PHYSEAL INJURY

정창훈
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LIST

1. Introduction
2. Classification
3. Treatment
4. Complication
   : premature physeal closure
Physeal Injuries

- 15-30% of all children fractures
- Peak in adolescent (11-12 years)
- Twice as common in boys
- Uncommon under age of 5
- Phalanx; mc
- Growth deformity: 1-10%
Causes of physeal injuries

- Trauma / Infection / Tumor / Vascular insults
- Irradiation
- Repeated trauma
Physeal anatomy

- Physis
  - Epiphyseal plate
  - Epiphyseal growth plate
  - Epiphyseal cartilage
Physeal anatomy

- **Zone of Ranvier**
  - Wedge-shaped of group of germinal cells
  - Circumferential growth of physis

- **Ring of LaCroix**
  - Fibroblast zone of Ranvier
  - Periosteum of metaphysis
  - Strong mechanical support
<table>
<thead>
<tr>
<th>Zone</th>
<th>Blood Supply</th>
<th>Extracellular Matrix</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germinal</td>
<td>Stem cell origin, O2: low</td>
<td>Abundant</td>
<td>Weakest area: cleavage plane</td>
</tr>
<tr>
<td>Proliferative</td>
<td>High blood supply (high O2), longitudinal growth</td>
<td>Abundant</td>
<td></td>
</tr>
<tr>
<td>Hypertrophic</td>
<td>Avascular &amp; low O2, cell size (x5-6)</td>
<td>Scant</td>
<td>Resistant to shear</td>
</tr>
</tbody>
</table>

**Metaphysis with blood vessels**

**Physis zone**

- Epiphyseal blood vessels
Blood supply to physis

- **Type A**
  - Periphery after traversing the perichondrium
  - Proximal femur, Proximal radius
  - prone to injury during epiphyseal separation

- **Type B:**
  - Epiphyseal side
  - therefore protected from injury during epiphyseal separation
<table>
<thead>
<tr>
<th>Less risk for growth disturbance</th>
<th>High risk for growth disturbance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cleavage plane</strong></td>
<td><strong>Hypertrophic zone</strong></td>
</tr>
<tr>
<td><strong>Type of epiphyseal injury</strong></td>
<td><strong>Type I, II</strong></td>
</tr>
<tr>
<td><strong>Type of blood supply</strong></td>
<td><strong>Type B</strong></td>
</tr>
</tbody>
</table>
Classification of the physeal injury

- Foucher, Poland (1898), Bergenfeldt (1933), Aitken (1936), **Salter Harris (1963)**, Ogden (1969), Peterson (1994)
Salter-Harris classification

Peterson I and VI
Goal of treatment

① To achieve and maintain an acceptable reduction
② To regain normal growth
Acceptable reduction

ANATOMIC REDUCTION

NON-ANATOMIC REDUCTION

Factors

- Age
- Location of the injury
- Amount of residual deformity
- the amount of time that has elapsed since the injury.
Acceptable reduction

① **Age at patients**

- Bone remodeling
- More deformity is accepted if the remodeling potential is high.
- Girl > 13 year-old
- Boy > 15 year-old
Acceptable reduction

② Location of injury

- Proximal humerus: highly remodeling potential (80%)
- Type I injury distal femur and proximal tibia
  - large undulating multiplanar physis
  - Vascular injury
Acceptable reduction

③ Amount of residual deformity

- S-H type III, IV: Anatomic reduction
- S-H type I, II: Non-anatomic reduction
- Distal tibia
  - Residual gap >3 mm in distal tibia (SH type I or II)
  - PPC rate 60%
  - Open reduction and removal of entrapped periosteum
Acceptable reduction

④ Time elapsed at reduction

- Optimal timing: ASAP
- Accepting any displacement in type I or II injuries after 7 to 10 days (Rang, Salter)
Treatment principles

1. Displacement: minimal or absent
   Splint for 1-2 weeks
   Recheck the x-ray
   Periosteal reaction (+)
   Type I epiphyseal injury
2. Gentle Closed reduction

Traction (75%)
Manipulation (25%)

75%
25%
3. **Type III or IV**

: congruency of articular surface and physis

**Congruency**

**Incongruency**
4. Internal fixation
9/M

3 months
5. **Neurovascular status**

- Ischemic time (2-3 days)
- Compartment syndrome (7 days)
6. Long term & Regular follow-up

7. Warning
Treatment according to Salter-Harris Classification
Salter-Harris I (Type III)

- CR and cast
- Location (thin periosteum): proximal femur, radius: IF
- 3.6 % premature closure

Spiegel et al JBJS 1974:1046
Salter-Harris II (Type II) MC

- Tangential (oblique) views
- CR IF
- OR: soft tissue impingement
- premature closure
  - 6.5%: (10~30% depends on location)
Salter-Harris III (type IV)

- anatomic reduction and maintenance of reduction,
- 10.9% premature closure
- Juvenile Tillaux fracture
Salter-Harris IV (Type V)

- Triplane fracture
- Comminution and open injuries are common
- Anatomic reduction
- Open reduction and internal fixation
- Premature closure
Type I

- 15.5%
- **Non-operative treatment** usually results in a good outcome; 3~4 weeks.
- Premature physeal closure (3.4%)
Type VI

- Part of the physis; missing
- Premature closure; nearly always occurs
- Initial surgery (wound care)
- Late reconstructive or corrective surgery

Open fracture
Long term and careful follow-up
COMPLICATIONS
Complications

- Malunion
- Infection
- Neurovascular problems
- Osteonecrosis
- Growth disturbance (unique)
  : 1-10% of all physeal injury
Growth disturbance

- 1-10% of all physeal injury
- Evident 2 to 6 months after injury
- Key factors:
  - Severity of injury
  - Type of injury
  - Age
- Early diagnosis
Harris growth arrest line

- Bony striations
- Slowing or cessation of growth
Assessment of growth disturbance

- Mapping of physeal bar
  - Extent and location of bar
  - Tomography, CT or MRI.
- Amount of growth remaining
Classification of partial growth arrest according to location

- Type A - peripheral
- Type B - central (tent)
- Type C - central, traversing (medial malleolus)
Treatment options

- Observation
- Completion of partial arrest
- Physeal bar resection
I. Observation

- Involve entire physis
- Little remaining growth
- Acceptable limb length inequality or angular deformity
Treatment option

II. Completion of an arrest

- Severe angulation expected
- Contralateral epiphysiodesis
  - Expected limb length inequality
    - > 20 to 25 mm
Treatment option

III. Physeal bar resection

① At least 2.5 cm of remaining growth
② At least 2 years of growth
③ <50% of the physis

☑ Corrective osteotomy
☑ Angular deformity < 20° - observation
☑ Angular deformity > 20° - osteotomy

Birch, ICL 1992;41;445
Resection-Type A

- Direct approach
- Excision of periosteum overlying bone bar
- Bar resection until normal physis can be visualized
- Burr, Roupe

Resection-Type B, C

- Trans-metaphyseal approach
- Preserve perichondral ring & zone if Ranvier and normal physis
- Dental mirror
- Bone of the epiphysis may be undermined in an attempt to allow the plug to stay with the epiphysis as the bone grows in length.

Jackson's modification
Interpositional material

- **Fat**
  - Autogenous
  - Lack of hemostasis: floating
  - Closing periosteum: BB
  - Protected weight bearing

- **Silicon-rubber**
  - Infection, FDA control

- **Cranioplast**
  - Easy available
  - No FDA control
  - Easy to handle
  - Hemostasis
  - Thermally nonconductive and radiolucent
  - No additional protection

- **Experimental**
  - Muscle (Martiana, 1996)
  - Chondrocyte (Park, 1994; Tobita, 2002…)
  - Cultured chondrocyte
  - Stem cell
Radiographic marker

1. Accurate radiographic measurement of subsequent growth
2. Differentiate overgrowth of the physis at the other end of the bone

(A) Metal markers are placed in the epiphysis and metaphysis
(B) A plug that stayed with the epiphysis as the physis grew away from the proximal marker and the growth arrest line
(C) A plug that stayed with the metaphysis as the physis grew

6 years male patient
9 years
10 years old boy: 1 year after op
SUMMARY

- Do no more harm to physis (germinal layer):
  - Urgently
  - Gentle reduction and rigid fixation
- Do not hesitate to open reduction
- Follow-up: regular and long-term

Thank you for your attention