Cervical Alignment & Osteotomy Planning

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Disclosures

Themistocles S. Protopsaltis

- (b) Globus
- (g) K2M

a. Grants/Research Support
b. Consultant
c. Stock/Shareholder
d. Royalties
e. Board member
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Case
Iatrogenic Cervical Kyphosis

Preoperative Chin-Brow to Vertical Angle

\[ \text{CBVA} = 30^\circ \]
Underestimated due to retroverting pelvis and flexing knees

Preoperative Clinical Picture

After 5 minutes of lying supine
Preoperative Osteotomy Planning

PA after PSO with 16deg in coronal plane

Lateral after PSO with 20deg correction in sagittal plane

Planned correction with a 20deg extension osteotomy at C7
Operative Procedure: C7 PSO

- Previous instrumentation removed
- Decompressive laminectomy from C6-T1
- Reinstrumentation from C2-T4
- C7 PSO
- Head was repositioned and osteotomy was closed
- All instrumentation was secured
- Iliac crest autograft

Post Operative XR’s

Lateral

AP
Post Operative Clinical Pictures

Clinical Comparison Photos

Post Operative CBVA

Preop CBVA=30°
**underestimated
Postop CBVA=15°
Case 2
PJF – Initial overcorrection? Leads to cervical deformity

70 yo F
Complains of back pain and fatigue, loss of balance

1 mo postop
Upper thoracic pain and prominence
PJF Case: Bone-implant failure

MRI shows fracture at UIV T3 with PJK

Plan?

PJF Case: Revised

Revised to C6 to T4 PSF&I
Braced with SOMI
1.5 y f/u
Cervical pain and fatigue with loss of horizontal gaze at the end of the day

Regional Cervical Measurements
Cervical Plumbline = 7.4 cm
T1 Slope = 33 deg
C2-C7 Angle = -22 deg
T1S – C2-C7A = 55 deg

2 Year f/u
2 Years postop
Wound drainage
Deep infection
s/p removal of hardware C6 to L2
Worsening cervical deformity
Regional Cervical Measures

- C2-T1 Plumbline = 11 cm
- T1 Slope = 39 deg
- C2-C7 Angle = -40 deg

Supine lateral

2 Year f/u
Plan?

Postop 3
I&D T6-7
T4-9 PSF&I

Plan?
Osteotomy Planning

Cervical Plumbline = 83
CL = 25
T1 Slope = 35

Option 1: Osteotomy Planning

Cervical Plumbline = 83
CL = 25
T1 Slope = 35
C7 PSO of 35 deg

Option 1: Osteotomy Planning

Cervical Plumbline = 34
CL = 57
T1 Slope = 35
C7 PSO of 35 deg
Option 2: Osteotomy Planning

Cervical Plumbline = 83
CL = 25
T1 Slope = 35
A/PSF&I
ACDF C4-5 and C5-6
Grade II resection posteriorly

Option 2: Osteotomy Planning

Cervical Plumbline = 52
CL = 51
T1 Slope = 35
A/PSF&I
ACDF C4-5 and C5-6
Grade II resection posteriorly

Option 2: Intraop/ Postop
Option 2: Final Follow Up

Residual CT deformity
But
Good global balance

Pre-osteotomy to Postop
Horizontal gaze Unsupported
Neck pain much improved

Case
Cervical or Thoracolumbar Deformity?
Case

74 yo M artist c/o back pain, gait imbalance, loss of standing balance, and loss of dexterity (change in brush strokes)

Case

MRI C-spine
Severe spinal stenosis C3 to C7

CBVA

CBVA = 46 deg
Regional Cervical Measurements

C2-T1 Plumbline = 9.5
C2 Slope = 64 deg
T1 Slope = 71 deg
C2-C7 Angle = 9 deg

Case 1 Postop

Underwent laminectomy and fusion C3 to T2
X-ray 2 days postop
Case 1 Preop
Standing preop full length Xray shows that there is major thoracolumbar deformity

Case 1
1 year postop
Content with functional limitations
Not interested in major deformity correction

Preop SVA and Pelvic Parameters
SVA 13.2
PT = 34
Pl = 62
LL = 16
T1 Pelvic Angle (TPA) SRS 2013

T1 PA = 43 deg

If TPA > 20 deg (Exceeds a good target PT)
Thoracolumbar deformity is present

C2 Pelvic Angle

C2 PA = 49 deg (Exceeds optimal PT)
Patient will have difficulty with comfortable horizontal gaze

C2 - T1 Pelvic Angle (CTPA) IMAST 2013

C2 – T1 PA = 6 deg

Some cervical deformity is present
however
Dominant deformity is Thoracolumbar
2 Year Postop

Content with functional limitations

Not interested in major deformity correction

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Thank You
Introduction

- Fixed sagittal deformity at the cervicothoracic junction results in high disability (Simmons, Spine 2006)
- Surgical correction 3CO challenging and high risk (Bridwell, Spine 2003)
- Vertebral column resections (VCR) and pedicle subtraction osteotomies (PSO) are commonly performed at or below the mid thoracic to lower lumbar spine for sagittal imbalance.

- The surgical techniques and outcomes of 131 patients
- Chin-brow to vertical angle to 0° – 10° of flexion
- Wide decompression
  - Increased lateral resection area greatly reduces the possibility of nerve root impingement
Cervicothoracic extension osteotomy

Surgical Technique: OWO
(Open wedge osteotomy)

- Complete removal of superior, inferior articular process and transverse process followed by neck extension.
Article

- Literature review on severe chin-on-chest deformities due to ankylosing spondylitis
- Six retrospective clinical studies
- Indication for surgery was primarily loss of horizontal gaze.
- The most common surgical technique was based on the original Simmons osteotomy at C7–T1.
- The complication rate was high, 26.9% to 87.5%, mortality rate of 2.6%.
- Permanent neurologic complication rate was 4.3%.
- All patients had improvement in horizontal gaze and chin-brow to vertical angles.
- Patient satisfaction after surgery appeared high.

Background

PSO vs. SPO
Technique

- Preop CT angio
- Complete Facetectomy
- Skull Base Rongeur (Lempert) for medial portion
- Tap for decancellation
- Curette for scoring anterior cortex prn
- Central resection
- Precontoured rod
- Mayfield/Halo Manipulation
C7 PSO Technique 1

Technique for C7 decancellation using lumbar tap > osteotome > curette

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Fixed long standing neck drop in elderly-CT and midsubaxial kyphosis
Patient Outcomes

- NDI scores (24.6%, 51.1 to 38.6, p=0.03).
- VAS scores (55.7%, 7.6 to 3.4, p=0.0083).
- There was an 18.4% increase in PCS scores (30.2 to 35.8).

Intra-operative Results and Complications

- EBL: 1110 ± 484cc,
- Average surgical time was 4.3 ± 0.6hrs,
- There were no intra-operative complications
  - One patient developed dysphagia postoperatively.
- There were no neurological complications in any of the 11 patients.
  - There were no changes in the intraoperative neurophysiological monitoring during correction.

Conclusion

- Cervicothoracic junction PSO being a safe, reproducible and effective procedure for the management of cervicothoracic kyphotic deformities.
Conclusion

- Correction of kyphosis and CBVA with a controlled closure
- Currently, the authors prefer the pedicle subtraction osteotomy at the cervicothoracic level for treatment of chin-on-chest deformity

Where Do We Go From Here?

New cervical deformity classification is required to define indications and contraindications for complex cervical reconstruction

Cervical Deformity Classification

Deformity Descriptor

- C: Primary Sagittal Deformity Apex in Cervical Spine
- CT: Primary Sagittal Deformity Apex at Cervico-Thoracic Junction
- T: Primary Sagittal Deformity Apex in Thoracic Spine
- K: Primary Coronal Deformity (C2-C7 Cobb ≥ 15°)
- CVJ: Primary Cranio-Vertebral Junction Deformity

5 Modifiers

- C2-C7 sagittal vertical axis (SVA)
  - C2-C7 SVA < 4cm
  - C2-C7 SVA 4 to 8cm
  - C2-C7 SVA > 8cm
- Horizontal gaze
  - CBVA < 10°
  - CBVA 10° to 25°
  - CBVA > 25°
- Cervical Lordosis Minus T1 Slope
  - CL-T1 < 15°
  - CL-T1 15° to 20°
  - CL-T1 > 20°
- Myelopathy
  - mJOA > 18 (None)
  - mJOA 15-14 (Mild)
  - mJOA 12-14 (Moderate)
  - mJOA < 12 (Severe)
- SRS-Schwab Classification
  - T, D, or L Curve Type
  - T, D, or L: 13 minus T1
  - T, M, or H: Pelvic Tilt
  - N, T, or V: C7-S1 SVA

New cervical deformity classification is required to define indications and contraindications for complex cervical reconstruction.
Rigid deformity subaxial deformity

Cervical plumb lines from the odontoid to C7 for all 100 volunteers were distributed in a narrow range (16.8 ± 11.2 mm).

Cervical Lordosis: C2 to C7, is 15° to 25°.

Cervical plumb lines from the odontoid to C7 for all 100 volunteers were distributed in a narrow range (16.8 ± 11.2 mm).

Cervical Lordosis: C2 to C7, is 15° to 25°.
Evaluation CBVA

- Global Balance (SVA)
- Cervical Lordosis
- PT Kyphosis
- Cervical Regional Balance (EAC/C2 Plumb)
- Flexibility

Xray Evaluation Regional

Flexible/Extension

Flexion/Extension
Background

- Rigid vs. Flexible
- Cord Compression (none/focal/global)

Cervical Deformity

- Flexible deformity with neurologic symptoms
- Semi-rigid kyphosis w/o neurologic symptoms
- Rigid subaxial kyphosis w neurologic symptoms
- Rigid subaxial or cervicothoracic kyphosis w/o neurologic symptoms
H and P

- 55 yo
- Progressive myelopathy
  - Multiple falls mobility
  - Upper and lower extremity numbness, tingling and dropping
  - Bowel and bladder incontinence
- Progressive neck pain
  - Neck pain is 8/10 bilateral arm pain 8/10 stiff neck
  - Previous ACDF/laminectomy
  - PE head forward position, looks down
  - Hyperreflexic, UE 4/5 diffusely
  - Spastic gait

Rigid subaxial deformity with neurologic symptoms

Spinal Kyphosis Causes Demyelination and Neuronal Loss in the Spinal Cord

A New Model of Kyphotic Deformity Using Juvenile Japanese Small Gaunt Turtles.

Kumara Kamio, MD; Masato Ohkawa, MD; Haj Nakamura, MD
Satoko Hiyama, MD; Katsunori Ohta, MD; and Toshihiko Tanabe, MD
Spinal Cord Morphology in Tension/Kyphosis

- SD/TD < 0.4 after surgery poor prognosis for recovery in CSM

Techniques for Treatment

540 Osteotomy-Subaxial Fixed Kyphosis
540 Osteotomy

- Stage one Posterior
- Mid cervical SPO
- C/T Jxn SPO
3 Point Bending

Cervical Kyphosis + Myelopathy

- 69 y/o male with severe myelopathy
- Wheelchair bound secondary to extremity weakness
Cervical Kyphosis + Myelopathy

Back/Front/Back
540
Circumferential Osteotomy for fixed cervical kyphosis: Novel Surgical Technique.
Vedat Deviren, M.D, Bobby K Tay, Mauricio Andrés Campos, Christopher P Ames, Vedat Deviren, M.D. (submitted to Spine)

METHODS: 14 patients with fixed cervical kyphotic deformity (average age 55 (23-68))

RESULTS:
Osteotomy
3.9 (3-6) levels anteriorly
6.6 (3-18) levels posteriorly.
Correction : 28 degrees (10-37).
Average EBL was 1484 cc (400-4600 cc)

CONCLUSIONS:
Safe, reproducible, and powerful method to correct fixed cervical deformity
Circumferential Osteotomy for fixed cervical kyphosis: Novel Surgical Technique.
Bobby K Tay, Mauricio Andres Campos, Christopher P Ames, Vedat Deviren, M.D. (submitted to Spine)

RESULTS:
- Average EBL was 1484 cc (400-4600 cc)
- LOS: 19 (3-55)
- ICU stay: 6.5 (0-15)
- Intubated days: 3.8 (0-15)

Rigid deformity with myelopahty
- Controlled correction is necessary to avoid neurologic complications.
- Multiple levels of osteotomies, (Ant/Post) permits reproducible correction
- Ant/Post multisegmental instrumentation avoid halo immobilization.
- Complications are not infrequent considering co-morbidities, curve severity and previous surgeries.

Where Do We Go From Here?
New cervical deformity classification is required to define indications and contraindications for complex cervical reconstruction
Thank you
Mid-Cervical Osteotomy

Dan Riew, MD
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Washington University Orthopedics

Disclosures:

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1) Biomet Maxan Anterior Cervical Plate, Solitaire-C
2) Osprey Interbody Graft
3) Medtronic Vertex

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Board: CSRS (President) , AOSpine International (Chair, Research Commission), KASS, ASOA
Deputy / Associate Editor: Global Spine J, JBJS

Cervical Osteotomy

• Pedicle Subtraction
• Smith-Petersen
• Anterior-Posterior
PSO for Iatrogenic Deformity

Failed Multiple Anterior & Posterior Operations
- Pseudarthrosis
- Kyphoscoliosis
- Skull Plate Pullout

PSO C4, C7 Revision Occ-T4

4 hrs 45 min. 250 cc EBL
Complication: Vertebral Artery Injury

6 Previous Operations
1998 anterior decompression/fusion
1999 A/P revision decompression/fusion
2002 posterior revision
2003 posterior revision
2006 posterior wound infection with revision

Myelo-radiculopathy
Anterior Difficult

Pedicle Subtraction Osteotomy (PSO)

- Posterior column is shortened
- Stable with no gaps
Unilateral Osteotomy
C1 Laminectomy
C1-2 Osteotomy
Right C7 Pedicle Subtraction &
Left Smith-Peterson Osteotomies

Total Surgical Time: 2 Hr 45 Min
Blood Loss: 250 cc
Fixed Kyphosis:

2-stage Osteotomy For Circumferentially Fused Spines
Dual Caspar Placement

Caspar Pins Distracted

72 y.o. s/p Laminaplasty C3-C7, later C2-C5 fusion
Lumbar Hyperextension to See Straight

Osteotomy C4-7
C6 Corpectomy, Discectomy C4-C5, C7-T1
Smith-Peterson Osteotomies C4-C7

Pre-op                         Post-op
Lumbar Spine No Longer Hyperextended
Back Pain Improved

Dual plates:

With Posterior Extension: Unplated Grafts Can Extrude
Upper Cervical Kyphosis
55 year old male with myelopathy
MVA Treated with Collar

Posterior C2-3 osteotomy C2-C7 fusion: 70° Correction

Cervical Deformity Surgery

• Most deformities DO NOT need correction
• Correction for:
  • Neurologic deficit
  • Intractable pain
  • Intolerable deformity
Intolerable Deformity

• Intolerable to patient
• Often age, activity dependent
• Older patients tolerate deformity

Thank You
Reduction Techniques for the Treatment of Upper Cervical Deformity

Jae Taek Hong M.D., Ph.D.
Kim MS, Lee HJ, Kim IS, Yang SH, Sung JH, Lee SW
St. Vincent's Hospital
Catholic University of Korea

Conflict of Interest Disclosure
☑ I have no conflict of interest

Overview
☑ Reduction Techniques for Upper Cervical Spine

1. Basilar Invagination
☑ Congenital Anomaly
☑ Rheumatoid Arthritis
☑ Osteoarthritis

2. C1 Bursting Fx (Jefferson Fx)
Basilar Invagination

- **Upward migration of the odontoid**
- Cranial settling
- Vertical subluxation of the axis
- Atlantoaxial impaction (AAI)
- Congenital anomaly
- Synovitis & cartilage destruction
  - C0-1 & C1-2 joints

Atlas
Best Method to Help

Treatment Option I

I. Transoral decompression
II. Occipitocervical fusion
Treatment Option II

Basilar Invagination

• Direct posterior reduction and fixation
  – Jian F et al, Neurosurgery, 2010
Motion limitation after CVJ Fixation

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<th>C0-C1</th>
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- CVJ
- Substantial movement
  - 50% of neck motion

Basilar Invagination

- Joint distraction and direct lateral mass fixation
  - Goel A et al, JNS Spine, 2004
Vertical Reduction

Vertical Reduction
Vertical Reduction

Objective

• To analyze the early clinical & radiological outcome of vertical reduction technique for basilar invagination

Materials & Methods

• 2010, 5 – 2013, 1

• 20 cases
  – RA; 12
  – Unknown; 1
  – Post-traumatic; 3
  – Congenital anomaly; 4

• M/F = 6/14

• Age
  60.3 yrs (28 – 76)

• F/U
  15.1 ms (3 – 34)
Materials & Methods

Diagnosis

- Redlund-Johnell and Pettersson, 1984
- Ranawat et al., 1979

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<td>Headache</td>
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<td>Dysphagia</td>
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Materials & Methods

- Parameter
  - Clinical Findings
    1. Sx
    2. JOA Score
    3. Complication
  - Radiological Findings
    1. Atlanto-dental interval (ADI)
    2. Ranawat Index
    3. CMA (cervicomedullary angle)
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<td>20</td>
<td>F</td>
<td>59</td>
<td>10</td>
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<td></td>
<td></td>
<td></td>
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<td>1.8</td>
<td>8.79</td>
<td>14.77</td>
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<td>155.59</td>
<td>12.65</td>
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</tbody>
</table>

CMA

Ranawat Index

Ranawat = 5.2mm

Ranawat = 17.6mm

P < 0.05
Results

• Complication
  – Unilateral graft dislodgment; 1
  – Infection; 1

• Fusion rate
  – Excellent
  – 20/20

Advantages

1. Direct reduction of brain stem compression
   – Avoidance of trans-oral surgery

2. Increase of the fusion bed

3. Decrease the level of fixation

4. Minimization of head traction
   – before or during surgery

5. Motion preservation; C0-C1

Concerns

1. C2 Neuropathic Pain

2. Amount of Distraction

3. Biomechanical Stability

4. Fate of C0-1 Joint
   ☐ Segmental Motion
   ☐ ASD
C2 Neuropathic Pain

- Literature Evidence
  - Goel et al, Neurosurgery 2002
    - Plate & Screw fixation
    - None (160pts)
    - Extremely low, 1/102
  - My series of C2 root resection
    - No occipital neuralgia after C2 root resection

Amount of Distraction

Biomechanical Stability

- Park J et al, JNS 2011
  - C12 intraarticular spacer technique has advantage for stabilizing C12 segment
C0-1 Joint (2 yrs)

RA
• F/60

• C/C
  – Severe occipital (left) & neck pain for 1.5 yrs
  – N/Ex; n-s
Problem Lists

1. C12 instability
2. Basilar invagination, mild
3. Subaxial subluxation C34
4. VA anomaly
   - V3 segment (persistent 1st intersegmental A)
   - V2 segment (HRVA)

- Occipital Headache
- Neck pain
- Neck tilting

Asymmetrical C12 Distraction
Atlas
Best Method to Help

Conclusion

• Vertical C1-2 reduction technique can be an optimal treatment option for reducible basilar invagination

• C0-1 motion should be considered

• Multicenter and long-term study is necessary