Craniocervical Stabilization

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Occipitocervical Instability

- Trauma
  - Occipital condyle fx.
  - OC dislocation
- Rheumatoid arthritis
- Neoplasms
- Congenital
Atlantoaxial Instability

- Trauma:
  - Odontoid fracture
- Rheumatoid arthritis
- Congenital anomalies
- Neoplasms
- Post transoral surgery

Management of Craniocervical Instability: Principles

- Pattern / degree of spinal instability
- Neural decompression
- Fixation technique
- Arthrodesis
- Immobilization
Occipitocervical Stabilization: 
Challenges

- Biomechanical:
  - Multidirectional ROM
  - Greater forces to be resisted
- Anatomic:
  - Limited fixation points
  - Small surface for grafting
- Bracing difficulties

Occipitocervical Stabilization: 
Foerster, 1927

- Odontoid fracture
- Onlay fibular strut graft fusion
- Bedrest
- Fusion extended to the occiput
**Occipitocervical Stabilization:**

**Early Techniques**

- Wire fixation
- Onlay bone grafting
- Methylmethacrylate
- Halo immobilization

**Occipitocervical Stabilization:**

**Limitations of Earlier Techniques**

- No immediate stability
- Halo immobilization
- High failure rate
Occipitocervical Stabilization: Evolution

- Rods/loops
  - Improved rigidity
  - Wires/cables
  - Occipital burr holes
  - Sublaminar

Rods/Loops: Disadvantages

- Bending
- Wire/cable failure
- Rod fracture
- Limited resistance to axial loads
- Rod pistoning
Rod Pistoning

- No rod bending
- No pistoning

Contoured Loops

- No rod bending
- No pistoning
Contoured Loops

Contoured Loops

Contoured Loops
Occipitocervical Stabilization: Evolution

- Plates/screws
  - Extension of lateral mass plate fixation

Plate/Screws: Disadvantages

- Plate hole configuration
- Plate bending at OC junction
- Screws placed in lateral occiput
- Screw pullout
Occipitocervical Stabilization: Evolution

- Occipital buttons
  - Pullout resistance

Occipital Screws

Hurlbert, J Neurosurg, 1999

- Greater pullout strength than cables/wires
- Thickness of bone varies
- Increased in midline (EOP):
  - Males: 11-17 mm
  - Females: 10-12 mm
- Decreased laterally
Pullout strength of occipital screws
Roberts, Spine 1998

- Bicortical > unicortical
- Unicortical = wire
- Unicortical in midline has acceptable pullout

Occipitocervical Stabilization:
Evolution

- Y-plate
  - Screws in occipital keel
  - Transarticular C1-2 screws
  - Limited to occiput-C2
Occipitocervical fusion with posterior plate and screw instrumentation: a long term follow-up study
Sasso, RC et al., Spine 1994

- 23 pts
- No halo
- Fusion: 100%
- 138 occipital screws without complications
- 1 VA injury (TA screw)

Biomechanical Evaluation of Occipital-Atlantal-Axial Fixation
Oda, Spine 1999

- Cadaveric study
- Cervical screws stronger than hooks/wires
- Strongest construct provided by 6 midline occipital screws
**Occipitocervical Stabilization: Evolution**

- Rod/plate combination
  - Simplified lateral mass screw placement

- Universal systems
  - Rod/screws
  - Allows for extension of OC fixation to thoracic spine
Occipitocervical Fixation: Universal Systems

- Rods
- Occipital plates
- Polyaxial screws
- Ext. to thoracic spine
- Versatility
- Ease of use
Cervical Screw Fixation Points

- Wiring techniques

C1 lateral mass

Cervical Screw Fixation Points

- C1 lateral mass
Cervical Screw Fixation Points

- C2 pars/ pedicle

Cervical Screw Fixation Points

- C1-2 transarticular
Cervical Screw Fixation Points

- C2 lamina
Cervical Screw Fixation Points

- C3-C7 lateral masses

Cervical Screw Fixation Points

- C7 pedicle
Occipitocervical Fixation: Complications

- Construct failure
  - Cervical > occipital
- Pseudoarthrosis
- Swallowing difficulties
- Vascular injuries
- Cerebellar hematoma

A systematic review of occipital cervical fusion: techniques and outcomes

- Meta-analysis study (34 papers)
- 799 pts
- Factors assessed:
  - Fusion rate
  - Time to fusion
  - Neurological outcome
  - Adverse events
A systematic review of occipital cervical fusion: techniques and outcomes  

- Constructs reviewed:
  - Wire/onlay bone grafting
  - Wire/rod
  - Screw/plate
  - Screw/rod

- Fusion rate: 93%
- Time to fusion: 90% fused < 4 months
- Neurological improvement: 65%
  - 73% in fused pts, 46% in non-fused pts
- Lowest fusion rate: wire/onlay graft construct
- Instrumentation failure: 21% (wire, screw failure)
- Post-op adverse events: 52%
Atlantoaxial Stabilization: Options

- Wire/graft arthrodesis:
  - Gallie
  - Brooks
  - Interspinous
- Screw fixation techniques

Gallie Technique

- Onlay graft
- Weakest construct
- Poor rotational control
- Odontoid displacement
Brooks Technique

- Wedge compression grafts
- Biomechanically superior
- Rotational control
- Sublaminar wiring

Interspinous Technique

- Interlaminar strut graft
- Limits dens displacement
- Single sublaminar wire
Results of C1-2 Arthrodesis:
Autograft and Wire

- Meta analysis study
- 147 pts.
- Type II odontoid fxs
- Failure rate: 13%

C1-2 Arthrodesis:
Reasons for Failure

- Bone grafting technique
- Wiring technique
- Inadequate immobilization
- Wire/ cable breakage
- Pseudoarthrosis
Development of Screw Fixation for C1-2 Instability

- Immediate internal immobilization
- Supplement posterior arthrodesis
- Reduce pseudoarthrosis rate
- Minimizes need for postop immobilization

C1-2 Screw Fixation: Technique Options

- Posterior transarticular
- Posterior segmental:
  - C1 lateral mass screw
  - C2 pars/ pedicle screw
  - C2 translaminar screw
Posterior Transarticular Fixation

- Magerl: 1986
- Demanding technique
- Low margin for error
- Limited by width of C2 pars

C1-2 posterior wiring vs transarticular screws
Reilly et al, J Spinal Disorders, 2003

<table>
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<th>Procedure</th>
<th>Pseudoarthrosis</th>
<th>Fib. Union</th>
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<td>Posterior Wiring (38)</td>
<td>7</td>
<td>4</td>
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<td>(Mean F/U: 53 mos)</td>
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<td>TA Screw Fixation (33)</td>
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<td>2</td>
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* p = 0.015
C1-2 Transarticular Screw Fixation: Technique

- Anatomy
- Preoperative assessment
- Intraoperative positioning
- Intraoperative imaging
- Screw insertion technique

C1-2 Anatomy

- Vertebral artery
- C2 pars interarticularis
- C1 lateral mass
- C1 anterior tubercle
- Spinal canal
Preoperative Assessment

- Reformatted sagittal CT:
  - Assess width of C2 pars interarticularis
  - C1 lateral masses
- Reducible vs non-reducible
  - Post C1 displacement
Vertebral artery anatomy at C2
Madawi, Crockard: J Neurosurg, 1997

- 25 C2 vertebrae
- Significant narrowing of pars in 20%
- Asymmetric vertebral artery groove in 52%
- Range: 1-7 mm

Anatomical suitability of the C1-2 complex for transarticular screw fixation
Paramore, Sonntag: J Neurosurg: 1996

- 94 patients
- Sagittal CT reconstructions
- 17 pts (18%) had narrow C2 pars
- 5 pts (5%) had marginal anatomy
- 18-23% risk of vertebral artery injury
Virtual Screw Placement
Patient Positioning

- 3-point head holder
- Lateral fluoroscopy
- Slight flexion
- Posterior translation
- Realignment of C1-2
- Position of C1 arch

Position of C1 Arch
Positioning Difficulties

- Hyperlordosis
- Cervicothoracic kyphosis
- C1-2 malalignment
Intraoperative Imaging

- Fluoroscopy:
  - Lateral view only
  - Sagittal trajectory
  - 2-dimensional

Intraoperative Imaging: Computer-Assisted Navigation
Screw Insertion

- Expose C1-2 facets
- Bone / cable construct
- Paramedian incisions at C7-T1 level
- Insert drill guide
**Screw Insertion**

- **Entry point:**
  - 4 mm rostral to C2-3 facet
  - 2 mm lateral to spinal canal
- **Aim towards C1 ant tubercle**

**Screw Insertion**

- **Trajectory:**
  - Anterior arch of C1
  - 5-10° medial
- **Screw size:** 3.5, 4.0 mm
- **Screw length:** 28-46 mm
Screw Insertion Difficulties

- C1-2 malalignment
- Positioning difficulties
- Suboptimal imaging
- Failure in obtaining adequate sagittal trajectory
- Failure to identify entry points

C1-2 Transarticular Fixation: Complications

- Screw misplacement:
  - Failure to engage C1
  - Vertebral artery injury
  - Spinal cord injury
- Screw failure
- Pseudoarthrosis
Vertebral Artery Injury

- Narrow C2 pars width
- Inadequate realignment
- Lateral entry point
- Caudal entry point
- Steep trajectory
- Lateral trajectory

Vertebral artery injury in C1-2 transarticular screw fixation
Wright et al. J Neurosurg, 1998

- 2492 TA screws in 1318 pts
- 31 pts had known VA injury (2.4%)
- 23 pts had suspected VA injury (1.7%)
- Risk of vertebral artery injury: 4.1%
- Risk of neurological deficit: 0.2%
- Mortality rate: 0.1%
Vertebral Artery Injury: Management:

- Screw insertion
- No second screw
- Neurological assessment
- Angiography
- Antiplatelet therapy (+/-)

Posterior C1-2 fusion with polyaxial screws and rod fixation
Harms and Melcher Spine 26: 2467-2471, 2001

- Alternative to transarticular screws
- Reduced risk to the vertebral artery
- Polyaxial screws
**C1 Lateral Mass Screw**

- Venous plexus
- C2 root
- Posterior arch
- Insert at base of C1 pedicle
C1 Lateral Mass Screws
C2 Pars/ Pedicle Screw

- Lateral entry point
- Superior and medial trajectory
- Vertebral artery
### C2 Laminar Screws

- 52 pts, 103 screws
- 98% fusion rate
- No vertebral artery injury
- Biomechanically = to C2 pedicle screw

Dorward and Wright. Neurosurg 68:1491-1498, 2011

### C2 translaminar screw fixation

- 52 pts, 103 screws
- 98% fusion rate
- No vertebral artery injury
- Biomechanically = to C2 pedicle screw
Translaminar vs pedicle screw fixation of C2: comparison of surgical morbidity and accuracy
Parker et al. Neurosurg 64:343-348, 2009

- 313 screws in C2 lamina or pedicle
- Higher breach rate with pedicle screws (no increased morbidity)
- Higher operative revision rate with translaminar screws for subaxial constructs
- No difference for atlantoaxial fixation

Biomechanical comparison of C1-2 posterior fixation techniques
Hott JS, Lynch JJ, Sonntag, VKH
J Neurosurg Spine, 2005

- Lateral mass / pars screws (LC1-PC2)
- Transarticular screws
- Cadaver spine
- Range of motion
- Screw pullout resistance
Biomechanical comparison of C1-2 posterior fixation techniques

Hott JS, Lynch JJ, Sonntag, VKH
J Neurosurg Spine, 2005

- LC1-PC2 equivalent to C1-2 TA screws
- Resists flexion, lateral bending, axial rotation
- Weaker resistance to extension
- Improved with interspinous graft
- Pullout resistance: LC1 and PC2 equivalent (superior to mid cervical lateral mass screws)

C1-2 Segmental Fixation:
Complications:

- Vertebral artery injury
- Spinal cord injury
- Screw failure
- Pseudoarthrosis
Odontoid Screw Fixation

- Bohler: 1982
- Nakanishi: 1982
- Alternative fixation for type II odontoid fxs

Advantages

- Preserves C1-2 joint
- Spares cervical rotation
- No bone graft
- No halo immobilization
Odontoid Screw Fixation

- Odontoid screw is as stable as C1-2 wiring in torsion and more stable in bending
  - Graziano, Spine 1993
- Single screw = 50% of unfractured odontoid
  - Doherty, Spine 1993
- 10% of odontoid fxs have ruptured TAL
  - Greene, Spine 1994

Odontoid Screw Fixation: Indications

- Type II odontoid fx
- Shallow type III fx
- Concomitant C1 fx
- Reducible
- Acute (< 8-12 wks)
- Requires intact transverse atlantal ligament (TAL)
Odontoid Screw Fixation: Technique

- 3-point head holder
- Mouth roll/cork
- Biplanar fluoroscopy
- Reduce the fx
- Incision at C5-6

Odontoid Screw Fixation: Technique

- Screw entry at C2-3
- Engage distal cortex of the odontoid
- Lag screw technique
- No advantage with 2 odontoid screws
1 vs 2 Odontoid Screws

- No added advantage with 2 screws:
  - Sasso, Spine 1993
  - Graziano, Spine 1993
- Fracture interdigitation more important:
  - Sasso, Spine 1993
- Odontoid too small for 2 screws in 66% pts:
  - Heller, Spine 1992
Clinical comparison of one and two screw odontoid fixation

- 42 patients
- Type II odontoid fxs
- Single screw: 20 pts
- Two screws: 22 pts
- No significant difference in union rates (81% vs 85%)
- 2 single screw fxs

Contraindications
- Non-reducible fx
- Chronic non-union
- Disruption of the transverse ligament
- Osteoporosis
- Oblique fx
Odontoid Screw Fixation:
Pitfalls

- Screw trajectory
- Screw insertion site
Odontoid Screw Fixation: Pitfalls

- Screw trajectory
- Insertion site
- Screw cutout / fx

Odontoid Screw Fixation: Pitfalls

- Screw trajectory
- Insertion site
- Screw cutout / fx
- Oblique fx
Odontoid Screw Fixation: Pitfalls

- Screw trajectory
- Insertion site
- Screw cutout
- Oblique fx
- Lag screw technique

Nonunion
Conclusion

- Anatomically/ biomechanically complex region
- Unique instability problems
- Stabilization options have evolved:
  - Easier to use fixation devices
  - Improved fusion rates and outcomes

Conclusion

- Surgical management:
  - Recognize pattern/ degree of instability
  - Identify site of neural compression
  - Select the appropriate stabilization construct
Thank-You