Spinal Trauma in Pediatrics and Adolescents

- Acute Stage Management

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Introduction

Overview

Rare

High Mortality

Cervical Spine Injury

: 60 – 80%

(Adult : 30 – 40 %)

MV accident : m/c

Fall, Abuse, Birth,

Sports

M : F = 2 : 1

Ave Age = 14 yrs

Age – Biomechanical Considerations

Larger Head Size-to-Body Raio

Incomplete Ossification

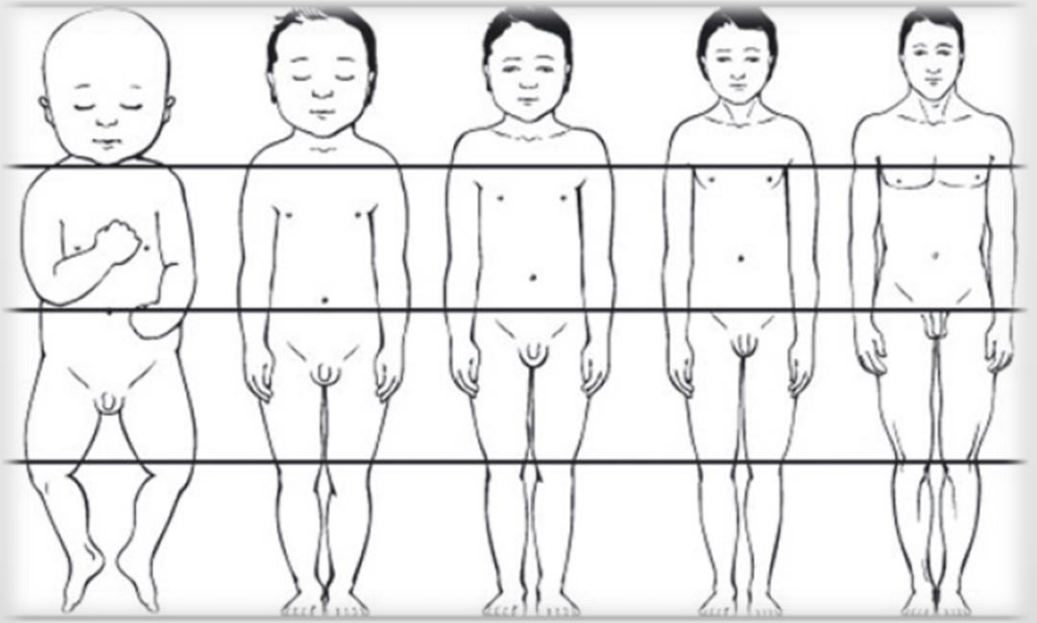
Body Wedging, Os Terminale

Highly Flexible to Ligamentous Laxity

Immature Neck Musculature

Shallow angled Facet : Horizontal Orientation

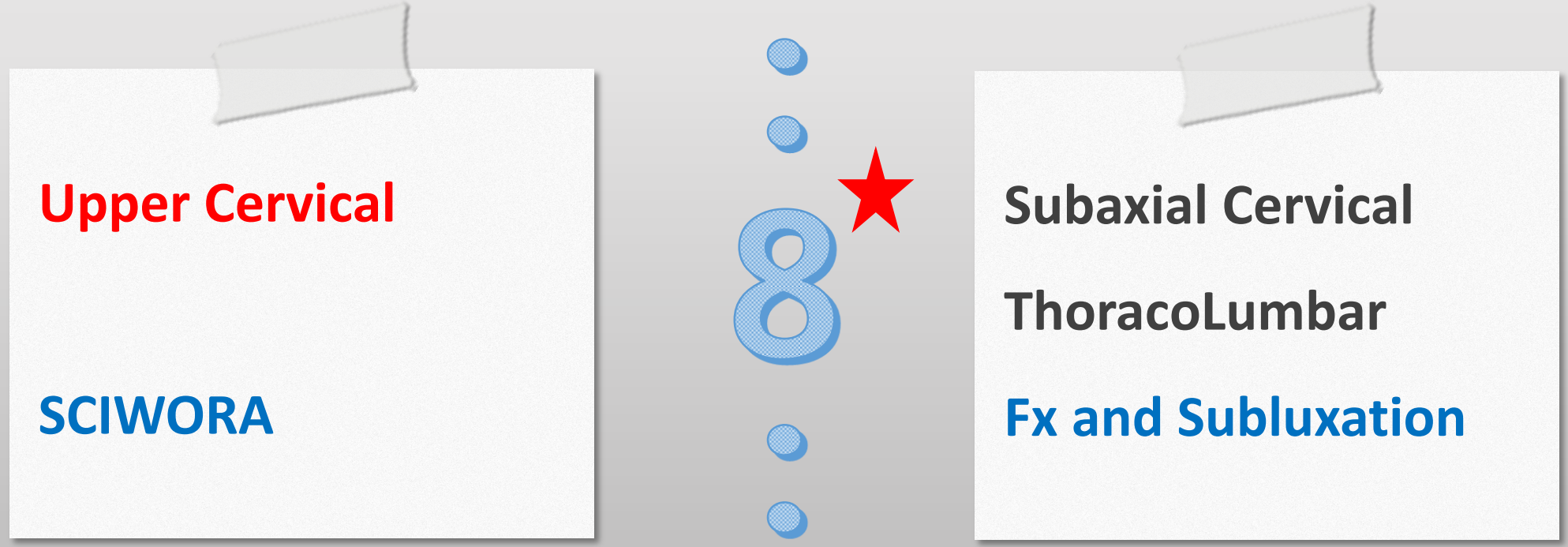
Fulcrum of Movement : C2-3



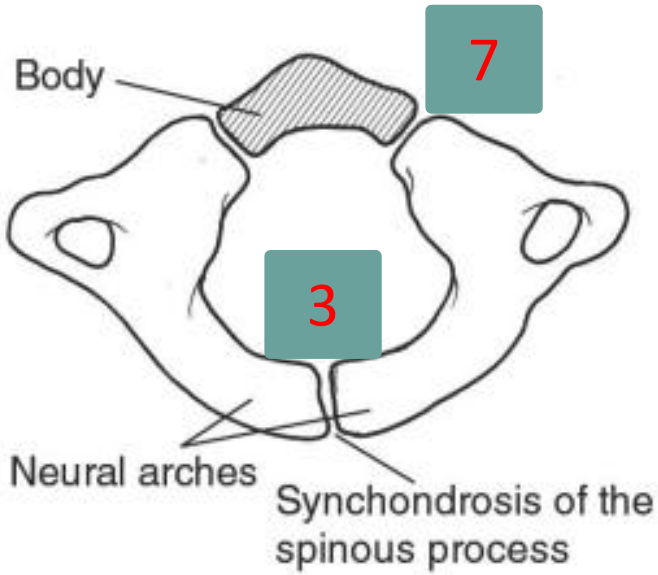
Cervical Injury Propensity

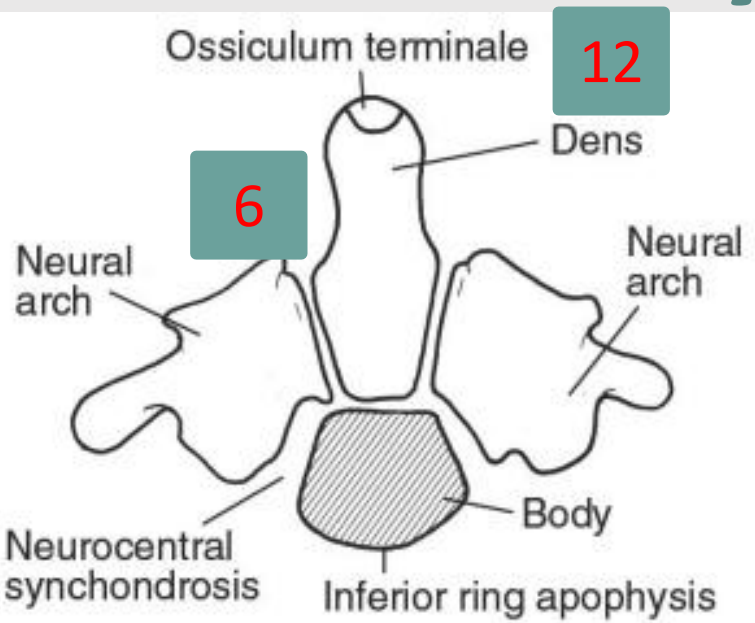
81% ≤ 1 yrs, 64% in 1~5 yrs, 76% in 6~9 yrs, 50% in 10~14 yrs

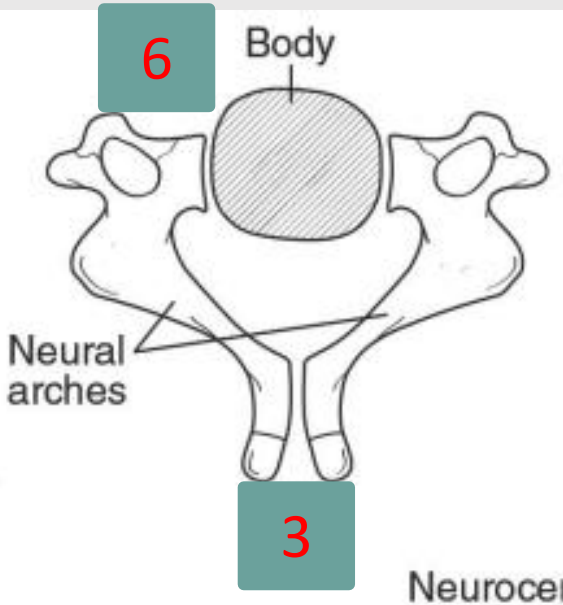
40~50% of Traumatic Brain Injury : associated with Cervical Injury

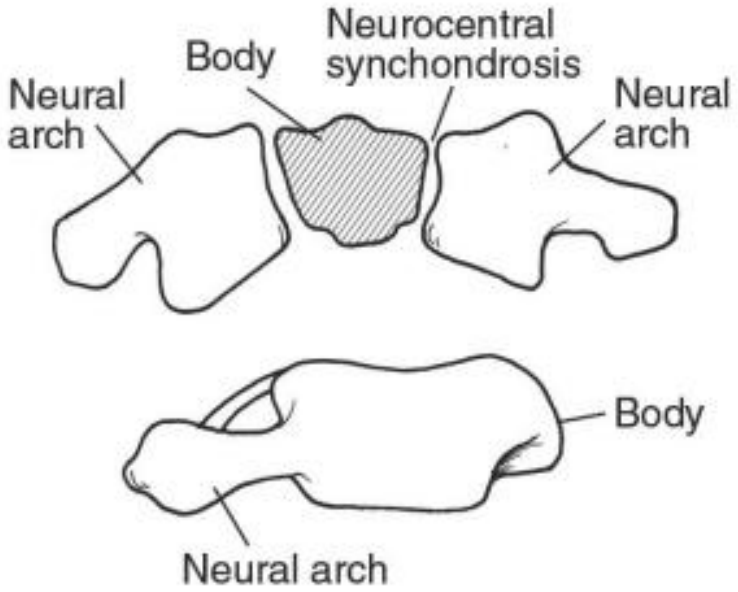


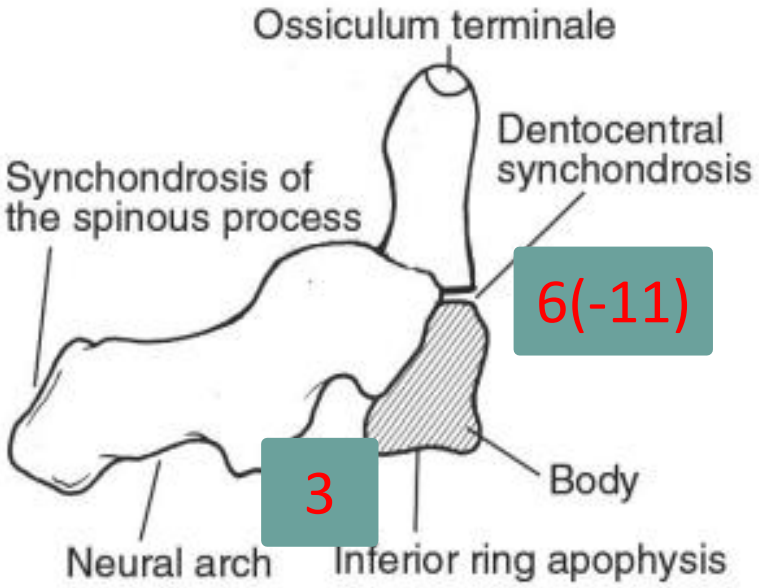
Development and Anatomy

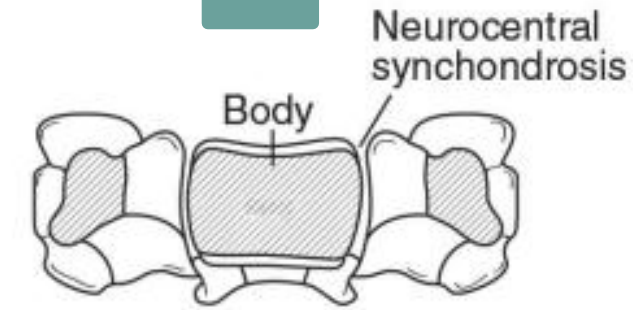


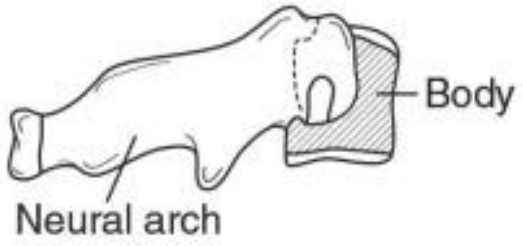












Outcome

Mortality Rate for Pediatric SCI = 28% (Adult = 11%)

Neurologic Recovery = Good

5 – 10 % in Severe SCI

75 – 85 % in Mild or Moderate SCI : Full Recover ≥ 1/2

	Living Independently at All 3 Interviews	Living With Parents at All 3 Interviews	Significance
Number of subjects	95	48	
Sex			$P = 0.118$, $\chi^2 = 2.450$
Male	61 (64%)	37 (77%)	
Female	34 (36%)	11 (23%)	
Race/ethnicity			$P = 0.239$, $\chi^2 = 1.388$
White	90 (95%)	42 (89%)*	
Age at injury (years)			$P = 0.979$
Mean (SD)	14.2 (4.1)	14.3 (4.0)	
Age at interview (years)			$P = 0.099$
Mean (SD)	29.1 (3.9)	28.0 (3.2)	
Range	24–36	24–34	
Duration of injury (years)			$P = 0.249$
Mean (SD)	14.4 (4.6)	13.5 (4.2)	
Range	8–30	7–24	
Level of injury			$P = 0.165$, $\chi^2 = 1.931$
Tetraplegia	56 (59%)	34 (71%)	
Paraplegia	39 (41%)	14 (29%)	
ASIA impairment scale			$P = 0.487$, $\chi^2 = 0.484$
A	63 (66%)	29 (60%)	
B, C, D	32 (34%)	19 (40%)	
Highest education			
BA or higher	34 (36%)	13 (23%)	$P = 0.295$, $\chi^2 = 1.095$
FIM motor items, mean (SD)	61.8 (21.7)	48.5 (23.7)*	$P = 0.001$
SF12, mean (SD)			
Physical component	46.7 (8.7)	43.7 (10.0)*	$P = 0.061$
Mental component	52.9 (7.1)	51.5 (7.3)*	$P = 0.278$
CHART, mean (SD)			
Physical	93.1 (10.6)*	79.3 (26.4)*	$P < 0.001$
Cognitive	97.2 (4.0)	95.2 (5.5)*	$P = 0.015$
Mobility	95.5 (9.8)	81.3 (19.6)	$P < 0.001$
Occupation	92.3 (17.2)*	68.5 (33.5)*	$P < 0.001$
Social integration	93.2 (12.9)*	87.4 (17.9)*	$P = 0.030$
Economic self-sufficiency	84.8 (27.6)*	80.4 (31.0)*	$P = 0.511$
Total CHART	557.4 (47.6)*	496.7 (77.4)*	$P < 0.001$
Married	40 (42%)	0	$P < 0.001$, $\chi^2 = 28.059$
Employed†	59 (75%)	14 (33%)	$P < 0.001$, $\chi^2 = 19.591$
Illegal drug use	15 (16%)	5 (11%)*	$P = 0.406$, $\chi^2 = 0.689$
Satisfaction with life‡			
Mean (SD)	26.4 (7.6)	21.5 (8.2)	$P = 0.001$
Range	5–35	5–35	
Medical complications			
Spasticity	45 (47%)	35 (73%)	$P = 0.004$, $\chi^2 = 8.445$
Pressure ulcer	30 (32%)	24 (50%)	$P = 0.032$, $\chi^2 = 4.604$
Severe UTI	10 (11%)*	14 (29%)	$P = 0.005$, $\chi^2 = 7.767$
Pain	70 (74%)	34 (71%)	$P = 0.718$, $\chi^2 = 0.131$
Hospitalization	18 (19%)	13 (27%)	$P = 0.265$, $\chi^2 = 1.243$
Bowel incontinence	10 (11%)	2 (4%)	$P = 0.206$, $\chi^2 = 1.598$

Data not available for all subjects.
Students and homemakers excluded.
Reported at third interview.

Evaluation

Spine Trauma

Classic Triad

Local Pain and Tenderness

Muscle Spasm

Decreased ROM

Nonverbal Children

Missing Cervical Injury = 23-fold

Multiple Level Injury with non-contiguous Fractures = 16%

Diagnostic Tool

Clinical Evaluation + **Radiologic Evidence**

AP + Lat

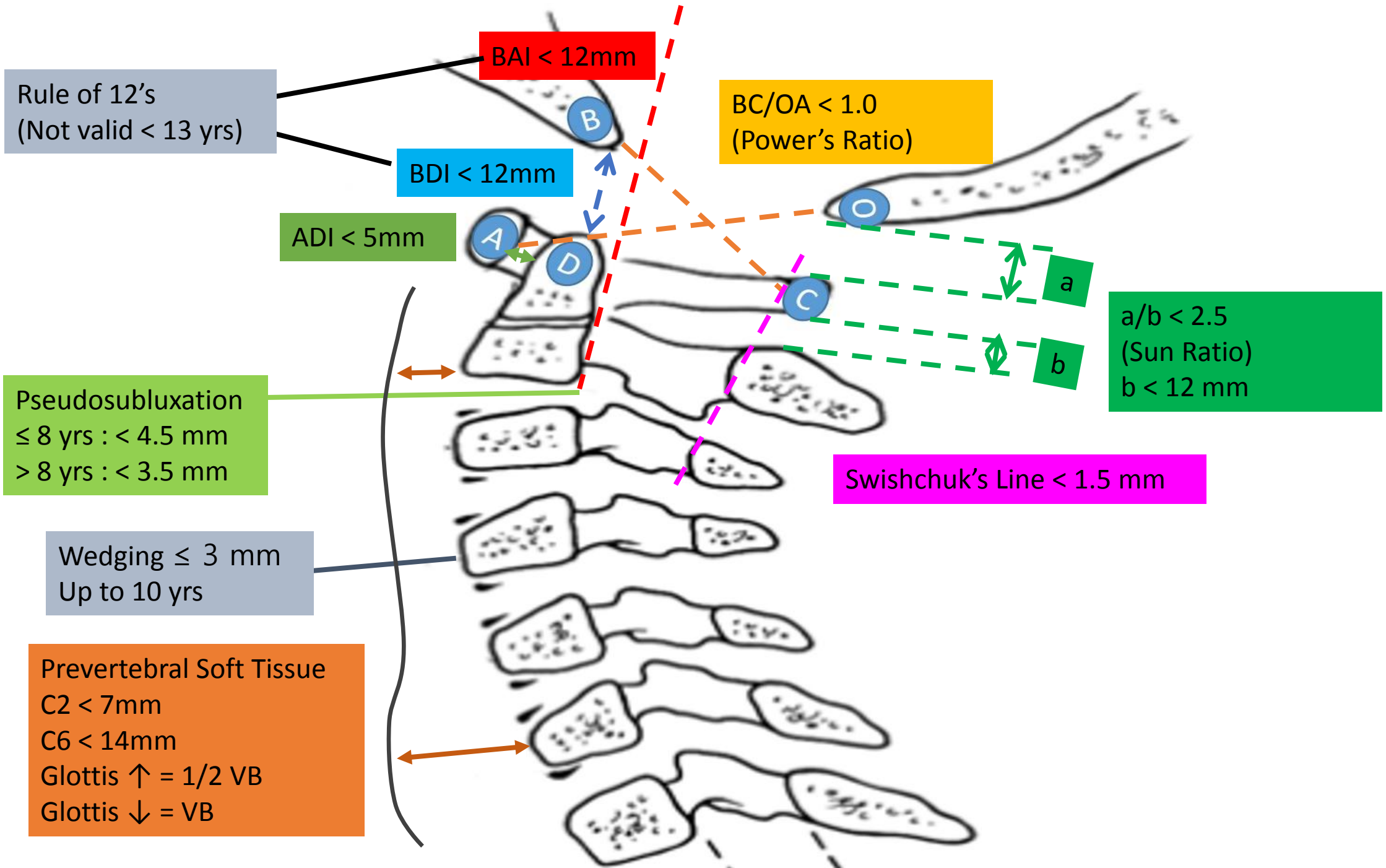
(± High Resolution CT)

8

AP + Lat + Open Mouth

(± High Resolution CT)

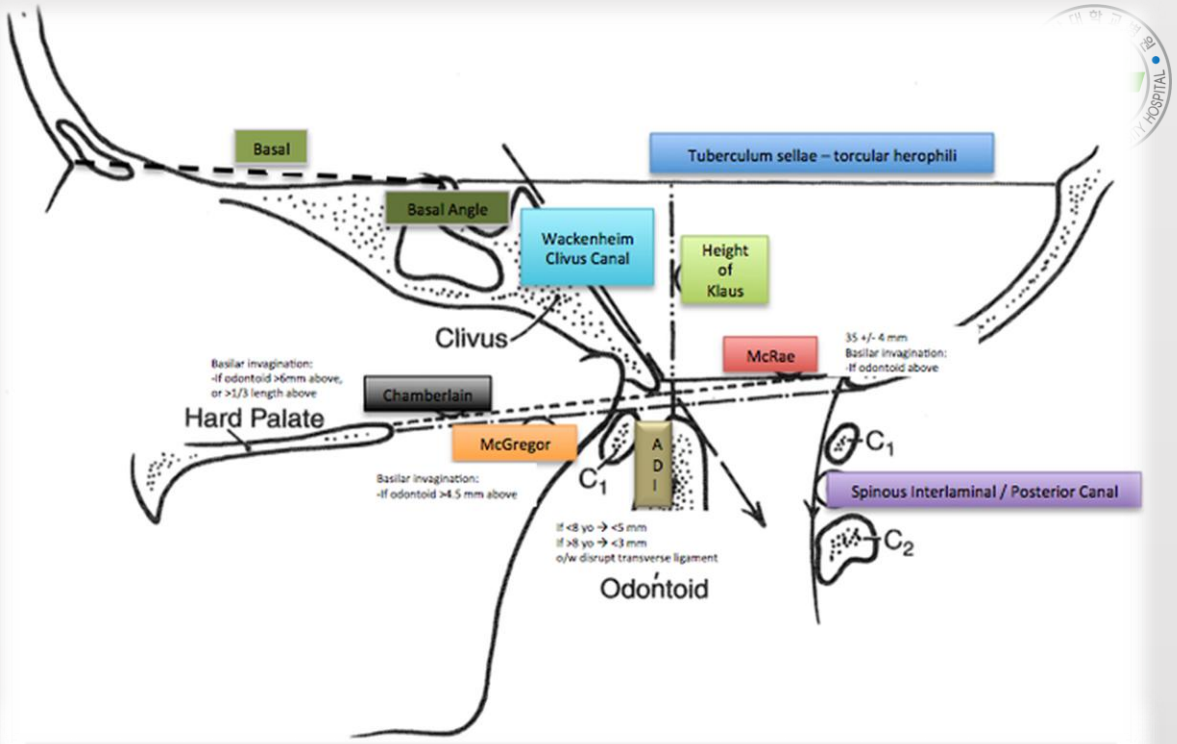
MRI, Dynamic Radiography(1-4 weeks after)


Rule of 12's
(Not valid < 13 yrs)
BAI < 12mm
BDI < 12mm
ADI < 5mm
BC/OA < 1.0
(Power's Ratio)
a/b < 2.5
(Sun Ratio)
b < 12 mm
Pseudosubluxation
≤ 8 yrs : < 4.5 mm
> 8 yrs : < 3.5 mm
Swishchuk's Line < 1.5 mm
Wedging ≤ 3 mm
Up to 10 yrs
Prevertebral Soft Tissue
C2 < 7mm
C6 < 14mm
Glottis ↑ = 1/2 VB
Glottis ↓ = VB
A
B
C
D
O
a
b

Radiologic Parameter

The important lines (CV Junction)

- Chamberlain's line
- Wackenheim's clivus canal line
- Mc Gregor's line (basal line)
- McRae's line
- Basal angle
- Bull's angle



A. PLATYBASIA

- Basal angle — < 150 degree
- Boogard's angle — < 136 degree
- Bull's angle — < 13 degree

B. BASILAR INVAGINATION

- Chamberlain's line — < one third of odontoid above this line
- Mcgregor's line — < 5 mm
- Mcrae line — odontoid lies below this
- Klaus height index — > 35 mm
- Atlanto-temporo mandibular index — > 22mm.

C. ATLANTO-AXIAL DISLOCATION *

- Atlanto-odontoid space — upto 3 mm in adults, upto 5 mm in children

Radiologic Parameter

Atlanto-Dental Interval (ADI)

Abnormal : > 5 mm in Pediatrics (Unreliable ≤ 1 yrs, > 3 mm in Adult)

3-6 mm = Transv Lig Damage (Flex > 5 mm & Ext > 4 mm)

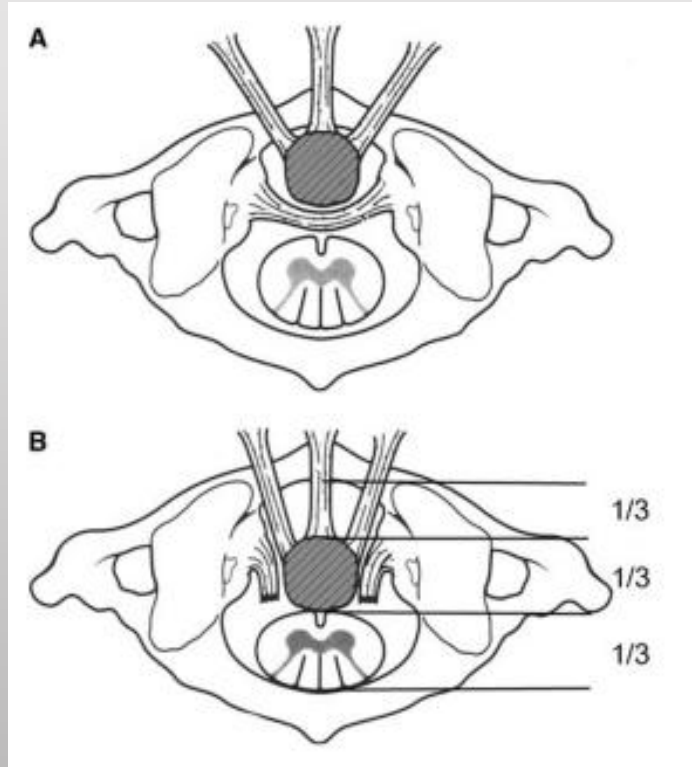
> 6 mm = + Alar Lig Damage

10 ~ 12 mm = Alar and Apical Lig Injury, High Risk of Cord Compression

Steel's Rule of Thirds (C1 Spinal Canal)

Posterior Atlanto-Dental Interval (PADI)

< 14 mm (Canal Space < 1/3) = Cord Compression



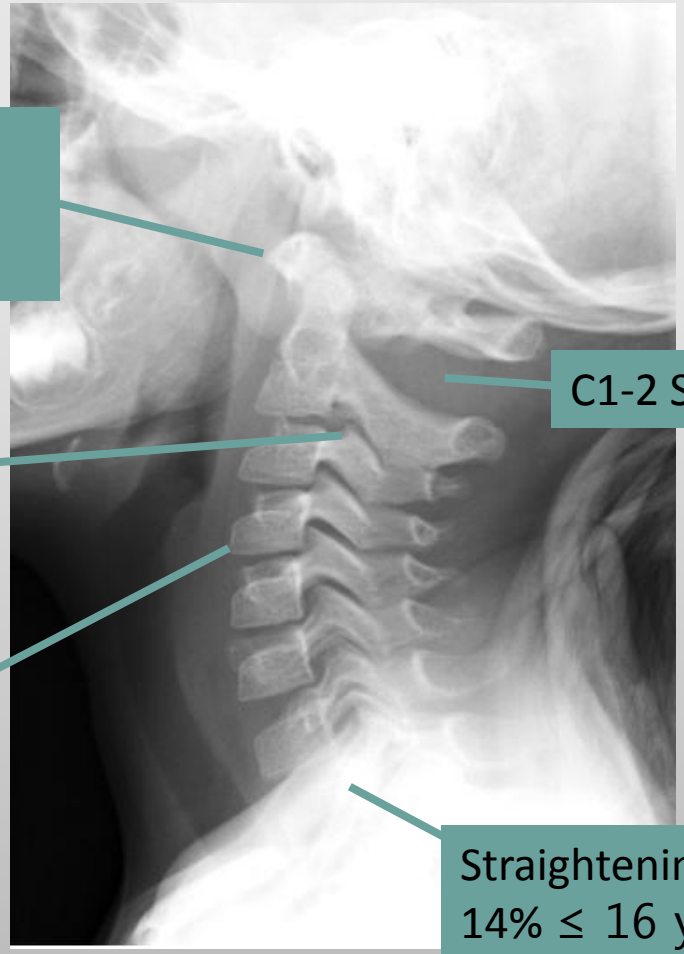
Normal Variants

Age	Variation in Anatomy
Less than 1 year	Vertebral bodies wedged anteriorly No cervical lordosis C1 body not visible
3 years	Dens ossifies Synchondroses of posterior spine fuse Differential growth of C1 on C2 (pseudo-Jefferson fracture)
3–6 years	Ossification center at tip of odontoid (ossiculum terminale) Vertebral bodies no longer wedged anteriorly Three ossification centers each for C1–C7 (C2 can have four centers) Synchondrosis of body of C2 and odontoid
8 years	Pseudosubluxation resolves Predens space < 5 mm
12–14 years	Secondary ossification centers visible at tips of spinous processes Ossification center at tip of odontoid fuses
20 years	Ossification centers on spinous processes fuse

Over-riding C1 Ant Arch on Dens during Extension (20% ≤ 8 yrs)

Pseudosubluxation C2/3 3/4
46 % ≤ 8 yrs

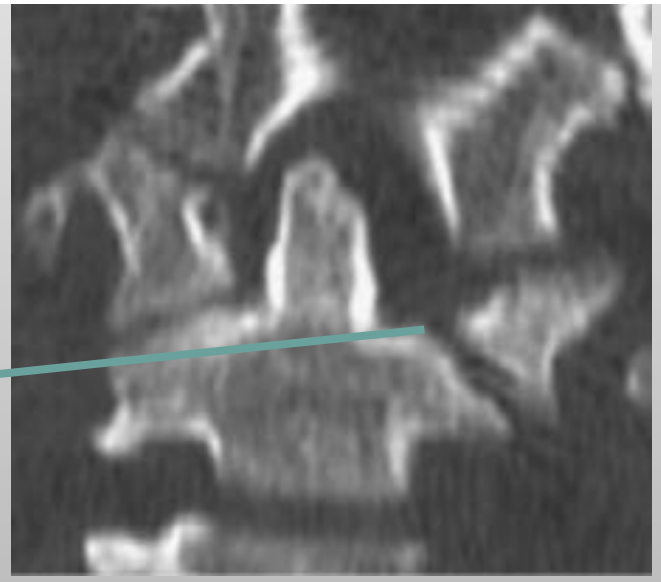
VB Wedging
< 5 yrs
Sagittal Index < 0.893 =Fx



C1-2 Space Widening

Straightening
14% ≤ 16 yrs

C1 Lat Mass Displacement

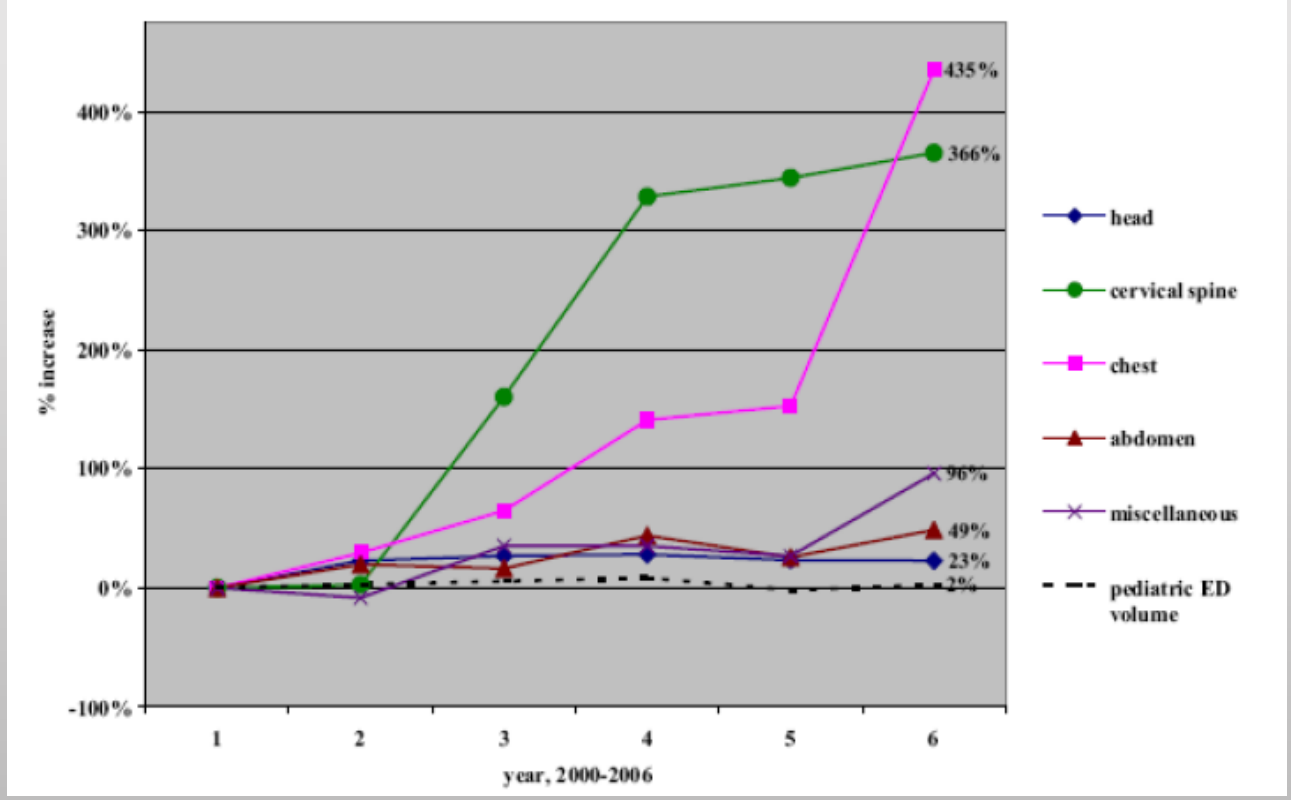


CT vs Plain Film

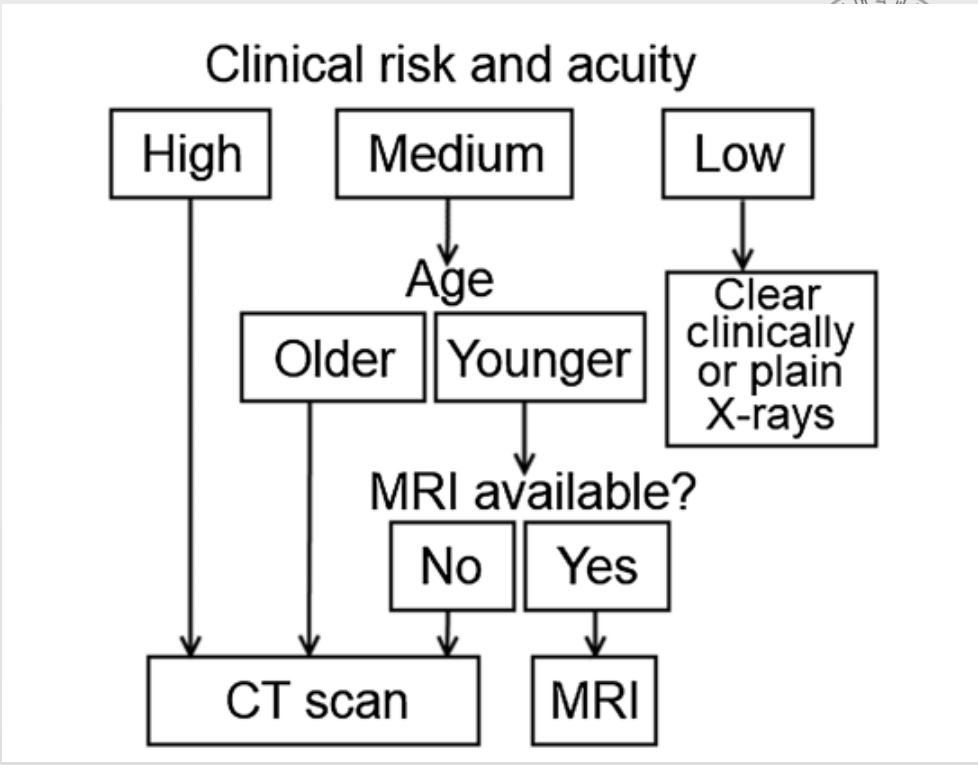
< 5 yrs : CT = Plain Film

Sensitivity - Adult : Child = 99% : 87%

CT Utilization ↑↑↑



CT Benefit vs Harm



Pediatrics (< 15yrs) : Radiation = Carcinogen

Breast, Thyroid, Lens – Most Sensitive

Life-Long Cancer Risk ↑ : 0.07~0.18% Lifetime Risk

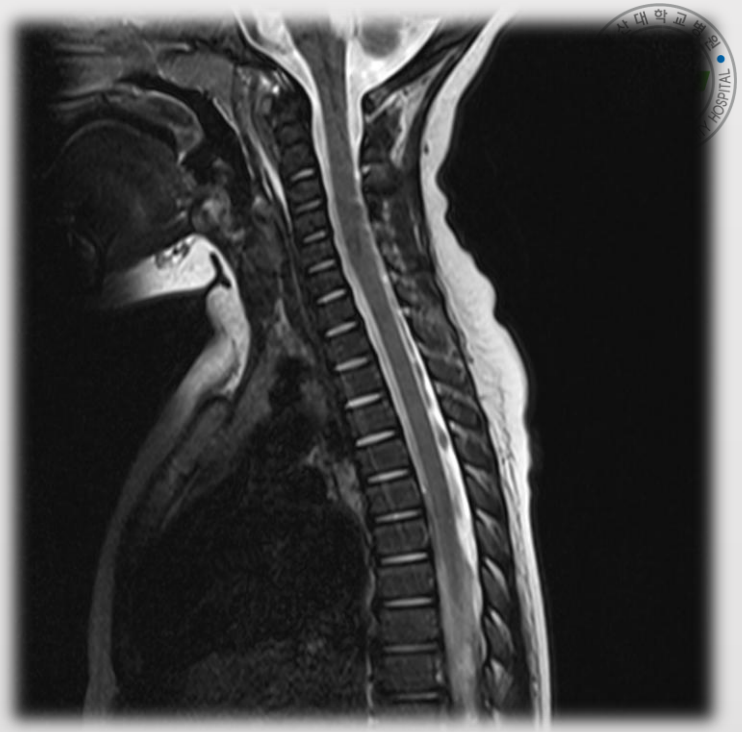
Very High Risk < 5 yrs : Thyroid Ca = 9-fold

Natural Annual Exposure = 300 mrem

Maximal Annual Occupational Exposure = 5000 mrem

CT = 3000 – 6000 mrem

MRI



1. Obtunded/Non-Verbal Pt with Severe Injury
2. Equivocal Plain Film
3. Neurologic Sx w/o Radiographic Findings
4. Inability to Spine Clearance within 72hrs of Admission

⇒ Dx ↑, Radiation ↓, Early Spine Clearance = Immobilization Cx ↓,

ICU Stay & Hospital Stay ↓

MRI – Px Factor

normal
Single-level Edema
Multilevel Edam
Mix of Hemorrhage and Edema

Poor Px

DWI (Diffuse Weighted Image)

SWI (Susceptibility-Weighted Image)

DTI (Diffusion-Tensor Image)

* Repeat MRI (1 week after) ???

Cervical Spine Clearance

Immobilization Cx (Cervical Collar)

Skin Breakdown

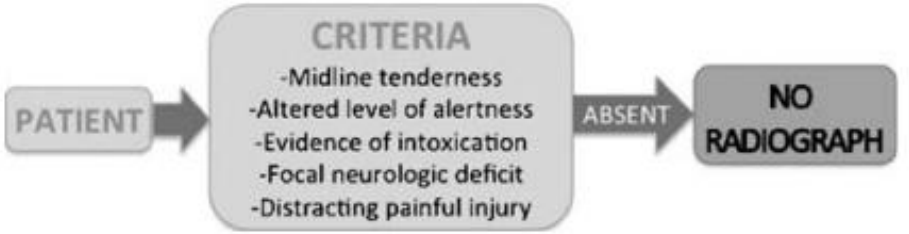
ICP ↑ : 4.6 mmHg ↑

Dysphagia

Pulmonary Cx

Decubitus Ulcer

NEXUS & CCSR



NEXUS (National Emergency X-Radiography Utilization Study)

Sensitivity : Specificity = 90.7% : 36.8%

Pediatric NEXUS : ↓20% Imaging Study

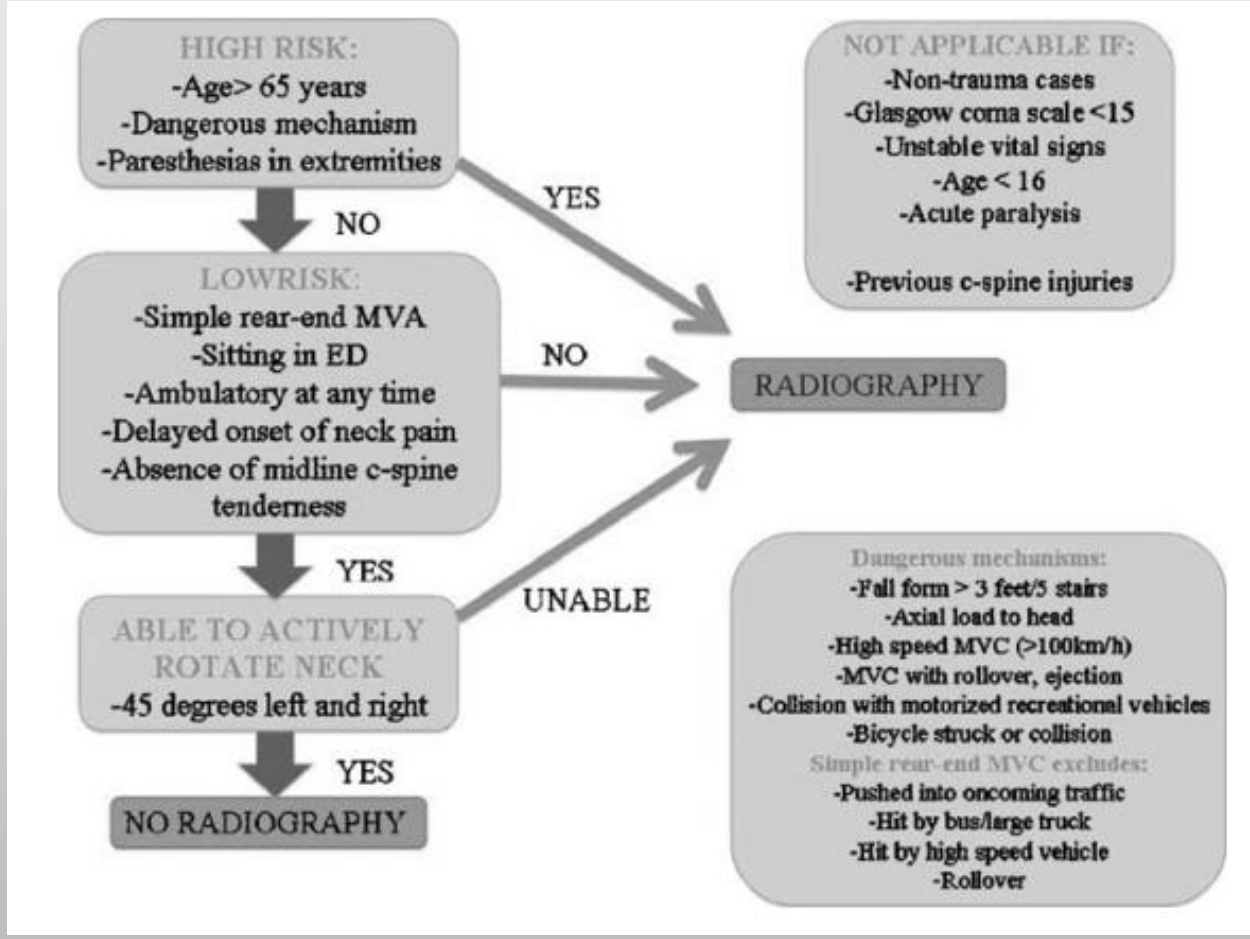
: Limitation – Few Patients ≤ 8 yrs & no ≤ 2 yrs

Infant or Very Young Child : not applied

CCSR (Canadian C-Spine Rule)

Sensitivity : Specificity = 99.4% : 45.1%

Not Studied in Pediatrics



Recommendations

American Association of Neurological Surgeons (AANS) 2013

NEXUS > 9 yrs

Start with Plain Film

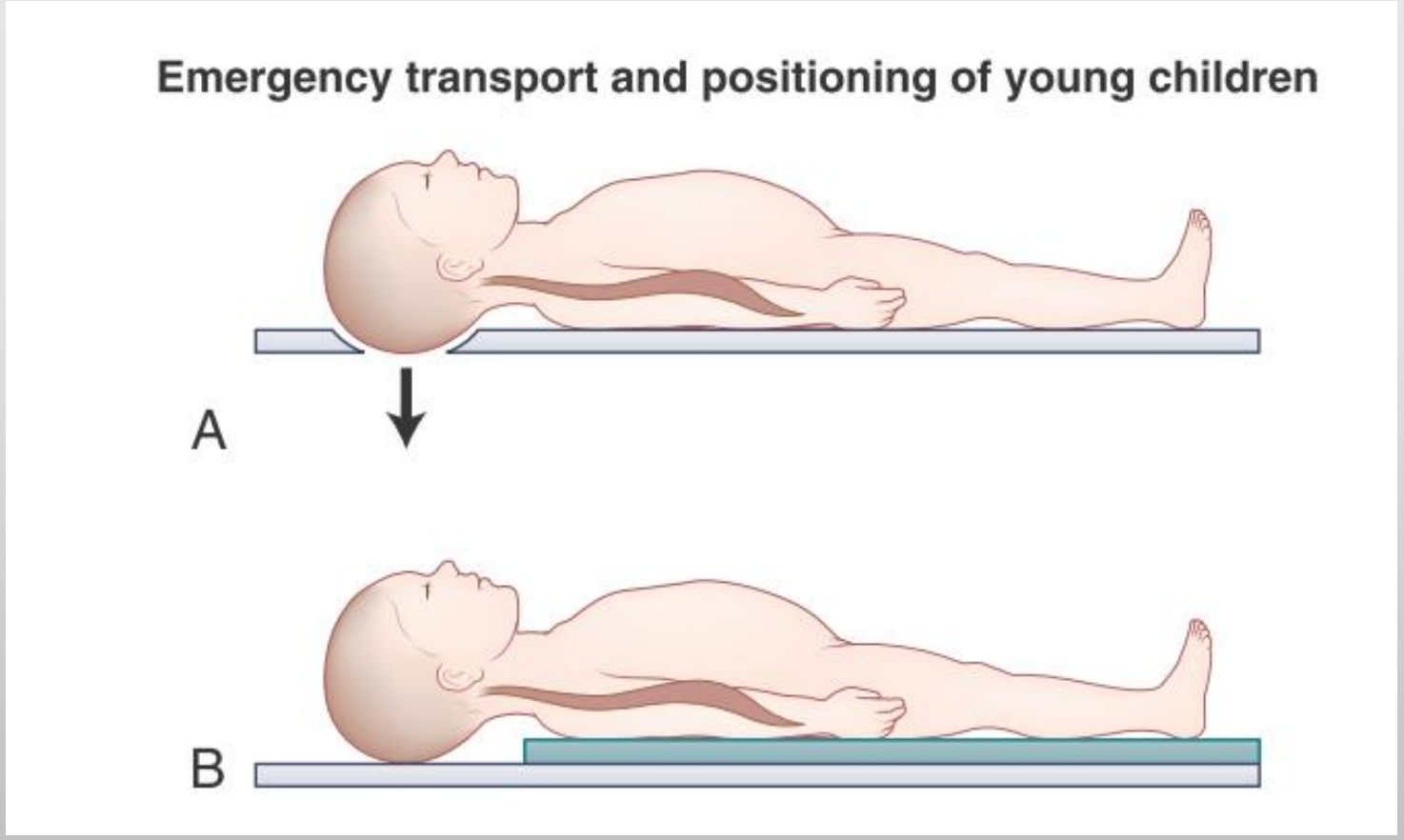
8 Factors of Pediatric Emergency Care Applied Research Network (PECARN) 2015

Altered Mental Status	Substantial Torso Injury
Focal Neurologic Findings	Predisposing Conditions to Cervical Injury : Down Synd
Neck Pain	Diving
Torticolis	High Risk MVA

Initial Management

Pediatric Transport Caution !!!

Well-fitting Cervical Collar ± Sandbags



8 years old !!!

Standard Spine Board

= Excessive Cervical Flextion

Back Elevation with Padding

(2.5 cm)

Prehospital Management

PROTECTION = PRIORITY / DETECTION = SECONDARY

Rigid cervical collar

“Log rolling”

Rigid transportation board remove

Rigid transfer slide

Ideally, Whole Spine Immobilization

Pediatric Cervical Collar

Infants and Young Children : often Uncooperative and Restless.

Rigid Collar + Supplemental Devices (enlose the head ;Kendrick Extrication Device) or Tape

Cervical Collar : Risk of Over-Distraction and Neurologic Injury in AOD ⇒ Sandbags + Tape

- If they are non-tender, do not have a focal deficit, and your exam is reliable, they do not need X-rays/immobilization.

Initial Resuscitation Flow Chart

Tx Goal = Prevent Secondary Injury

ABCDE

Airway, Breath, Circulation, Disability, Environment

Spinal Shock vs Neurogenic Shock

Table 1 Traumatic spine injury checklist for the first hour

Checklist
☐ Spine immobilization and maintain spine precautions
☐ Keep SBP >90 mmHg
☐ Administer supplemental O_2 if indicated for SpO_2 <92 %
☐ Consider early intubation for failure of ventilation
☐ Rule out other causes of hypotension
Do not assume neurogenic shock

Avoidance Hypotension

No Reports in Traumatic Pediatrics, Similar Reports in Pediatric Spinal Deformity

Target Mean Arterial BP : 85 ~ 90 mmHg (over 80 mmHg) for 1st week

MAP (Children) ? “Slightly hypertensive!”

Initial Resuscitation Flow Chart

FiO_2 ↑, O_2 Sat > 95% - Intubation, Ventilator

Hct > 28

CVP : Normal to High

Pain Control

Treat Compression Lesion

*** Cervical Tong Traction**

≤ 12 yrs : Increased Cx Rate (Skull Fx, Abscess, Overdistraction)

Spinal Shock vs Neurogenic Shock

Spinal Shock

Transient Areflex below Injury Level

Initial Hypertension (Catecholamines)

→ Hypotension

Flaccid Paralysis

Bowel / Bladder Dysfunction (Some : Priapism)

Sx > 48 hrs : Recovery ≈ 0 %

Bulbocavernous Reflex : Recovery Indicator

Neurogenic Shock

Loss of Sympathetic Tone, Vasomotor/Cardiac Regulation

Clinical Triad

⇒ Hypotension + Bradycardia + Hypothermia

More commonly in injuries above T4

Secondary to Sympathetic Outflow Disruption from T1 – L2

Neurogenic Shock Management

Above T4 Lesion, Within 14 hrs

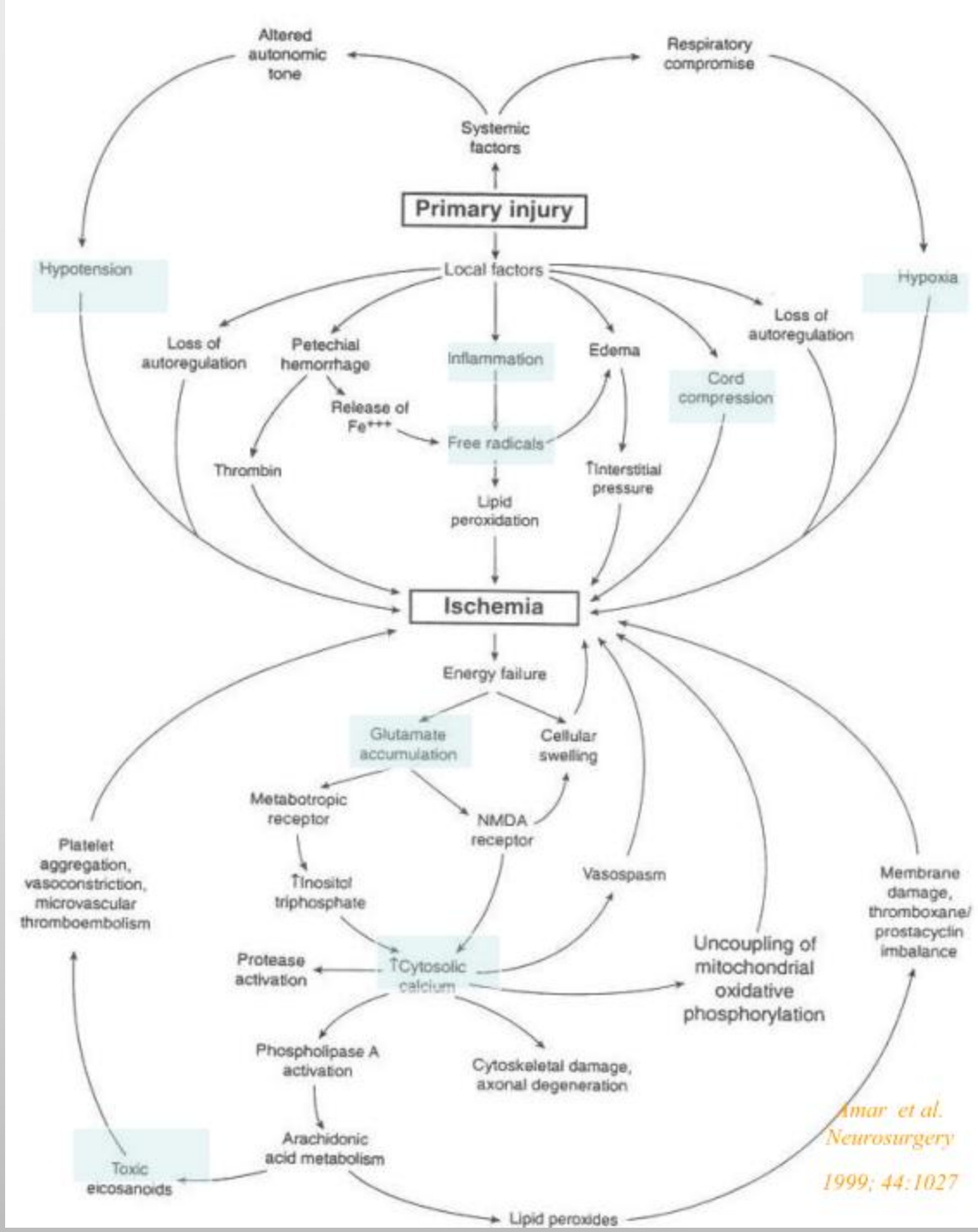
Bradycardia + Hypotension

1st Line Tx = Volume Resuscitation (20ml/kg bolus + 60ml/kg/1st hour)

2nd Line Tx = Vasopressor, Atropine

Pathogenesis of SCI

- Hypotension
- Hypoxia
- Inflammation
- Glutamate
- Toxic eicosanoids
- Cord compression
- Free radicals
- Calcium changes



Steroid Megadose

NASCIS (National Acute Spinal Cord Injury Study)

Steroid Megadose : No Clear Benefit, especially Injury below Conus Medullaris

≤ 13 yrs : Excluded in Study

Steroid Megadose in Older SCI Children (8-16 yrs)

No Benefit to Recovery

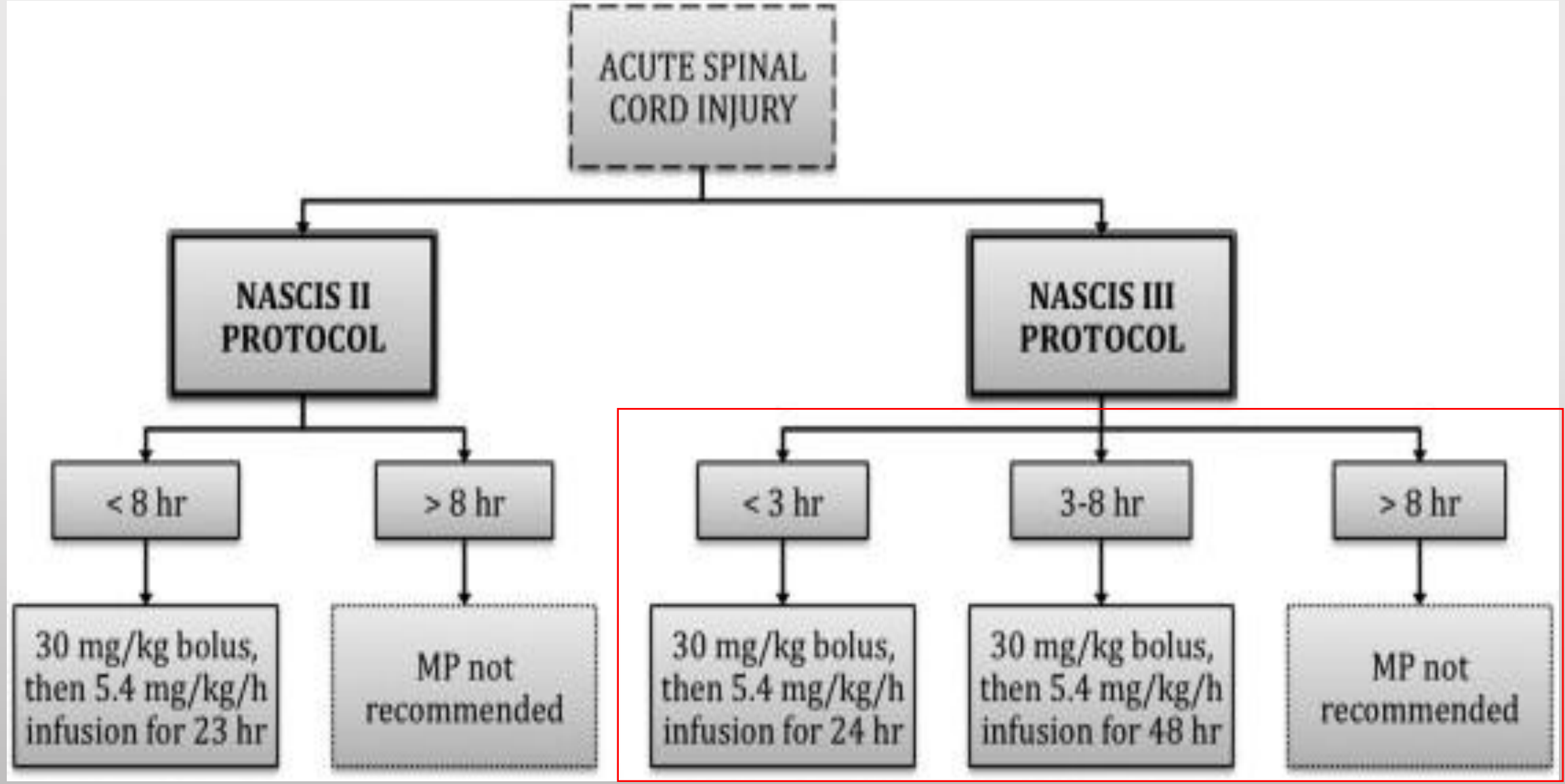
No Infectious Cx Risk

⇒ Physician's Decision

Not Good
&
Not Bad

No Trial Study for Pediatric SCI !!!

NASCIS Protocol



Modulation and Regeneration Tx

Medical

- Gangliosides
- Opiate antagonists
- Excitatory Amino Acid Receptor Antagonists
- Ca^{++} Channel Blockers
- Antioxidants
- Free Radical Scavengers

Surgical

- Tissue implantation
- Stem Cells
- Regenerative strategies
- Regeneration conduits

Specific Conditions

With Case Illustration

Consideration for Management

Future Growth

Risk for Postoperative Deformity

Robust Capacity for Healing and Fusion

Unique Anatomical, Biomechanical, Physiologic Characteristics

⇒ **More Conservative Tx**

(External Bracing is Sufficient for Majority Case)

Spinal Cord Injury

Primary Spinal Cord Injury

Cutting, Compression or Stretching of Spinal Cord

Secondary Spinal Cord Injury

Later Response

Swelling, Ischemia or Movement of Unstable Bony Fragments

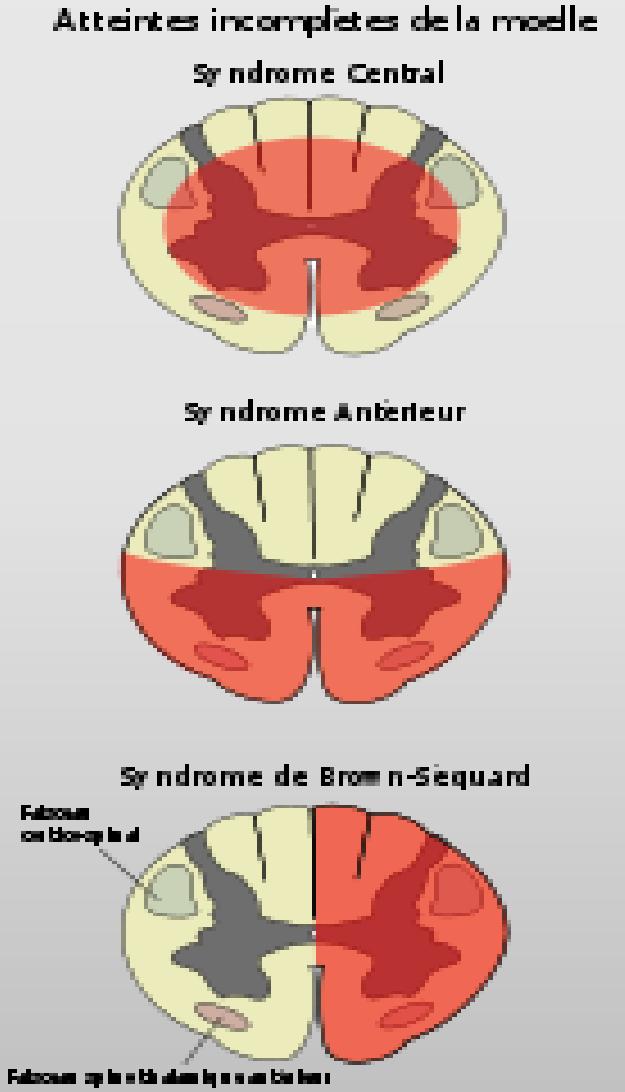
Complete

Less common

Loss of Motor and Sensory Function below the Level of Injury

Incomplete

Some Preservation of Motor and Sensory Function



SCIWORA

MRI ↑
SCIWORA ↓

Spinal cord injury without radiographic abnormality

Conventional X-rays, CT scans, Myelograms, Dynamic Flexion-Extension Radiographs

≤ 8 yrs (Birth ~ 16 yrs)

Low Energy Sports-related Injury

Full Recovery in most Cases (≈100%)

Recurrent : up to 10 weeks, Severe Sx

TABLE 1. Classification of SCIWORA by MRI Type

MRI Imaging Type	
Type I	No detectable abnormalities
Type IIa	Extraneural abnormalities
Type IIb	Intraneural abnormalities
Type IIc	Extraneural and intraneural abnormalities

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Delayed Neurologic Deficit Onset (30min - 4 days) : 30-50%

SCIWORA

Treatment = Immobilization

Duration : controversial

Some report : not helpful (not Improve Outcome, not Prevent Recurrence)

Some report : Immobilization for 8 wks = 17 % recur / 12 wks = 0% recur

❖ Recommendation

: Immobilization for 12 weeks → Dynamic Radiography : No instability

→ Brace Off + 12 weeks activity modification

* MRI check : Just after Injury → 6-9 days after Injury

Atlanto-Occipital Dislocation (AOD)

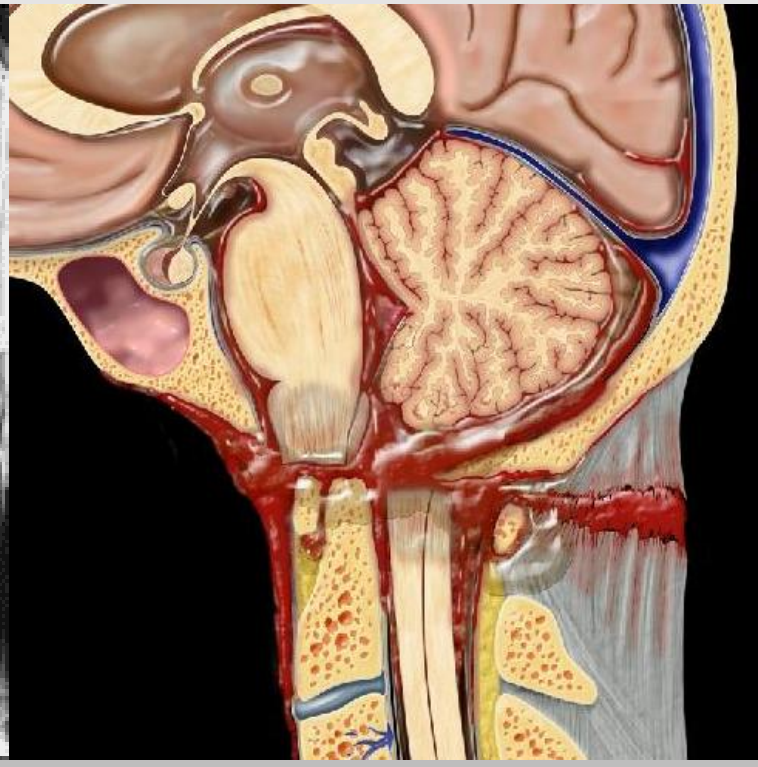
Rare, but **Fatal** (High Mortality and Neurologic Deficit, **Mortality 50%**)

Difficult Dx d/t Concomitant TBI & Image View Limitation

Cranial N Injury : CN VI, XII

Hydrocephalus, Syringomyelia

- BDI > 12 mm
- BAI > 12 mm or > - 4mm
- Power's Ratio > 1
- Condylar-C1 (CT scan) > 3 mm



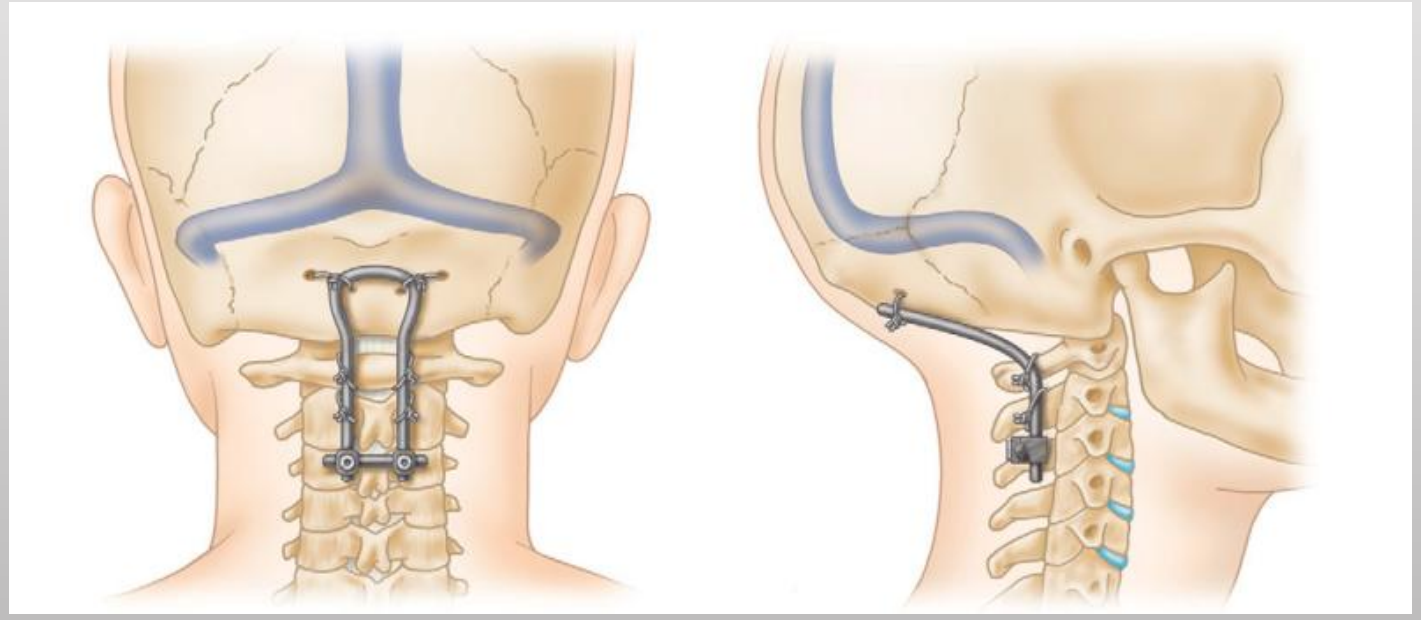
Atlanto-Occipital Dislocation (AOD)

Treatment

Initial Tx = Immobilization (Halo w/o Traction or Minerva casting)

Surgical Fixation (5 – 7 days after Trauma, OC Fusion or O-C1-2 Fusion)

Postop Halo Immobilization : 12 – 16 weeks



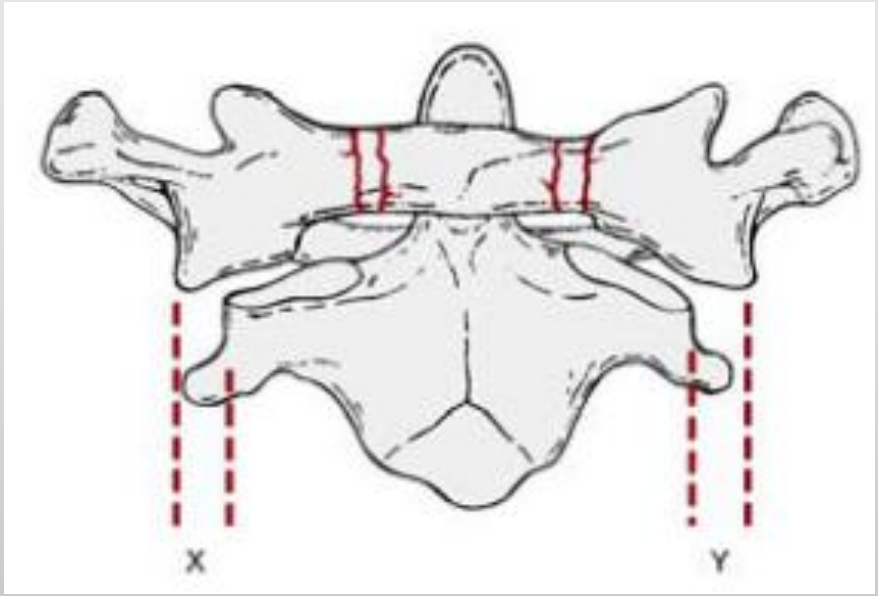
Atlas Fx (C1 Fx)

Rare in Pediatrics

Jefferson Fx = Both Ant & Post Ring Fx

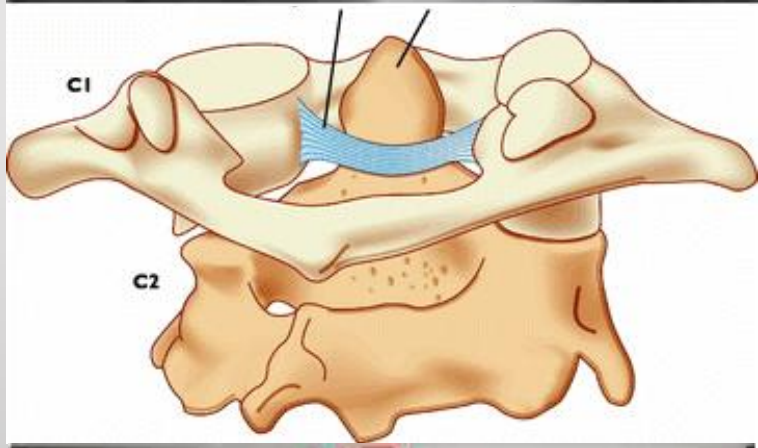
Instability

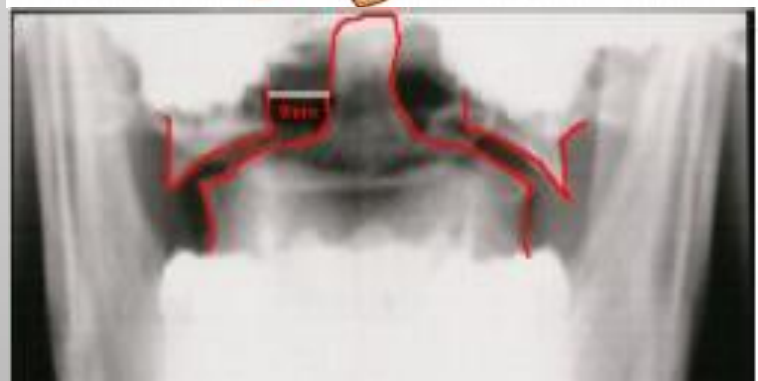
- Transverse Lig Injury
- Rule of Spence



Treatment

- Immobilization (Halo, Minerva) ± Traction
- Surgical Stabilization : Rare





AtlantoAxial Instability (C1-2 Instability)

Traumatic Lig Injury : Transverse Lig Disruption

Non-Traumatic Cause : Inflammation, Malignancy, Down Syndrome...

Treatment

Surgical Stabilization followed by Immobilization 8 ~ 12 wks (Halo, Minerva, etc)

: Wire, Screw

Down Syndrome

aSx (98 ~ 99%)

OP Ix = ADI > 10 mm, PADI < 14 mm

High Cx Rate

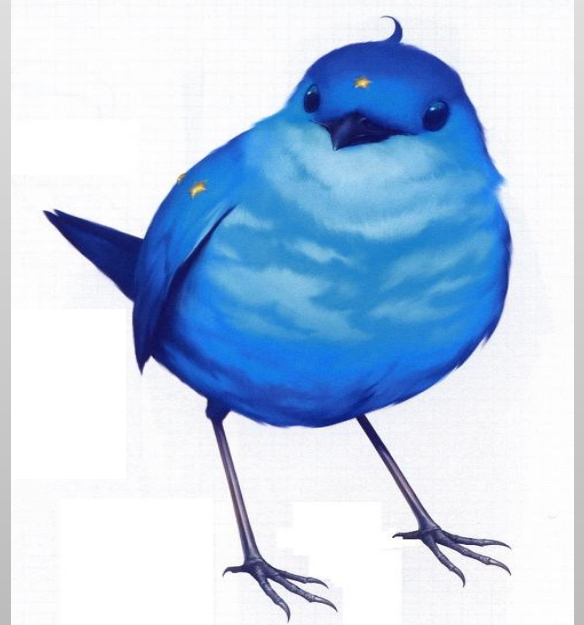
AtlantoAxial Rotatory Subluxation (AARS)

AARF : Fixation > 3 months

Common Cause of Torticollis in Pediatrics

Manifestation

- Neck Pain (Painful Torticolis)
- Cock-Robin Position : Rotation + Lat Flexion
- SCM Muscle Spasm on Side of Chin
- Occipital Neuralgia
- Movement Pain with SCM Spasm : Acute Subluxation
- AARF : Pain Subside + ROM
- Neurologic Deficit : Rare

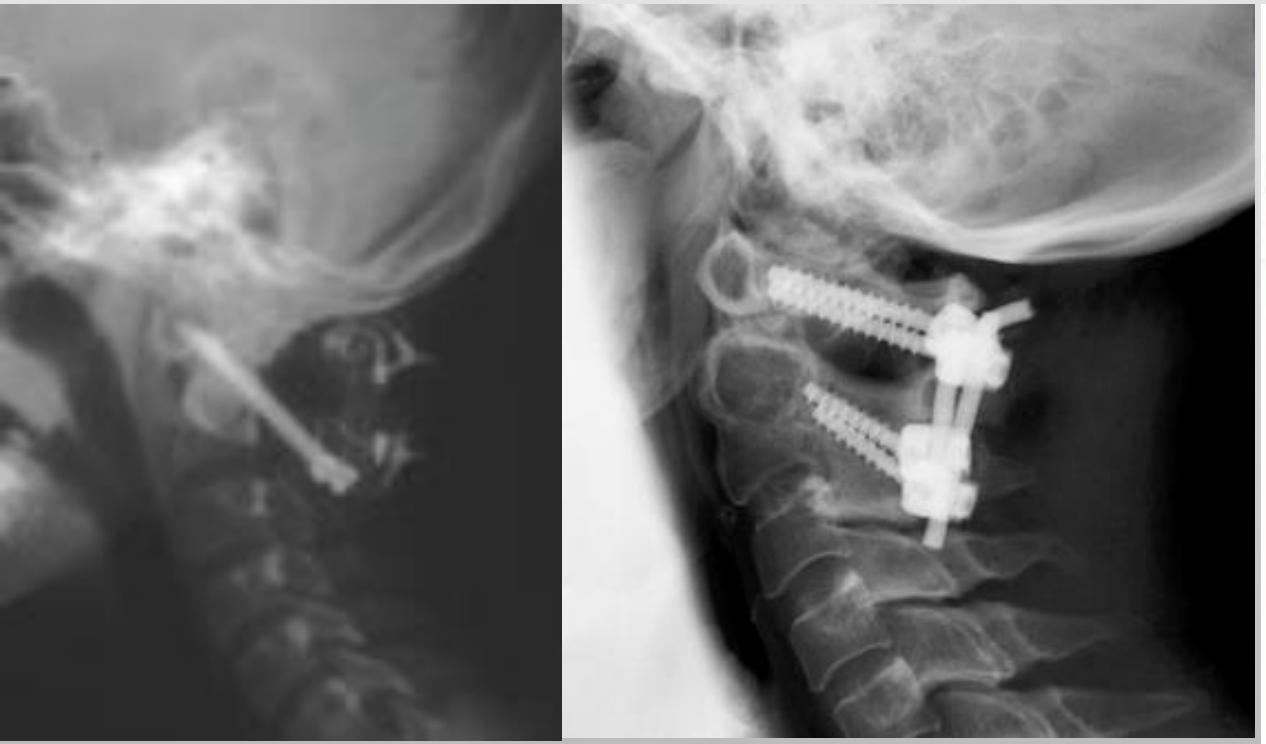


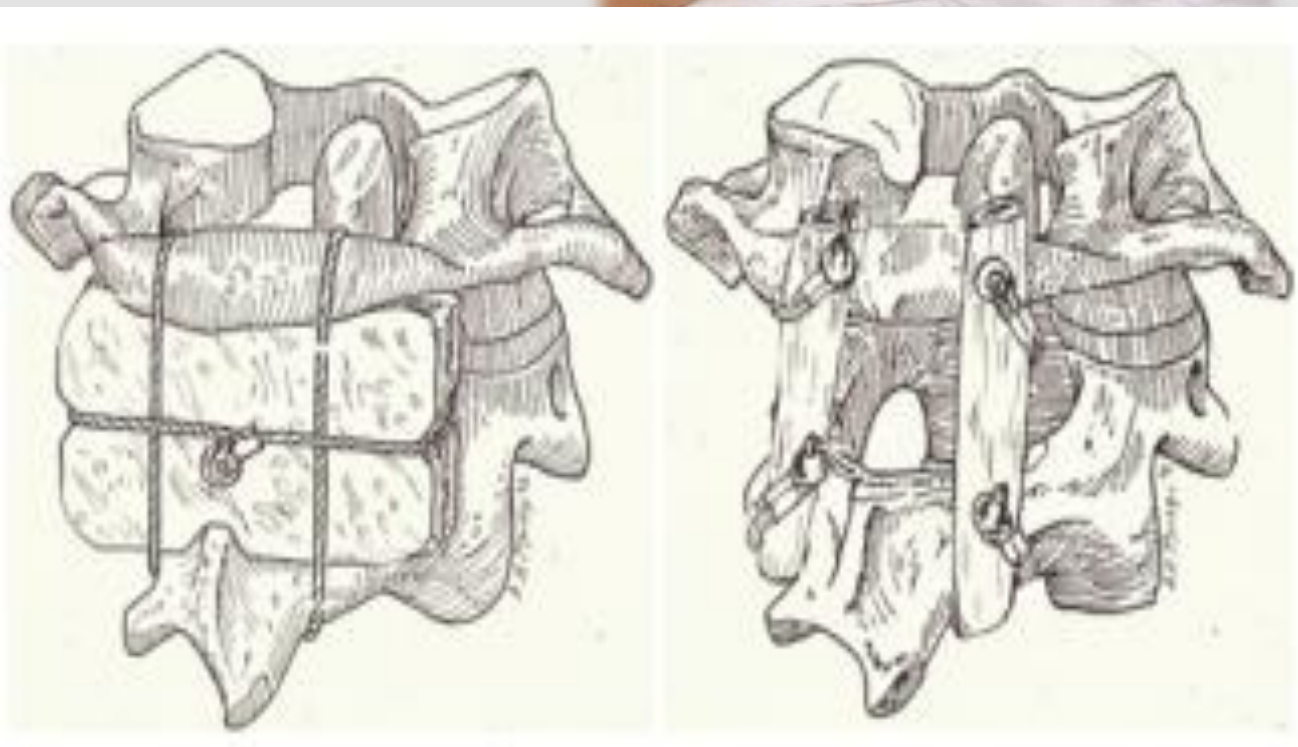
AtlantoAxial Rotatory Subluxation (AARS)

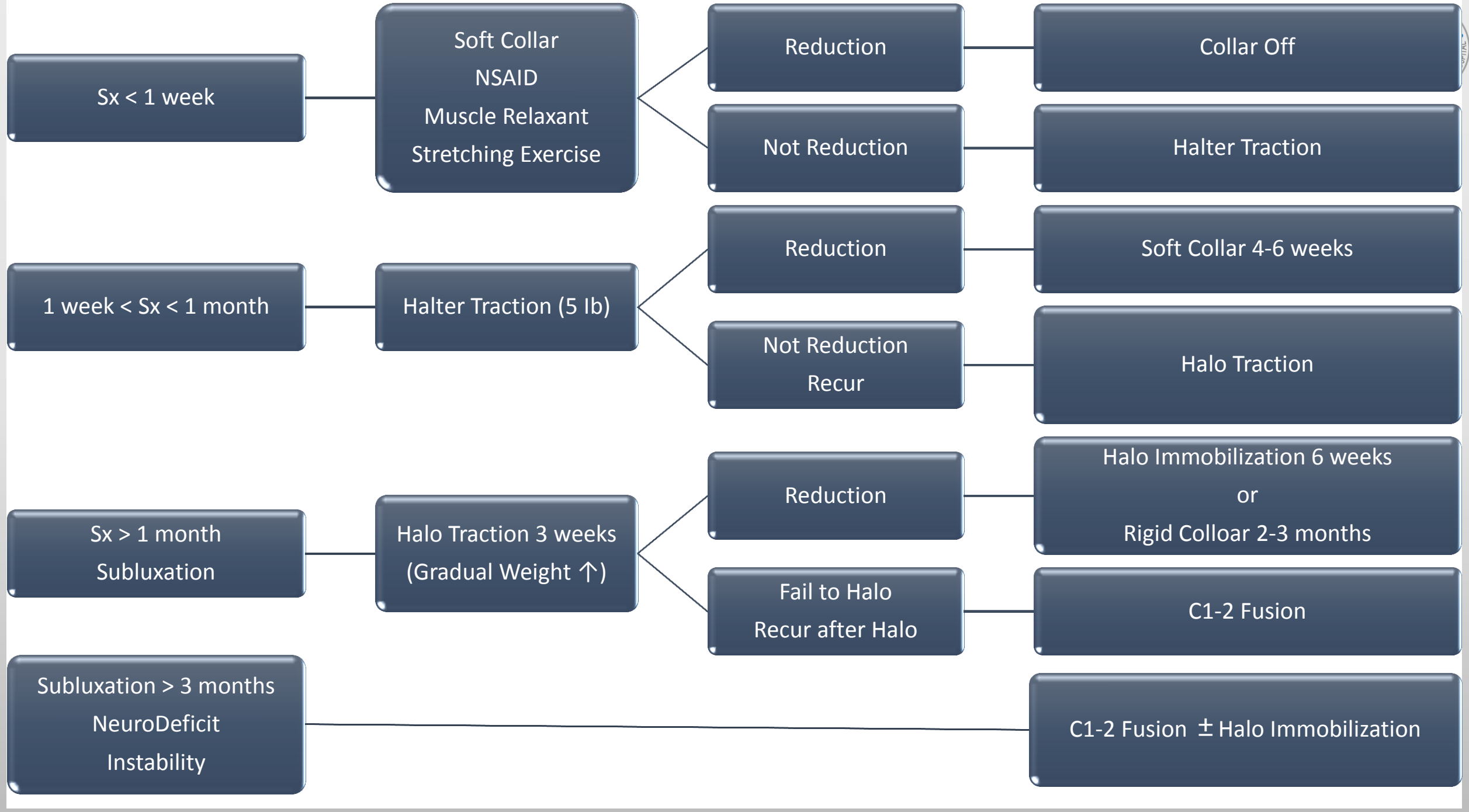
Treatment

Depending on the Timing of Injury and Duration of Symptoms

Some Cases : Spontaneous Reduction

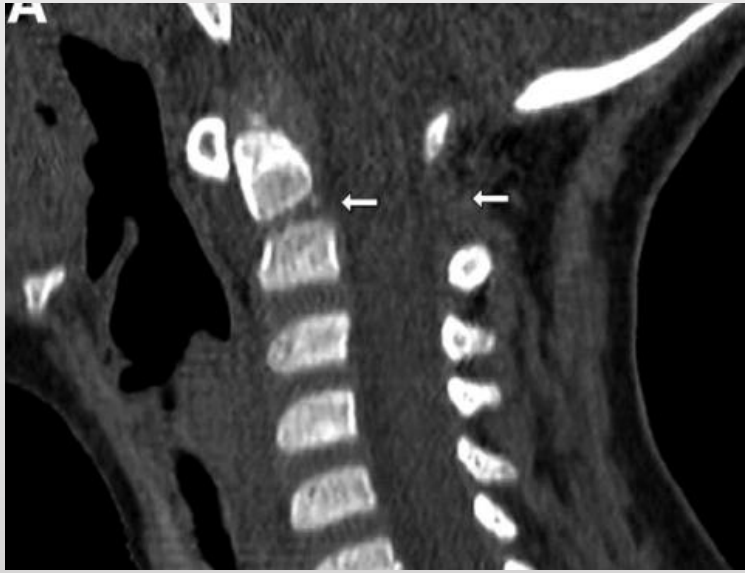





Sx < 1 week
Soft Collar
NSAID
Muscle Relaxant
Stretching Exercise
Reduction
Collar Off
Not Reduction
Halter Traction
1 week < Sx < 1 month
Halter Traction (5 Ib)
Reduction
Soft Collar 4-6 weeks
Not Reduction
Recur
Halo Traction
Sx > 1 month
Subluxation
Halo Traction 3 weeks
(Gradual Weight ↑)
Reduction
Halo Immobilization 6 weeks
or
Rigid Colloar 2-3 months
Fail to Halo
Recur after Halo
C1-2 Fusion
Subluxation > 3 months
NeuroDeficit
Instability
C1-2 Fusion ± Halo Immobilization

Odontoid Fracture

< 7 yrs : Typically Avulsion of the Synchondrosis between Body and Dens



m/c Cervical Spine Fx in Pediatrics

Ant Displacment >>> Post Displacement

Treatment

Closed Reduction (Especially < 3 yrs)

: Extension/Hyperextension Maneuver + Immobilization (Halo, Minerva) 6 - 8 weeks ⇒ Dynamic X ray

Not Reduction : Halo or Halter traction

Surgical Reduction : Rare (10 weeks Immobilzation → Not Fusion → OP)

Os Odontoideum

Unsupported Round Ossicle separated from the Body

Unrecognized Fracture vs Congenial Anomaly

Manifestation

Asymptomatic ~ Myelopathy

Management

Controversial : Some aSx Patients show Decompensation and Death

C1-2 Fusion

Hangman Fx

Traumatic Spondylolisthesis of C2 = Bilat Pars Intercularis Fx

Neurologic Injury : Rare

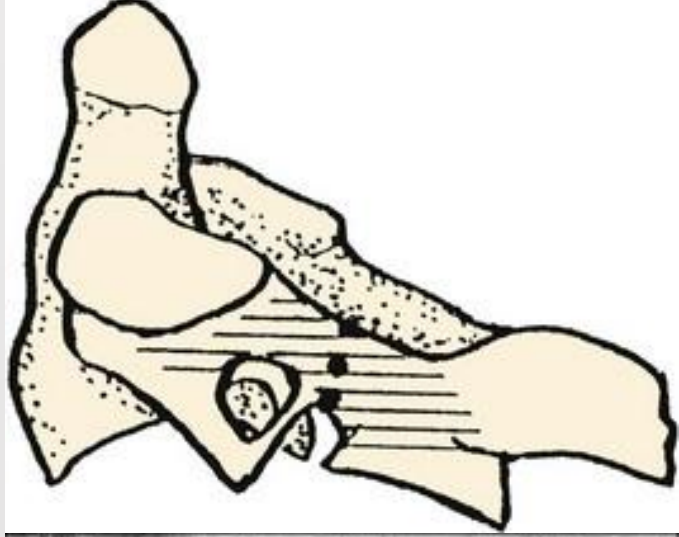
Common < 2 yrs

- Large Head-to-Body Size Ratio
- Poor Muscle Control

DDx : Persistent Synchondrosis

Treatment

- Immobilization (Minerva, Halo, etc) : 8 - 12 wks ⇒ 80% healing
- Nonunion : Ant of Post Fusion



Tear Drop Fracture

Sudden Hyperflexion + Axial Compression

3 Columns Disruption

Neurological Impairment : Usual

(Anterior cord syndrome)

Highly Unstable

SubAxial Cervical Spine Injury

SubAxial Cervical Spine (C3-7) Injury

Young Children and Infant : Rare

Adolescent and Older Children : Common

≤ 9 yrs : > 10 yrs = 22 ~ 31% : 70 ~ 73%

Manifestation

Cervical Rigidity, Muscle Guarding in Unconsciouness

Neck Pain, Radicular Pain, Numbness, Neurologic Deficit

Infant : Motor Weakness, Hypotonia

SubAxial Cervical Spine Injury

Compression Fx

m/c SubAxial Cervical Fx in Pediatrics

Ant Body Wedging

: < 7 yrs : Normal d/t Incomplete Ossification (Notable at C3)

Usually Stable Injury

Nonoperative Tx

Immobilization for 3 ~ 6 wks

Dynamic Image : 2 ~ 4 wks after Trauma

SubAxial Cervical Spine Injury

Burst Fracture

Rare in Pediatrics

Treatment

: No Neurologic Deficit + Minimal Canal Compromise = Traction + Halo Immobilization

: Neurologic Deficit + Significant Canal Compromise = Surgical Decompression + Fusion

⇒ Anterior Approach

d/t Deformity secondary to Ant Growth Plate Destruction

SubAxial Cervical Spine Injury

Vertebral Growth Plate Fracture

- Synchondrosis Injury at the Cartilaginous Endplate
- Ossification Center Fusion
  - Primary Center = 7 - 8 yrs
  - Secondary Center = 25 yrs
- Treatment (According to Endplate Displacement)
  - Ant Displacement : Conservative Tx with Orthosis
  - Post Displacement : Ant Reduction of Bony Nucleus + Orthosis 4 - 5 mo

SubAxial Cervical Spine Injury

Facet Fracture Dislocation

2nd m/c SubAxial Cervical Injury in Pediatrics (Adolescent)

Unilateral D/L : Bilateral D/L = Root Injury : Spinal Cord Injury

< 50% of the Width of a Vertebral Body = Unilateral Facet Dislocation

> 50% of the Width of a Vertebral Body = Bilateral Facet Dislocation

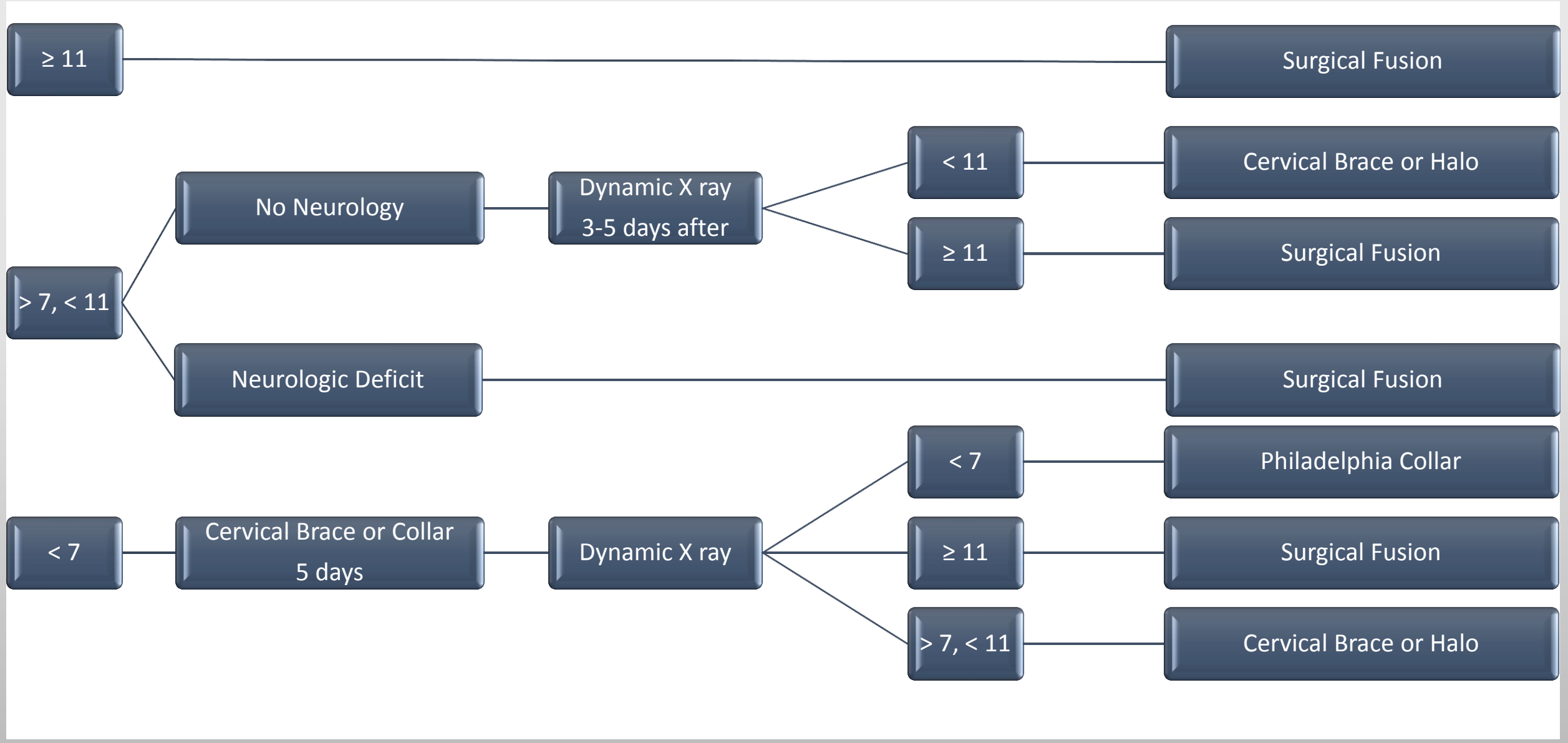
Perched Facet

Treatment

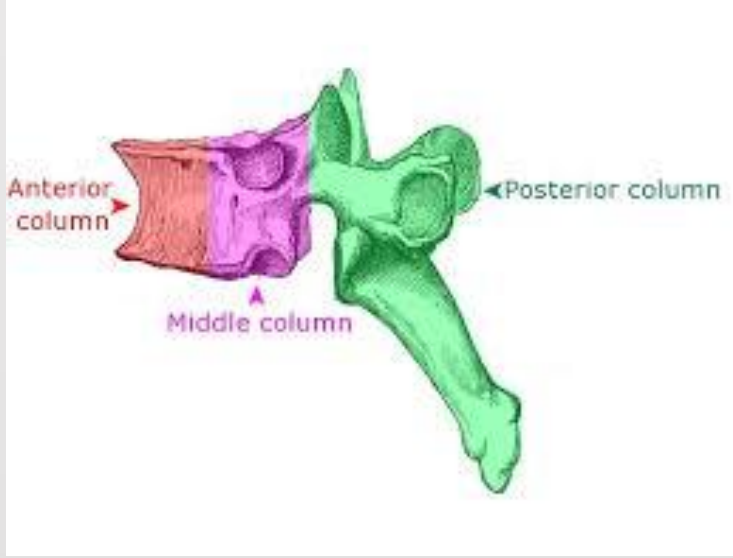
: Unilat D/L – Traction and Reduction ⇒ Fail : Open Reduction + Arthrodesis

: Bilat D/L – Unstable (Quadriplegia, Poor Px) ⇒ Reduction and Stabilization

Angular Deformity (Lig Injury)



Thoracolumbar Injury



Rare in Pediatrics

Two Classification System

Denis Classification : 3 Column Theory

Thoracolumbar Injury Classification and Severity (TLICS) Scale

3 Category : (1) Injury Morphology, (2) Integrity of PLC Complex, (3) Neurologic Status

Score ≥ 5 = Surgical Fixation

Score = 4 = Intermediated

Score ≤ 3 = Conservative Tx

Good Reliability and Validity in Pediatrics ≥ 9 yrs

Thoracolumbar Injury

Compression Fracture

m/c Fx Pattern in TL

Stable

Treatment

Kyphotic Wedge < 10 : Bed rest → Activity

Kyphotic Wedge > 10 : Hyperextension Immobilization 2 months ± Brace 1 yr

Kyphotic Wedge > 30 : Circumferential Fusion d/t Long-term Deformity Risk

Thoracolumbar Injury

Burst Fracture

≥ Ant + Middle Column Injury

Lower T and Upper L

Bony Fragment Retropulsion : Conus Medullaris or Cauda Equina Syndrome

Treatment

No NeuroDeficit : Conservative Tx (Extension-molded Casting 2-3 months + TLSO Brace 6-12 months)

Kyphosis > 30, Height Loss > 40%, Canal Compromise > 50%, PLC Injury : Surgical Fixation

Thoracolumbar Injury

Chance Fracture

Flexion-Distraction Injury

Lap Belt Injury in TA

X ray : Empty Facet Sign

50% : associated Intraabdominal Injury

Treatment (based on Severity)

- Only Bony Fx w/o Lig Injury = Hyperextension Cast
- Lig Injury = Surgical Fixation

Thoracolumbar Injury

Fracture-Dislocation

Very Unstable

Neurologic Deficit : Complete Paralysis

Treatment : Surgical Fixation

Progressive Neurological Deficit or Displacement

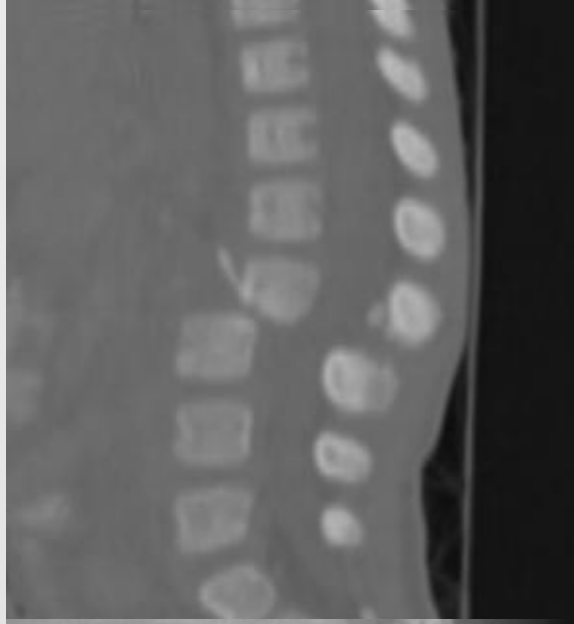
Kyphosis > 17

PLC Injury

Cf) Minimal Displacement Fx-DL : Conservaitive Tx

(Immobilization 8-10 weeks + Brace)

< 10 yrs = Longer Fusion for Reduce Paralytic Scoliosis



Thoracolumbar Injury

Limbus Fracture

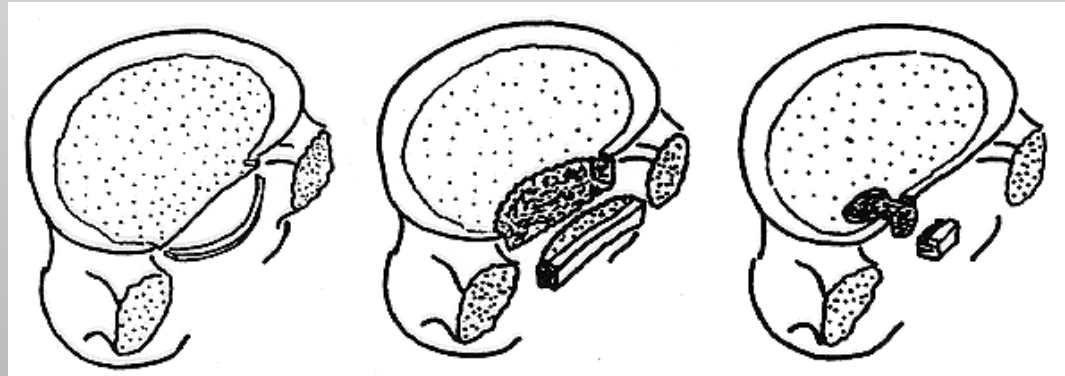
Post Vertebral Endplate

Disc Herniation Between unfused Peripheral Ring Apophysis of the Epiphyseal Endplate and Central Cartilage

Low Back Pain in Adolescent and Young Adult

Treatment

- Conservative : Rare Success
- Surgical Decompression : Less Spontaneous Resorption
- Fusion : rare



Thoracolumbar Injury

Basic Rule

Stable Fx = Conservative Tx

Unstable Fx = Surgical Stabilization

Orthoses

Thoracolumbosacral Orthosis (TLSO)

Jewett Brace (used if hyperextension is desired)

SOMI (sterno-occipito-mandibular immobilizer) Brace : Upper T (T1-T4)

* Duration : at least 3 months

Sacral Fracture

Rare

Associated Injury

Unstable Pelvis Fx

TL Fx

Neurologic Deficit

Bowel, Bladder, Sexual, Lower Extremity Dysfunction

Classficiation

Surgical Treatment < 72 hrs after Trauma

> 72 hrs : Difficult to Reduction and Neural Decompression

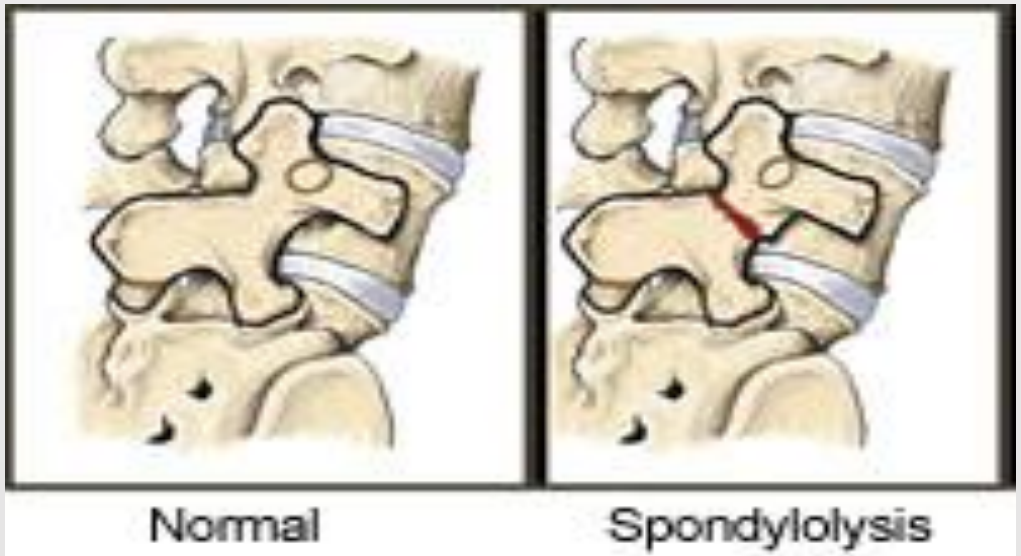
Spondylolysis

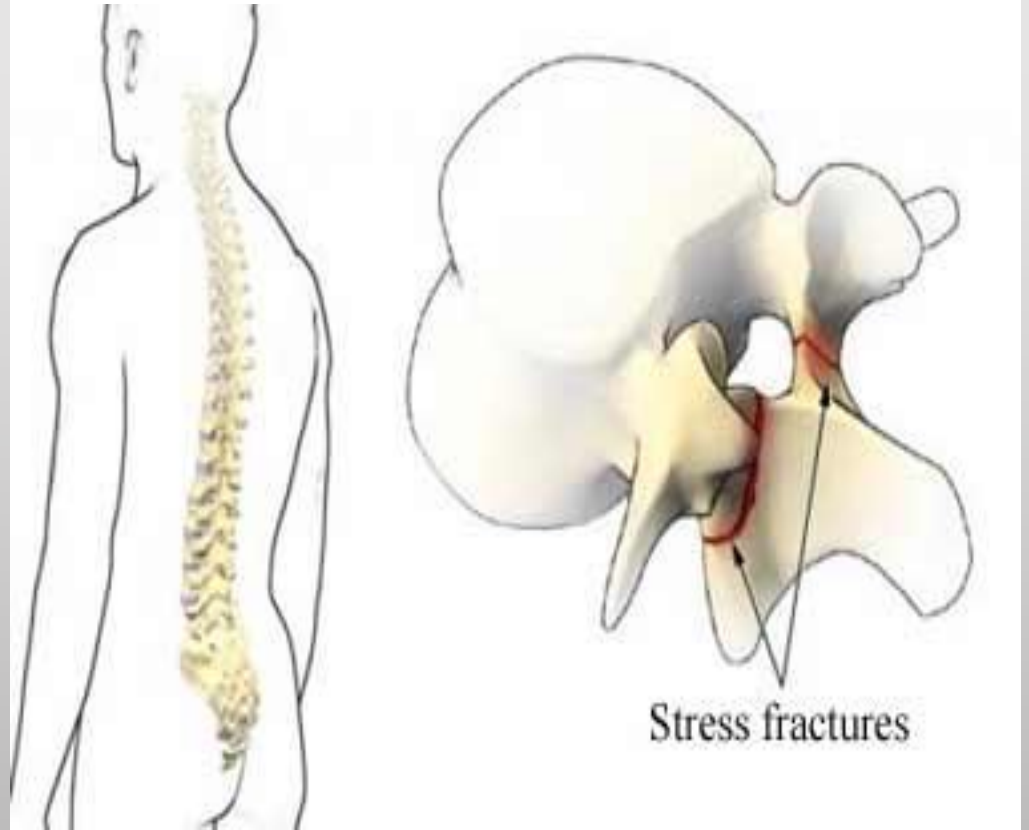
Chronic Repetitive Hyperextension Loading

Youth Athletics

Radiologic Findings

- X ray
- Bone Scan
- PET
- SPECT





Spine Stabilization

Consideration

Adolescent = Adult

Spine Maturity : 9 yrs ≈ Adult

Younger Spine (< 9 yrs) : Small Pedicle, Small Spinal Canal

rhBMP-2

What Is the Most Effective Means to Achieve Spinal Stabilization in Pediatric Patients With a SCI?

What Is the Most Effective Treatment of Post-Traumatic Spinal Deformities in Pediatric Patients With a SCI?

Most Effective Means for Spine Stabilization

Indications for surgery

unstable injury

Irreducible fracture or dislocation

progressive neurologic deficit from com

progressive deformity

≤ 3 yrs : Wiring

≥ 10 yrs : Rigid Instrumentation

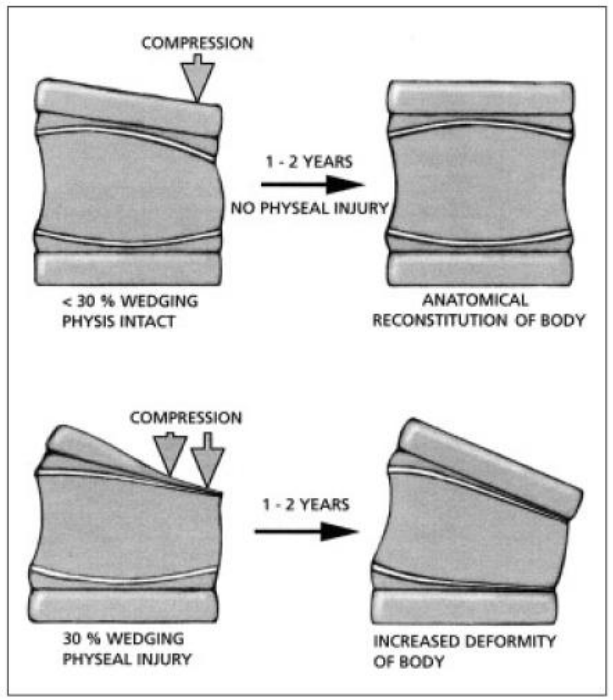
Authors	Title	No. Patients	Level of Evidence	Main Points
Lalonde *et al*	An analysis of burst fractures of the spine in adolescents.	11	Very low	(1) Shorter hospital stay with operative treatment (2) less loss of correction for operative patients (3) more kyphosis in nonoperative treatment but safe alternative
Lui *et al*	C1–C2 fracture-dislocations in children and adolescents.	12	Very low	(1) Higher frequency of atlantoaxial dislocations under the age of 13 and more fracture of the dens over 13. (2) dens fracture more likely to have neurological injury (3) Halo-vest is sufficient for dens fracture fusion for AAD
Odent *et al*	Fractures of the odontoid process: a report of 15 cases in children younger than 6 yr.	15	Very low	Conservative treatment has less complications than open reduction with wiring (only 3 cases with posterior wiring). Minerva cast gave good results
Altiok *et al*	Issues in surgical treatment of thoraco-lumbar injuries associated with spinal cord injuries in children and adolescents.	79	Low	Modern segmental systems seem to give better results with less complications but are still having a significant no. of complications
Finch and Barnes	Major cervical spine injuries in children and adolescents.	32	Very low	(1) Instrumentation in pediatric SCI gives good fusion (8 patients) (2) posterior stabilization provides good results
Eleraky *et al*	Pediatric cervical spine injuries: report of 102 cases and review of the literature. (Review) (30 refs)	102 (30 surgical)	Low	(1) Prognosis of neurological recovery is related to initial injury (2) fusion and instrumentation can be performed safely in children and produce good outcomes
Ruge *et al*	Pediatric spinal injury: the very young.	47	Low	Greater proportion of very young children (under the age of 3) had instrumentation (including Halo Vest)
Hadley *et al*	Pediatric spinal trauma. Review of 122 cases of spinal cord and vertebral column injuries.	122	Low	16% of patients underwent surgical stabilization. No difference between surgical and nonoperative treatment for recovery. 34 of the 38 patients with incomplete neurological deficit improved at least 1 grade. 6 of 20 ASIA A improved at least 1 grade
Rekate *et al*	Pediatric spine and spinal cord trauma. State of the art for the third millennium. (Review) (59 refs)	68	Low	(1) Occipitocervical fusion is safe in children as young as 11 months (2) screw fixation is feasible as young as 4 yr (3) adolescents should be treated with the same instrumentation as adults
Carreon *et al*	Pediatric spine fractures: a review of 137 hospital admissions.	137	Low	(1) More complications in the surgical group (2) most patients showed neurological recovery
Kenter *et al*	Pediatric traumatic atlanto-occipital dislocation: 5 cases and a review.	5	Very low	Atlanto-occipital dislocation: good outcome with posterior spinal fixation
Muzumdar and Ventureyra	Spinal cord injuries in children.	Review	Low	Patients with spinal cord compression and worsening neurological status are candidates for decompression and fusion
Rahimi *et al*	Treatment of atlantoaxial instability in pediatric patients. (Review) (13 refs)	23	Low	Immediate occipitocervical stabilization can significantly improve neurological status in occipitocervical dislocation
Parisini *et al*	Treatment of spinal fractures in children and adolescents: long-term results in 44 patients	44	Low	Conservative treatment is an option in stable fractures without neurological lesion. For the unstable lesion, then early surgery is mandatory
Duhem *et al*	Unstable upper pediatric cervical spine injuries: report of 28 cases and review of the literature. (Review) (28 refs)	28	Very low	No neurological deterioration either with conservative or operative treatment

Most Effective Tx of Post-Traumatic Deformity

Prophylactic Bracing of Scoliotic Curves <10° : Prevent Surgical Correction

Initiation of Bracing in Curves between 10° and 20° : Prevent or Delay Surgery

Initiation of Bracing in Curves > 20° : No Effect



Authors	Title	No. Patients	Level of Evidence	Main Points
Bergstrom *et al*	The relation of thoracic and lumbar fracture configuration to the development of late deformity in childhood spinal cord injury.	76	Very low	Column injury pattern did not correlate with the late development of scoliosis or lordosis, but it may influence eventual kyphosis.
Bergstrom *et al*	The effect of childhood spinal cord injury on skeletal development: a retrospective study.	80	Very low	Younger age of onset was shown to be associated with more severe scoliosis.
Dearolf *et al*	Scoliosis in pediatric spinal cord-injured patients.	130	Low	Scoliosis was developed in 97% of patients injured before the adolescent growth spurt.
Mayfield *et al*	Spine deformity subsequent to acquired childhood spinal cord injury.	40	Very low	Preadolescent patients, paraplegic or quadriplegic, should not have a laminectomy.
Lancourt *et al*	Paralytic spinal deformity following traumatic spinal-cord injury in children and adolescents.	50	Very low	Age at injury was the most important risk factor in the development of scoliosis.
Parisini *et al*	Treatment of spinal fractures in children and adolescents: long-term results in 44 patients.	44	Very low	In children, a traumatic spinal cord lesion may develop a deformity that is mainly scoliotic, kyphotic, or lordotic in >90% of the cases.
Osenbach and Menezes	Pediatric spinal cord and vertebral column injury.	179	Low	33% managed surgically and are usually older.
Mehta *et al*	Effect of bracing on paralytic scoliosis secondary to spinal cord injury.	42	Very low	Based on the results of this study, aggressive prophylactic orthotic treatment for patients with paralytic SCIs seems warranted.

Skull Traction

≤ 6 yrs : Not Recommend

1 – 6 yrs : Halo Traction (General Anesthesia)

< 1 yr : Open Reduction + External Orthosis d/t No Halo Ring (Fragile Calvaria)

7 – 12 yrs : Traction Weight ↓

2 – 3 lb/Level (Max 25% of Child's Body Weight)

Overdistraction Risk

Spine Orthoses

Purpose of Spinal Orthosis

Alignment of Skeletal Structure

Protection of Head from Impact

Reduction of Gravitational Loading

Post-operative Immobilization

Restriction of Motion

Prevent Progression of Deformity

Pain Control

Spinal Orthoses

Cervical Orthoses (CO)

Cervicothoracic Orthoses (CTO)

Thoracolumbosacral Orthoses (TLSO)

Lumbosacral Orthoses (LSO)

Sacroiliac Orthoses (SIO)

Cervical Orthoses (CO)

Soft

- Thomas

Semi-Rigid

- Philadelphia, Malibu, Aspen

Rigid

- Halo, Guilford, SOMI, Minerva

Cervical Collar

Soft Collars

Little Immobilization

75~100% normal motion

Hard Collars

Limit Flexion & Extension

25~30% normal motion

No limitation of lat bending

Halo-Vest Device

Most Rigid and Early Mobilization

Choice for most Children

Thin Calvaria ⇒ Torque : 2 – 4 in/lb (1 – 3 yrs : 10 Small Pin)

Age ↓ ⇒ Pin ↑ : ↓Torque to each Pin (8 Pin + 2 in/lb, ≤ 2 yrs : 8 - 10 pins, > 5 yrs : 4 pins)

≤ 6 yrs : Brain CT before Halo

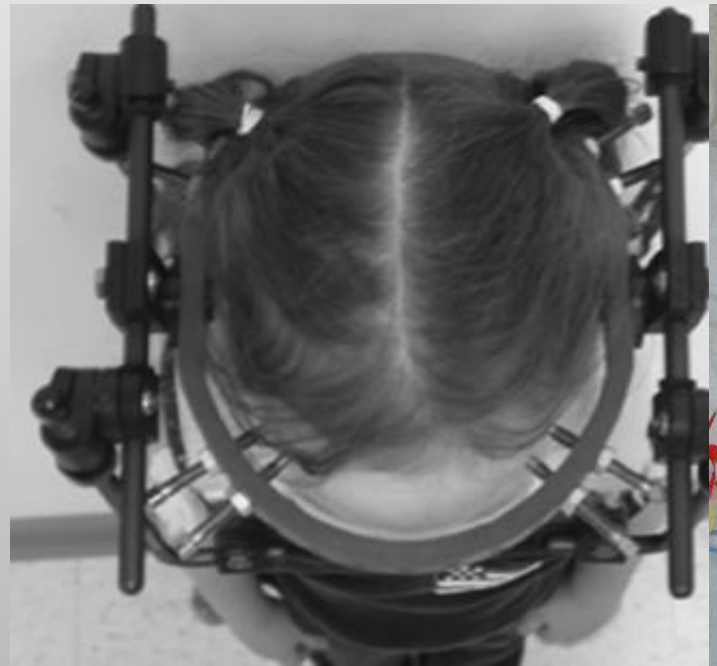
Complication : Higher than Adults

Pin Loosening : Replace and Retighten (6 in/lb)

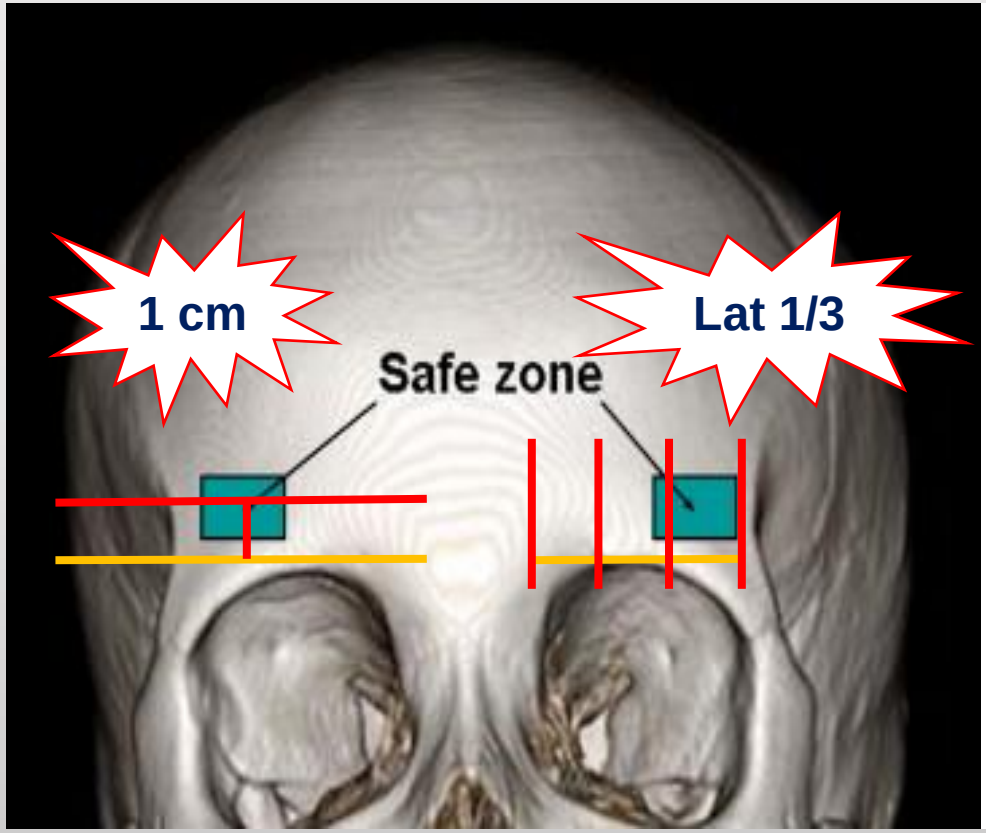
Pin Site Infection : 31 % (Adult 6 %)

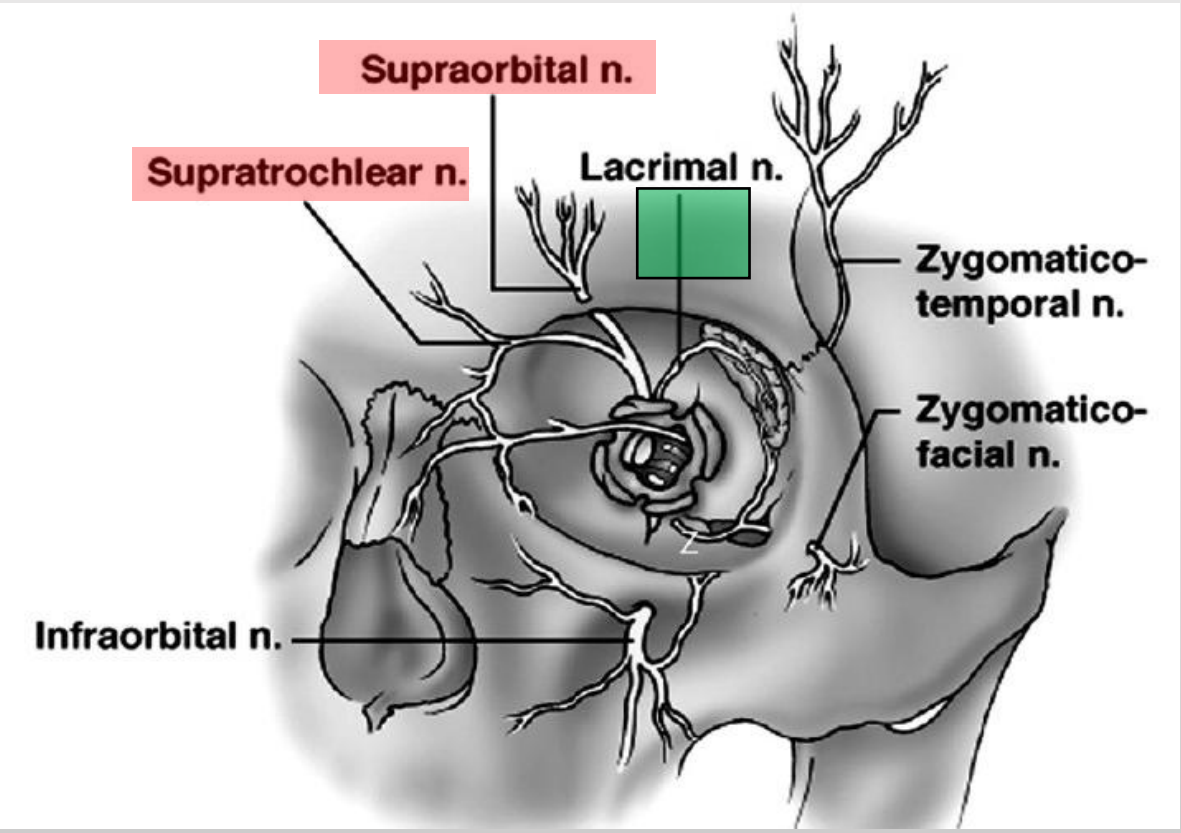
Alignment Slippage

Mechanical Dysphagia



Halo-Vest Device





Minerva Cast

Rare Occasions

Unable to Halo Device

No Effect at C1/2 lesion

Cf> SOMI

Molded Body Splint

Long-term Immobilization of Infants

Adverse Effect of Cervical Collar

pain

Respiratory Compromise

Pressure Sores

Increased ICP

Complicates Care

Higher Rate of Radiographs

Higher Cost of Care

Determining Patients Who Can Be Cleared Without Imaging

- Cervical spine imaging is not recommended in children who are > 3 years of age and who have experienced trauma and who:
  - are alert,
  - have no neurological deficit,
  - have no midline cervical tenderness,
  - have no painful distracting injury,
  - do not have unexplained hypotension,
  - and are not intoxicated.

(Level II)

- Cervical spine imaging is not recommended in children who are < 3 years of age who have experienced trauma and who:
  - have a GCS score > 13.
  - have no neurological deficit,
  - have no midline cervical tenderness,
  - have no painful distracting injury,
  - are not intoxicated,
  - do not have unexplained hypotension,
  - and do not have an MVC, a fall from a height > 10 feet, or non-accidental trauma (NAT) as a known or suspected mechanism of injury.

(Level II)

Cervical Spine Immobilization

Q1. Can I clinically clear a pediatric cervical spine without radiographs?

Yes

Q2. Should odontoid and flexion and extension radiographs be routinely obtained in an initial radiographic evaluation of the pediatric cervical spine?

No

Q3. Because CT is more sensitive that plain radiographs, should I routinely bypass plain radiographs and just order a cervical spine CT for all pediatric trauma patients who cannot be clinically cleared?

No

Q4. Do I need to get a cervical spine CT if the patient has persistent neck pain but normal cervical spine radiographs?

Yes

Surgical Fixation

General Principles

Older Children ; Preoperative Reduction with Skull Traction

< 8 : Closed Reduction in Operation Room (Fluoroscopy, General Ansthesia)

Awake intubation : Not applicable

Fiber-Optic Nasotracheal Intubation : Minimal Head Movement

SLIC

	Description	Points
Morphology		
	No abnormality	0
	Compression	1
	Burst	+1 = 2
	Distraction	3
	Rotation/Translation	4
Disco-Ligmentous Complex		
	Intact	0
	Intermediate	1
	Disrupted	2
Neurological Status		
	Intact	0
	Root injury	1
	Complete cord injury	2
	Incomplete cord injury	3
	Continuous cord compression in setting or neurological deficit	+1

TLICS

	Description	Qualifier	Points
Injury Mechanism			
	Compression		
		Simple	1
		Lateral angulation > 15◦	1
		Burst	1
	Translational/Rotational		3
	Distraction		4
Posterior Ligamentous Complex			
	Intact		0
	Suspected/Intermediate for disruption		2
	Injured		3
Neurological Status			
	Nerve root involvement		2
	Cord, cornus involvement (incomplete)		3
	Cord, cornus involvement (complete)		2
	Cauda equina involvement		3

Recent Technical Consideration

Utilization of Rigid Instrumentation (Screw and Rod) ↑

≥ 4 yrs : Usual

18 yrs : Able

Autobone Graft

Iliac Crest, Rib, Calvaria

Halo Device in 7 months old (10 pins + Finger Tightening)

IOM : Effective in Young Children

TABLE 3. Monitoring Results According to Age Groups: True Positive, False Positive, True Negative, and False Negative Defined According to Szalay *et al*[24]

Patients less than 4 years of age	30	
True negative	27	90%
True positive	2	6.6%
False positive	0	0%
False negative	0	0%
Unobtainable baseline data	1	3.3%
Sensitivity		100%
Specificity		100%
Patients older than 4 years of age	270	
True negative	228	84.4%
True positive	32	11.8%
False positive	4	1.5%
False negative	0	0%
Unobtainable baseline data	6	2.2%
Sensitivity		100%
Specificity		98%

Unique Complications in Pediatrics

Posttraumatic Deformity, Growth Arrest

Intrinsic Factor

Vertebral Apophyses Injury – Vertebral Body Change, Loss of Post Lig Support

Extrinsic Factor

Weak Trunk Muscles, Spasticity

Iatrogenic Factor

Improper Instrument Segment, Laminectomy w/o Fusion

Remaining Growth = 0.7mm X No of Fusion Segments X Remaining Growth Years

Crankshaft Phenomenon with Post Fusion Only

Take Home Message

1. Traumatic Spine Injury in Pediatrics : Relatively Rare (< 8 yrs : Upper C)
2. Transport : Fitting to Children
3. Radiologic Evaluation : X ray First
4. Meticulous Conservative with General Care
5. Development of Post-traumatic Deformity and Growth Arrest
6. Consider Developmental Anatomy

Thank you