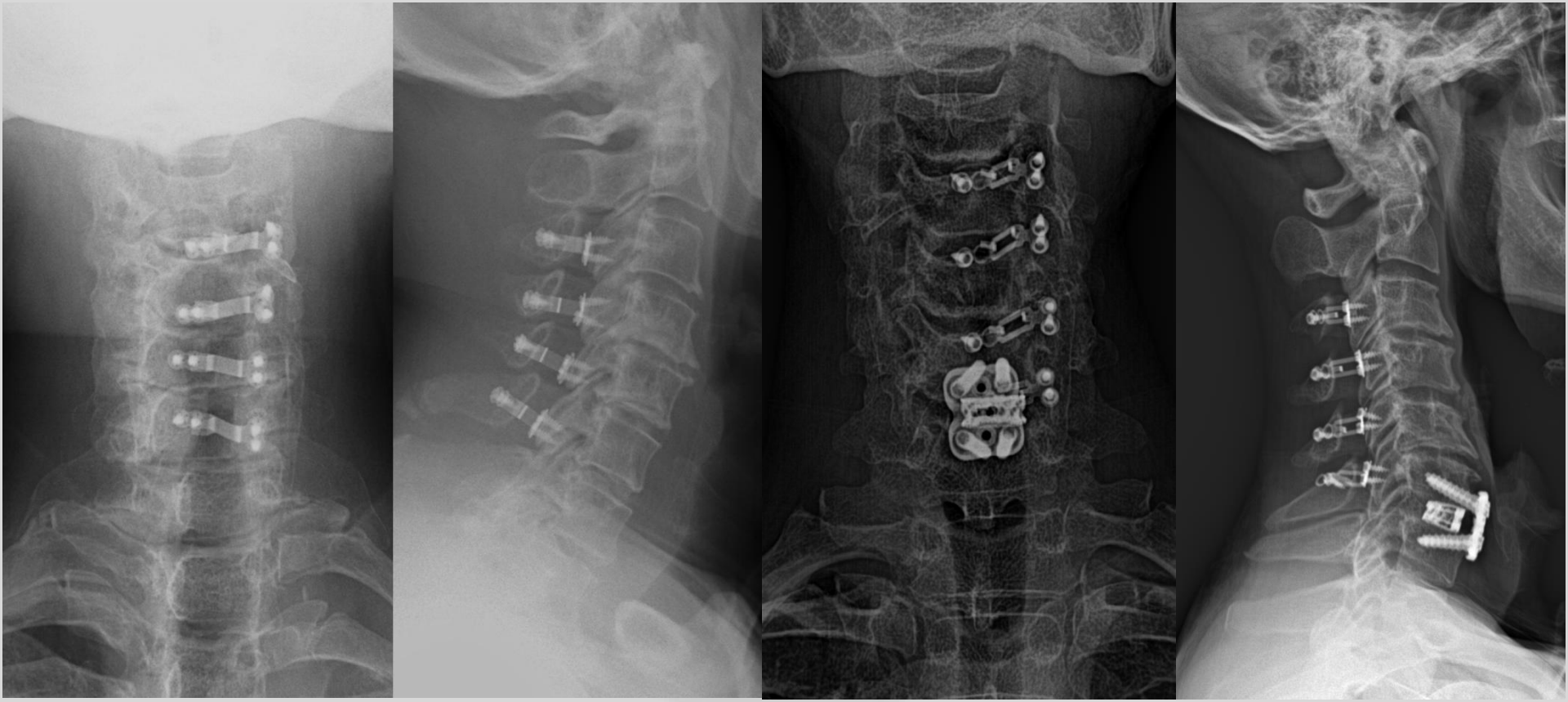




Cervical Laminoplasty

- Posterior decompression but maintains motion
  - Usually performed from C3 - 7
- Contraindicated with severe axial neck pain
- Pros
  - Able to address multiple levels without fusion and without destabilization
  - Non-union not concern (option for smokers, chronic steroids, etc)
  - Lower complication rate than multilevel anterior
    - Especially in OPLL
- Cons
  - Post-operative neck pain, still some loss of motion

Cervical Laminoplasty



Comparison of Treatment of Options

ACDF — anterior decompression + fusion

Directly address ventral compressive pathology

Restores/maintains alignment

Sacrifices motion at fused levels

Risk of swallowing/voice changes

CDA — anterior decompression + motion preservation

Closest to ACDF for 1–2-level soft-disc disease

Suitable facets/alignment and no instability

Evidence in myelopathy is less mature.

Laminectomy + fusion (LF/PCF)

Useful when instability or alignment concerns matter

Geater muscle dissection and fusion-related burden.

MUCH higher risk of wound healing issues/Infxn

Laminoplasty

Posterior multilevel canal expansion while retaining motion

Best suited to lordotic/stable spines without a need for fusion

Axial pain/alignment are considerations.

Abdelmalek et al., 2025; Yang et al., 2023; Bakr et al., 2023.

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CDA vs ACDF in myelopathy

Study design

Matched retrospective cohort; 110 patients total; 55 CDA and 55 ACDF; minimum 2-year follow-up.

Neurologic result

Postoperative Nurick scores were not significantly different (p = 1.00).

Patient-reported result

NDI improvement was greater after CDA (p = .040).

- **Overall complications and revision rates were statistically similar**
  - **Individual events (dysphagia, dysphonia, infection, construct failure, heterotopic ossification, ASD) did not differ significantly**
- **Cannot generalize to multilevel disease, severe spondylosis, facet arthropathy, instability, or significant deformity.**
- **Conclusion: CDA is a motion-preserving alternative for carefully selected anatomy, not a general replacement for ACDF in cervical myelopathy.**

Abdelmalek G, et al. Spine J. 2025;25(5):921–928. doi:10.1016/j.spinee.2024.11.003.

Laminoplasty vs posterior cervical fusion

Outcome	Laminoplasty	Posterior fusion	Between-group finding
Estimated blood loss	99.3 ± 91.7 mL	186.7 ± 142.7 mL	Lower with laminoplasty (p=.003)
Length of stay	3.0 ± 1.6 days	4.5 ± 3.3 days	Shorter with laminoplasty (p=.012)
Routine discharge	88.4%	62.8%	Higher with laminoplasty (p=.006)
24-mo mJOA / pain / QoL	Similar	Similar	No significant differences
NDI change at 24 mo	−19.6 ± 18.9	−9.1 ± 21.9	Greater improvement with laminoplasty (p=.031)

- 24-month Propensity-matched quality outcomes database analysis
- Matched sample was small (43 laminoplasty and 191 fusion candidates before matching)
- Significant selection bias remains possible.

Yang E, et al. J Neurosurg Spine. 2023;39(5):671–681. doi:10.3171/2023.6.SPINE23345.

Laminoplasty vs laminectomy + fusion

SINGLE-CENTER MULTILEVEL DCM COMPARISON (2023)

- Both operations provide posterior decompression
- Evaluated ≥3-level elective procedures from C3–C7 and reported perioperative outcomes, complications, revisions, neck pain, and alignment.
- Neurologic and disability outcomes are often similar, while laminoplasty tends to reduce operative burden (blood loss, length of stay, cost).
- Fusion may be favored when instability, significant axial pain, or alignment concerns make motion preservation less desirable.

Bakr O, et al. N Am Spine Soc J. 2023;15:100232. doi:10.1016/j.xnsj.2023.100232.

Laminoplasty vs fusion: pooled patient-centered outcomes

- **2026 SYSTEMATIC REVIEW AND META-ANALYSIS**

Evidence base

12 retrospective studies; 7,581 patients (LP 1,848; LF 5,733).

Cost

Pooled mean treatment cost lower with LP by about $21,621; very high heterogeneity (I^2 = 95%).

Pain

PCLF showed greater pooled pain reduction (VAS MD 1.60; 95% CI 0.36–2.84), with substantial heterogeneity.

- Opioid-use data were inconsistent and could not be pooled
- One included study reported 12-month return-to-work of 88.9% after LP vs 64.3% after LF
- Most studies were observational
  - Only 25% were rated high quality

Karthikeyan V, et al. Global Spine J. 2026;16(1 Suppl):43S–52S. doi:10.1177/21925682251357202.

Complications Compared by Approach

- DIFFERENT PROCEDURES HAVE DIFFERENT RISK PROFILES

Procedure	Characteristic risks	What recent comparative evidence suggests
ACDF	Dysphagia / dysphonia; pseudarthrosis; anterior construct issues	In matched comparisons, dysphagia more common than after laminoplasty; short-term LOS may be shorter.
CDA	Heterotopic ossification; implant-related issues; strict selection constraints	Small matched CSM cohort: overall complications and revision not significantly different from ACDF.
Laminectomy + fusion	Posterior wound/muscle morbidity; C5 palsy; nonunion / junctional issues	More blood loss and longer stay than laminoplasty in QOD matched study; may be appropriate when stabilization is needed.
Laminoplasty	C5 palsy; axial neck pain; loss of lordosis / postoperative alignment concerns	Often lower perioperative burden than fusion; preserves motion but does not correct instability.

Karthikeyan V, et al. Global Spine J. 2026;16(1 Suppl):43S–52S. doi:10.1177/21925682251357202.

What predicts outcome beyond procedure choice?

- 2022 Swedish registry cohort (n = 717; laminectomy alone vs laminectomy + fusion)
  - Reported overall PROMs improvement of 43.8% at 2 years and 36.3% at 5 years after imputation
- Lower baseline myelopathy score predicted worse follow-up myelopathy score
  - Age and worse baseline NDI predicted worse disability outcomes
- Fusion was associated with more surgeon-reported complications (rate ratio 1.81; 95% CI 1.17–2.80), but treatment groups differed at baseline
- Longer symptom duration, irreversible cord injury, comorbidity, and number of operated levels can complicate recovery

de Dios E, et al. Eur Spine J. 2022;31:3433–3442. doi:10.1007/s00586-022-07359-9.

Practical selection matrix

Clinical / anatomic feature	Often favors	Reasoning / caveat
Focal 1–2-level ventral compression	ACDF or possible CDA	Direct anterior decompression; CDA only if facets, alignment, bone quality and stability are appropriate.
Multilevel stenosis + preserved lordosis + stable spine	Laminoplasty	Posterior decompression with motion preservation and generally lower perioperative burden.
Instability / spondylolisthesis / need for stabilization	Laminectomy + fusion (or anterior fusion strategy)	Fusion addresses instability
Fixed kyphosis or major ventral compression	Anterior or combined strategy may be needed	Posterior cord drift may be insufficient
High axial neck pain or alignment concern	Careful consideration of fusion	Stabilization, but no guarantee of pain relief

Clinical synthesis from Yang et al., 2023; Bakr et al., 2023; Abdelmalek et al., 2025; Karthikeyan et al., 2026.

Bottom Line

ACDF / selected CDA

Best fit for appropriate anterior/focal disease

CDA evidence in myelopathy remains limited to selected 1–2-level cases.

Laminoplasty

Strong motion-preserving option for multilevel stenosis with lordosis and no instability

Laminectomy + fusion

Useful when posterior decompression is needed and stability/alignment justify fusion

Highest risk of complications

Across all approaches

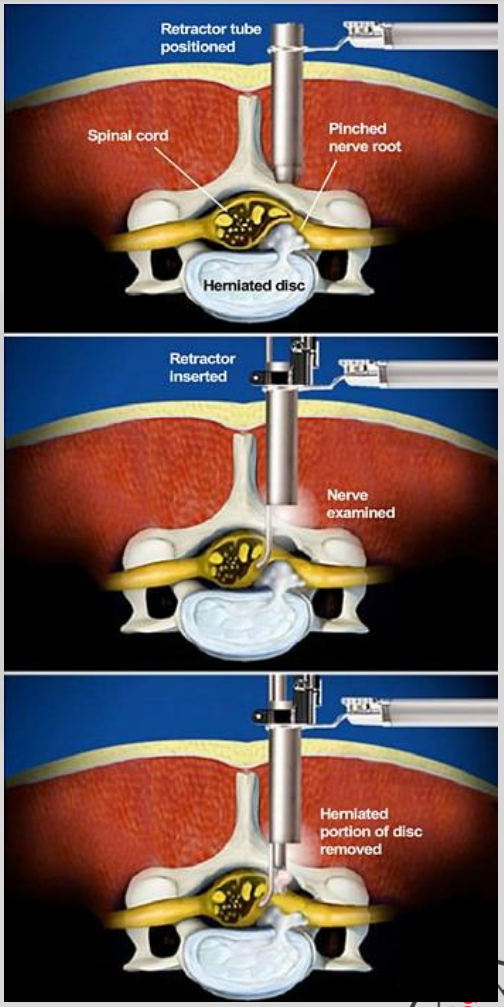
Earlier appropriate decompression and realistic counseling about residual deficits matter

Baseline severity is a primary predictor of post-op functioning

Clinical synthesis from Yang et al., 2023; Bakr et al., 2023; Abdelmalek et al., 2025; Karthikeyan et al., 2026.

Recent Advancements in Surgical Treatment

- **Endoscopic & Minimally Invasive Techniques**
  - Endoscopy-assisted ACDF: lower blood loss, faster recovery, high fusion rates
  - Endoscopic posterior decompression: reduced tissue trauma
- **Novel Anterior Techniques**
  - 3D-printed patient-specific implants
- **Dynamic MRI for Surgical Planning**
  - Changes operative plan in ~60% of cases (RCT data)
  - Improved early neurological recovery rates



https://southeasternspine.com/service/micro-endoscopic-posterior-cervical-discectomy/

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Advances in Laminoplasty, Robotics & Navigation

- **Robotics, Navigation & AR**
  - Clinically acceptable screw accuracy ~98% (meta-analyses)
  - ↓ blood loss, complications, radiation exposure
  - Experience-neutralizing effect across surgeon skill levels
- **Emerging Technologies**
  - AI for surgical planning; Augmented reality guidance
  - Adjunctive biological therapies; patient-specific implants







Thank You

