SCOLIOSIS

Lateral curvature of the spine with a rotatory component of the vertebrae (Vertebral body rotated towards the convexity. Adolescent scoliosis is common and it usually present at or about the onset of puberty.

International scoliosis classification

1. **Idiopathic**: Infantile, Juvenile, Adolescent, Adult

2. **Neuropathic**: Cerebral palsy, myelomeningocele., Polio, Spinocerebellar degeneration, cord tumor, cord trauma, spinal atrophy

3. **Myopathic**: Muscular dystrophies (Duchenne, Limb-Girdle, FSH), Arthrogryphosis, Congenital hypotonia, myotonia dystrophica

4. **Congenital**
   - Failure of Formation – Hemivertebra, Failure of Segmentation bar, Mixed [failure to form or segment]

5. **Bone Dysplasia**: Achondroplasia, spondyloepiphyseal dysplasia, diastrophic dwarfism, Morquio’s syndrome Metabolic Rickets, Osteogenesis imperfecta

6. **Miscellaneous**: Neurofibromatosis, Marfans syndrome, Homocystenuria, Ehlers-Danlos syndrome

Etiology for Idiopathic scoliosis

1. **Endocrine system**
   Patients with idiopathic scoliosis often taller. Studies on somatomedin (Insulin like GH) levels conflicting but significant differences found.

2. **Postural equilibrium**
   Abnormalities in the vestibular system in the brain stem in scoliosis have been demonstrated.

3. **Neurotransmitter** - Scoliosis experimentally produced by removing pineal gland in chickens. No specific neurotransmitter defect identified. ?Melatonin
4. Genetics - Increased incidence in affected relatives found. Mother and father - 80%, Mother and sister - 20%, Mother - 10%, Sister - 3%. Indicative of multifactorial mode of inheritance.

Pathogenesis

Lordosis may be the biomechanical initiator of deformity.

Thoracic lordosis lies in front of normal axis of rotation. This causes rotation of lordotic section in flexion.

Changes of vertebral shape are effects secondary to rotation of lordosis [Dickson]

Natural history of untreated scoliosis

| Back pain | 56% |
| Progression | 15% |
| Cosmetic | 12% |
| Unmarried | 63% |

Pulmonary function

| FVC | Nil with curve < 60° |
| 30% with curve 60-100° |
| 50% with curve > 100° |

Psychosocial

| Cause psychosocial problems |

Mortality

| Comparable to normal population |

History

Deformity: Onset and progress

Pain: Dull ache, Relation to Posture or activity

Neurology: usually normal [exceptions: neurofibromatosis]

Growth spurt: Onset of menarche means approximately 2/3 rd of the adolescent growth spurt has been completed

Previous treatment

Family history
Epidemiology [Cobb Angle Prevalence]

>10°  3%
>20°  0.3%
>30°  0.1%
>40°  <0.1%

Sex  >10° of deformity  F:M = 3.6:1
     >30° of deformity  F:M = 10:1

(With increasing curve severity there is an increasing female predominance.)

1. Is the curvature Structural or nonstructural

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<thead>
<tr>
<th></th>
<th>Structural</th>
<th>Nonstructural</th>
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<tbody>
<tr>
<td>Curve is</td>
<td>Fixed curve</td>
<td>Flexible</td>
</tr>
<tr>
<td>Bony changes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Curve Disappears</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>on forward flexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progresses</td>
<td>Yes</td>
<td>No</td>
</tr>
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2. Standing, sitting Height

3. Inspection  Front, lateral, Back
   Look for asymmetry
   Comment on shoulder level
   Distance from arm to the trunk
   Pelvic tilt
   Skin lesion (Café au lait spots, Lipoma, tuft of hair, soft tissue swellings), scars,
   Muscle wasting

4. Adam’s test
   The right scapula is more prominent “Rib Hump”
   Method: The patient bend forward with feet together
   and the knees straight. The patient’s arms are dependent
   and the hands are held with the palms opposed.
Scoliometer
Measures spinal rotation in scoliosis.
Good for screening.
More than 7° of rotation (corresponds to 20° of coronal curvature) should be referred.

5. Compensated or decompensated curve
A plumb line is dropped from C7 spinous process
passes through the gluteal cleft

6. Maturity Assessment
A. Breast Grading (Tanner system)
   I Elevation of papilla only
   II Breast bud stage (small mound)
   III Further enlargement of II
   IV Projection of areola to form a secondary mound above the level of breast
   V Projection of papilla only due to recession of the areola to the breast

B. Pubic hair stage
   I Preadolescent; no pubic hair
   II Slight growth of long, slightly pigmented hair along the labia
   III Darker, coarser hair over the pubis
   IV Hair is adult type with no spread to medial
       spread of the thighs
   V Spread to the medial side of the thigh
7. Curve Flexibility
1. Lateral bending, scoliosis disappears
2. In children: suspend the patient with the head

Radiological Examination
1. Normal
   - Cervical: 30° of lordosis
   - Thoracic: 20-40° of Kyphosis
   - Lumbar: 40° of Lordosis
   - Sacral: Kyphosis

2. Sagittal alignment
   - Clinical: Ear lobe to the highest point of the iliac crest
   - X ray: C7 to 2 cm from front of S1 and 5 cm from front of S2

   Coronal alignment
   - Plumb line from the C7 spinous process to the natal cleft.
3. Assess puberty

4. Look for spondylolisthesis
   Congenital spinal deformity
   Any dysmorphic features of Neurofibromatosis

5. Define the scoliosis [Discussed under classification]
   a. Anteroposterior view [long films, PA, Standing]

**Cobb Method of assessment**

End vertebra: Those tilted maximally at the top and bottom

Line from the upper end plate, upper vertebra and lower vertebra

The perpendicular lines drawn to these lines and the angle of the intercept is the angle of scoliosis.

**Neutral vertebra or stable**

The vertebrae which are bisected by a midsacral line is bisected by mid-sacral line and a neutral
Vertebra is one where both pedicles equally visible.
Apical vertebra

The vertebra at the centre of the curve is the apical vertebra.
It is the most deviated and rotated vertebra in the curve.
In future, measurement should always be from same vertebrae.

Assessment of rotation of the vertebra [Mohr’s]

Look at the pedicle
See whether it is symmetrical: indication for rotation

Risser’s Sign

Extent of the apophysis of the iliac crest

The lower the Risser grade [I,II] at curve detection, the greater the risk of progression.

IV and V: not much spinal growth left and surgery can be done

b. Lateral view

In scoliosis commonly hypokyphosis in the sagittal plane (exception is neurofibromatosis in which kyphoscoliosis is seen)
There is high incidence of Spondylolisthesis or lysis in patient with scoliosis.

c. Side bending view

Supine right and left side-bending films demonstrate curve flexibility and give a good indication of the amount of correction that can be anticipated from surgery.
In severe deformities, bending films help in deciding whether to perform anterior procedures. For patients with severe rigid curves, it may be desirable to consider anterior releases or wedge resection before the posterior procedure.

**MRI**

Indicated:
1. Jeuwanile scoliosis
2. Abnormal curve [left sided idiopathic thoracic spine]
3. Sudden increase in growth
4. Presence of any neurology
5. Excessive Kyphosis

Some surgeons routinely get MRI prior to surgery

**CT-Myelography** Abnormal neurology but normal MRI

CT Myelogram to rule out spinal dysraphism

**School screening [Scoliometer]**

Incidence of scoliosis of 10° is 2%

For curve

- >10°: F:M 1.4:1
- >20° F:M 4:1
- >30° F:M 10:1

5% needed brace

0.1% needed surgery
Types of Scoliosis

I Thoracic Scoliosis

90% right convexity
Average 6 vertebrae
Apex T8, T9
Upper end vertebrae T5, T6
Lower end vertebrae T11, T12

II Lumbar Scoliosis

70% left convexity
Average 5 vertebrae
Apex L1, L2
Upper vertebra T11, T12
Lower vertebra L3, L4

III Thoracolumbar

80% right convexity
Average 6-8 vertebrae
Apex T11, T12
Upper vertebrae T6, T7
Lower vertebrae L1, L2

IV Double

90% R thoracic and left lumbar
Thoracic: Apex T7
Lumbar: Apex L2
Types of adolescent idiopathic scoliosis Linke

I. Curve Pattern
   - Thoracic curve worse than lumbar spine

II. Double or single
    - Double curve more than single curve.

III. Riser’s sign
    - At presentation, Risser’s 1 or 2, high risk of progression

IV. Age
    - <10 yrs progression is more than those over 10 years

V. Menarche
    - Curve detected before menarche progression is higher
IV Curve Magnitude  The larger the initial curvature, [≥50º] more the chance of progression

IV Sex  The risk for curve progression is 10 fold higher in females compared to males.

VI Braced or not  When curve is >30º, only 20% in braced progressed compared to 67% who were unbraced.

**Magnitude of Curve progression**

<table>
<thead>
<tr>
<th>Curves</th>
<th>3 years</th>
<th>5 years</th>
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<tr>
<td>30º to 50º</td>
<td>7-10 years</td>
<td>10-14 years</td>
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<tr>
<td>12º/year</td>
<td>12º/year</td>
<td>2º/year [after maturity]</td>
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Spine stops growing: 14 yrs for females and 16 yrs for males

**Treatment**

1. **Bracing**

   Indicated when the curve is between 30º to 40º or when curve is 20º with rapid progression [10º/year]

   2 types: Milwaukee brace for the curve above T7

   Boston brace for the curve below T7 (Apical)

   Bracing may help to halt or slow curve progression.

   May achieve 50% correction

Disadvantages:

Should be worn 23 hours day.

At least 50% of correction is lost when brace is weaned

Compliance is a problem
2. Surgical treatment

Indication

- **> 50º**  Surgery (Mature or immature) untreated progression 2º/yr
- **40º - 50º**  Gray zone and individualized
- **30º - 40º**  Immature spine Brace treatment and mature spine leave it along
- **20º - 30º**  Immature, Observe [6 monthly] and mature discharge.

**KING** (Selection of fusion levels in a thoracic idiopathic scoliosis).

- I  Lumbar curve more than thoracic 10%
- II  Thoracic curve more than lumbar 33%
- III  Thoracic curve only 33%
- IV  Long thoracic curve 10%
- V  Double Thoracic curve 10%

Principle of surgery

1. Pre-operative assessment, consider patients height, nutrition
2. Define the curve and rule out spinal dysraphism [MRI]
3. Major surgery and needs expertise, ICU care
4. Fusion: present trend is fuse less. Avoid fusing distal to second lumbar vertebra
5. Anterior fusion is preferred as fusion area is smaller than posterior approach
6. In severe cases, need anterior and posterior fusion
7. In addition to Posterolateral fusion, instrumentation of the spine is required
8. When significant rib hump is present, requires costectomy
9. Goal is to achieve sagittal and coronal balance and prevent progression of the curve

Selection of spinal fusion
1. Harrington’s Criteria: From upper neutral vertebra to lower stable vertebra.

2. King’s criteria for fusion depending on type of curves

Type I curves are managed by fusion to L-4.
In curve types II through V, a selective thoracic fusion

Present Trend with newer instrumentation
Less fusion to preserve mobility and minimize low backache

A vertical line is then drawn perpendicular to the pelvic line centered on the sacrum. The lowest vertebra most closely bisected by this line is called the stable vertebra.
Ending the fusion at the stable vertebra gives uniformly good results.

When the fusion falls short of the stable vertebra, the curves tend to progress.
Fusing beyond the stable vertebrae, especially in type II curves, tends to aggravate the lumbar curve and also removes additional valuable motion segments.
Fixation

I. Historical
Harrington Rod system
Luque sublaminar fixation
Wisconsin instrumentation

II. Newer Fixation
Texas Scottish Rite hospital
Cotrel Dubousset Horizon
Moss Miami
ISOLA

Idiopathic scoliosis is a 3 dimensional deformity
Coronal angulation of the vertebra
Torsion
Apex vertebral lateral translation

3 deformities can be corrected by 2 newer fixation
CD system: “Rod rotation maneuver”
ISOLA: “Translation technique”

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<th>Cotrel DeBousset</th>
<th>ISOLA</th>
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<tr>
<td>“Rod rotation maneuver”</td>
<td>“Translation technique”</td>
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<tr>
<td>Multiple hooks: Pedicle, Laminar (Supra/Infra), Transverse</td>
<td>Hooks, Sublaminar wires, Pedicular system</td>
</tr>
<tr>
<td>Principle load: borne by multiple vertebra: end vertebrae, apical, intermediate</td>
<td>Principle load by mainly apical vertebrae rather than end vertebrae</td>
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Ideal radiological correction

1. Well centered fusion mass with the appropriate fusion levels
2. Lowest fusion vertebra should be the stable vertebra. [not in a case of selective fusion as suggested by King’s criteria]
3. Upper most vertebra in fusion should have neutral to rotation.
4. Sagittal alignment is Lordosis at lumbar region, Kyphosis at the Thoracic and slightly lordotic Thoracolumbar region

Rib osteotomy (Thoracoplasty)

Posterior angle 8-10 ribs (rib hump)
Exposed lateral to the erector muscle, subperiosteal and osteotomised.
Thoracoplasty may compromise pulmonary function and need an intercostals drain

Anterior surgery

Indicated: In congenital scoliosis
Used by some surgeons routinely for adolescent scoliosis
> 75º in Female

Dwyer system was first system used.
Zielke system
Miami system

Advantages
Better correction with a shorter fusion level
Reduce the incidence of proximal junctional Kyphosis
Reduce implant prominence
Reduce denervation of posterior spinal muscle

Disadvantages
Negative effect on Pulmonary function with trauma to diaphragm
Longer paralytic ileus
Incidence of Pseudarthrosis is not well reported
Combined approach

1. Surgery in Adults for scoliosis and is rarely in Idiopathic scoliosis (>70° and rigid)
2. Congenital scoliosis
3. Scoliosis surgery: in immature patients (to prevent crankshaft effect)

Complications

1. Neurologic deficit. To avoid use:
   1. Intra-operative monitoring (SSEP);
   2. Stagnara’s wake up test
   3. Clonus test
      When neurology is recognized, undo the correction
2. Wound infection (1-2%)
3. Pneumothorax
4. Dural tear
5. Inappropriate ADH secretion
6. Implant failure
7. Flat back syndrome: Early fatigability and pain due to loss of lumbar lordosis
   (Minimized by rod contouring)
8. Pseudarthrosis - Solid fusion should occur by 6 months. Occurs 1-2%
9. Back pain - Appears to be due to Fusion below L4, Loss of lumbar lordosis:
10. Crankshaft phenomenon: Immature patient with scoliosis after posterior fusion.
   (due to increase anterior growth)
CONGENITAL SCOLIOSIS

Can progress rapidly

Incarcerated

Non-incarcerated

Classification [Winter]

I Failure to develop:
   Hemivertebra
   Fully segmented [nonincarcerated]
   Partial segmented
   Nonsegmented

II Failure of segmentation: Bar

III Combination: Wedge and Bar

Worst combination:
   Bar on one side and Nonincarcerated wedge on other side

Assessment

Progress of the curve: 1. Bar with nonincarcerated has worst curve progression
   2. Site: Thoracic and thoracolumbar have worse prognosis
   3. Age of Presentation: young patient have worse

Problems

1. Rapid deterioration of the curve requiring early surgery
2. Very rigid curve makes surgery technically difficult
3. Spinal cord anomalies is very often associated
   GUT, KFS 25%
   Heart disorder 10%
MRI
Always indicated
Any other congenital problems [MRI]
40% intraspinal abnormalities: Spinal dysraphism, Syringomyelia, Low lying conus

Treatment
1. Bracing as little roll
2. Once diagnosed, assess curve progression by follow up: every 4 months
3. Anterior and posterior surgery early

Hemiephyseodesis is ideally done at 5 yrs when curve is over 40°. The graft is placed at the convex side both anterior and posterior.

Excision of a fully segmented Hemivertebra is also an attractive option probable at lumbar region. The approach is both anterior and posterior. This should be combined with one level instrumentation

Association
- Klippel Flail syndrome, Block vertebrae, Diastematomyelia, Other spinal dysraphism, Ductal actasia

Congenital Kyphosis
1. Failure of formation is more common
2. Is likely to progress
3. Is the commonest cause for paraplegia [Neurofibromatosis is the II commonest]
4. < 4 yrs: Posterior fusion is adequate
   > 4 yrs: Posterior and anterior surgery
**DIASTOMETAMYELIA**

Female : Male = 8:1

2 segments of the spinal cord: with a septum by fibrous, cartilage or bone

60% occurs in the lumbar region

90% x-ray shows a wide interpedicular distance

40% associated with vertebral deformity like Hemivertebra

10% in all congenital anomaly of the spine

Clinical

- Hairy patch: 75%
- Calf muscle asymmetry in 50%
- Cavus deformity; unilateral in 50%
- Scoliosis in 75%

Treatment

Referred to neurosurgery
NEUROMUSCULAR SCOLIOSIS

Classification
1. Neuropathic
   a) UML: I. Cerebral Palsy
      II. Spinocerebellar: Friedreich’s CMT
      III. Syringomyelia
      IV. Spinal cord tumor/Trauma
   b) LML: I. Polio
      II. Spinal muscular atrophy
      III. Kugelberg-Welander disease, Wernig-Hoffmann

2. Myopathic: Arthrogryposis
   DMD
   Myotonical Dystrophica

Cerebral palsy and DMD are important and common

Assessment
1. Family conference
   Education and informed consent.
   High incidence of complication to be discussed.

2. Non-op: TLSO or Modify wheelchair with support
   Physiotherapy

3. Surgery

Nutritional assessment: Albumen >3.5 g/l; Lymphocyte [>1.5]

7. Imaging spine: X rays
   MRI
Surgical principles
1. Always long fusion: otherwise transitional deformities
2. Posterior: Sublaminar wiring or pedicle screw
3. Young or Severe deformity: Anterior release and posterior surgery
4. Pelvic included in fusion or not: Avoid in ambulant patient.
5. Pedicle fixation: go as high as possible; sublaminar and hook above
6. Need allograft

Scoliosis in Cerebral Palsy
Rapid deterioration of the curve.
Sometimes: Ilium forms part of the curve and there will be pelvic obliquity.
In this situation rule out hip dislocation.
Usually requires long fusion and fusion to the pelvis using Galverston technique
Incidence of scoliosis is 7% in ambulant cerebral palsy; 40% in the wheel chair patients and 82% spastic quadriplegia.
Usually have pelvic obliquity at presentation
Avoid surgery: when there is no sitting balance or head control.
Usually there is extensive Curve with pelvic obliquity and curve gets rapidly fixed.

Duchene Muscular Dystrophy
95% develop scoliosis
>20º always progresses and needs early surgery as waiting causes deterioration of pulmonary function.
It is probably better to fuse spine to the pelvis as there is late deformity can occur between spine and pelvis. [Galverston technique]

In DMD, the Vital capacity reduced by 4% per year + 4%/10º deterioration of the curve.
When scoliosis surgery at 20º scoliosis and nocturnal ventilator support can prolong average survival to 25 years.
INFANTILE SCOLIOSIS

Less than 3 yrs;
Common in Boys

There has been decrease in prevalence of infantile scoliosis

Common type is left thoracic 90% [cf. in adolescent it is right thoracic curve]
It is associated with plagiocephaly and considered to be part of molded baby syndrome.
Most resolves on observation.

Rib Mehta’s angle
(Difference at the apical rib)
is of prognostic value

The RVA difference (RVAD) is the difference between the values of the RVAs on the concave and convex sides of the curve [apical vertebra]. If the convex apical rib head does not overlap the apical vertebral body, a curve with an initial RVAD of 20° or more is considered progressive.

One line perpendicular to the apical vertebral endplate and another from the mid neck to the mid head of the corresponding rib.

Treatment
Progressive: Need casting
Mehta’s angle helps in differentiating: Resolving Vs Progressive
**Juvenile scoliosis**

- 4-10yrs
- Female: male 2-4:1
- 20-25% associated with intrathecal pathology. MRI
- Look for: Tethered cords, Syringomyelia
- Thoracic curves the most common.
- 70 % progress and require treatment and of these 50% require surgery

**Indications for surgery**

- Similar to adolescent idiopathic scoliosis
- Often requires anterior and posterior fusion to avoid crankshaft phenomenon.

**Paralytic scoliosis**

- When pelvic obliquity is present in neuromuscular scoliosis, understanding the curve pattern will help avoid a common pitfall:

  - An oblique sacrum and pelvis must be considered as part of the curvature and should be included in the instrumentation and fusion.
COMPLICATIONS OF SPINAL SURGERIES

1. Infection post op <1%
2. Discitis 0.1%
3. Epidural abscess 0.06%
4. Infection with Halo pin 20%
5. Recurrent laryngeal nerve 7%
6. Bone extrusion: single level < 1%
    Multiple level 10%
7. Bone graft site 20% complications
8. Nerve damage 7%: LCNT with anterior and superior cluneal nerve
9. Hematoma 20%
10. Herniation <1%
11. Chronic pain 20%
12. Dural Tear
    Microdisc 1.8%
    Macro disc 5.3
    Revision 17.5
13. Mortality <1%

Dural leak
Sometimes recognized only after surgery
    Head ache – Post neck pain
Dural cutaneous fistulas may lead to meningitis, arachnoiditis or epidural abscess, pseudomeningocele, fistulas, sciatica, strabismus (VI cranial nerve)

Diagnosis
Immunofixation electrophoresis B 2 transferrin (this is produced only in CSF)
Can be diagnosed within 3 hours

MRI will detect pseudomeningocele
Treatment

1. Prevention

2. Operative
   a. Intra-operative tear
      Adequate exposure
      Demonstrate any leak before closure: Valsalva maneuver
      In revision spine: Start from unscarred to scarred area
   
   b. When there is tear
      Repair 5'0' gortex suture or 6'0' ethilon
      Trendlenburg position may decrease fluid from the defect
      Start few mm proximal to the laceration
      Check the repair with Valsalva maneuver
      Tight fascial closure: if necessary lateral release incision
      No wound drain
      Smooth reversal of anesthesia
      Urinary catheter and bed rest for 3 days
      Take it easy for 10 days

      If dural rupture is lateral: inaccessible, plug the dural rent with a small pieces of muscle and suture or fascial patch graft or Fibrin Glue= Fibrinogen and clotting factor and second bottle Thrombin and Calcium.

   Alternatives
   1. Epidural blood patch (20 ml of blood) works in 90%
   2. Percutaneous aspiration and injection of fibrin glue
**Pseudarthrosis following spinal fusion**

Lumbar spine surgery: success is only 70%.
There is a high chance of pseudarthrosis.
Smoking and pseudarthrosis has a strong relation.
Pseudarthrosis: is diagnosed only after 1 year. Although can be suspected at 6 months

**Incidence**
10%-20%

**Clinical**

Pain in the back or in the legs
Pain more on activity
Localized back tenderness
Visible nonunion on X ray
Movement on Flexion-extension view

**CT scan**
Gold standard

**Risk factors**

1. Length of fusion: multilevel fusion, there is increase chance of non-union
2. Type of graft: Less with autograft [cancellous] than allograft
3. Inter-transverse fusion did worse
4. Infection
5. Systemic: Osteoporosis; Growth and thyroid hormone
6. NSAID usage, Chemotherapy, Radiation, Steroids
7. Smoking: 40% in smokers Vs 8% in non-smokers
8. With the use of rigid fixation: 90% fusion and without 70%

**Clinical importance**

1. Pseudarthrosis: does not mean clinical failure
2. When symptomatic pseudarthrosis: 70% can be helped regrafting and clinical outcome correlates with bone healing