ARGENT HOTEL, METROPOLOTIAN BALLROOM I & II

OPERATIVE MANAGEMENT OF PEDIATRIC FRACTURES: DECISION MAKING, TECHNIQUES AND COMPLICATIONS (C)

Moderator: John M. Flynn, MD, Philadelphia, PA

SYMPOSIUM

Although most fractures in children can and should be treated with casting, operative management may provide the best results in certain specific cases. Increasingly, patient expectations, socioeconomic factors, and a proliferation of literature on operative treatment have complicated decision making. The goal of this program is to clarify the indications for the operative management of pediatric fractures, highlighting recent developments, specific proven techniques, and methods for avoiding and treating complications. The audience will be polled on their preferred treatment for a series of fractures, then after a group of short lectures, the faculty will participate in an interactive, case-based panel discussion

I. Introduction
John M. Flynn, MD, Philadelphia, PA

II. Forearm Fractures
John M. Flynn, MD Philadelphia, PA

III. Elbow Fractures
James H. Beaty, MD, Memphis, TN

IV. Femur Fractures
Paul D. Sponseller, MD, Baltimore, MD

V. Pathologic Fractures through Cysts
John P. Dormans, MD, Philadelphia, PA

VI. Recognition and Management of Traumatic Growth Arrest
Richard E. Bowen, MD, Wilmington, DE

VII. Panel discussion
Moderated by James R. Kasser, MD, Boston, MA

•The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an "off label" use). For full information, refer to page iv. If noted, the author indicates something of value received. The codes are identified as: a - research or institutional support; b - miscellaneous fundings; c - royalties; d - stock options and e - consultant or employee. For full information, refer to page iv.

PEDIATRIC FOREARM FRACTURES
SURGICAL INDICATIONS, TECHNIQUES, COMPLICATIONS

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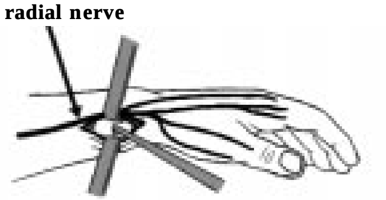
SYMPOSIA

I. Diaphyseal Forearm Fractures

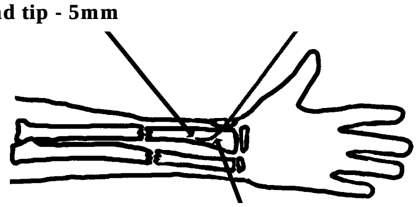
In general, the vast majority (90-95%) of pediatric forearm fractures can and should be treated with closed reduction and casting. In certain special situations, operative treatment will yield better results.

A. Surgical Indications
- Adult-like adolescents (≥14 y/o girls, ≥15 y/o boys)
- "Floating" elbow–ipsilateral supracondylar humerus fracture
- To stabilize fracturs while caring for wounds
  - Open fracture
  - Compartment syndrome
- Pathologic fracture
- Unacceptable alignment after re-fracture
- Failure of closed reduction with malalignment
  - >10° angulation in children > 8-10 y/o
  - >15° angulation in children < 8-10 y/o
  - >30° malrotation

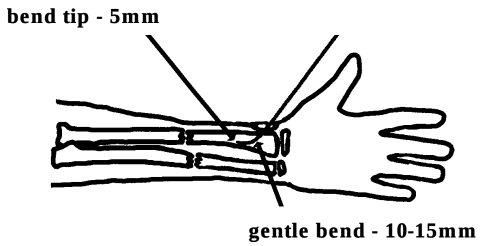
B. Techniques
- Both bone vs. single bone fixation
  - Single bone: adjunct to casting, less disruptive of fracture site, limited incisions, less hardware to remove
  - Both bone: more likely to hold perfect anatomic reduction, earlier motion; more incisions, fracture site disruption, and hardware to remove
- Intramedullary fixation
  Generally the preferred fixation in pediatric forearm fractures
  - Advantages: small incision, fracture not opened, easier removal
  - Disadvantages: no compression, may not hold anatomic reduction, irritation at pin entry site
  - Approach
    - Ulna: olecranon tip, just distal and lateral to olecranon, distal ulna
    - Radius: lateral distal metaphysis



- Implants
  - Kirchner wires
  - Elastic nails



PEDIATRICS



- Technical tips
  - Radial k-wire: reduce fracture to at least 50% apposition, make 2cm incision just proximal to radial styloid, identify and protect the radial nerve, bend tip of wire 30° and make gentle bend 10-15mm from end to facilitate entry, advance wire to fracture site and use bent tip to facilitate reduction, stop at level of radial tuberosity, bend 180° at entry site, cast or splint for ~ 4 weeks
  - Ulnar k-wire: drill percutaneously across olecranon apophysis to diaphysis, tap across fracture site and well into distal diaphysis, can close over and pull late (may be prominent) or leave out and pull at 4-6 weeks in the office (will need to protect after removal)
- Compression plates
  Rarely used in the skeletally immature, except: older adolescents, comminuted fractures, obliterated intramedullary canal (e.g. re-fracture), need for immediate motion
  - Approach
    - Ulna: direct dorsal-ulnar
    - Radius: volar distal 2/3, Thompson (posterior) proximal 1/3
  - Implant
    - 2.7 mm DCP often best
    - 1/3 tubular weak; may use in small kids—protect in cast
    - 3.5mm DCP big but useful for big adolescents
- 4 cortices on either side of fracture

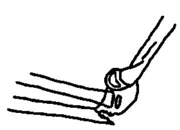
Complications

- Superficial radial nerve injury at pin insertion site
- Re-fracture after implant removal
- Loss of motion
- Infection
- Synostosis

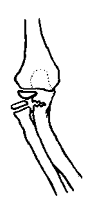
II. Monteggia Fractures

When treated soon after injury, most Monteggia fractures can be successfully treated with correction of the ulnar deformity, reduction of the radial head and immobilization to neutralize the deforming muscle forces. Frequent early follow-up with good quality radiographs is essential after closed reduction.

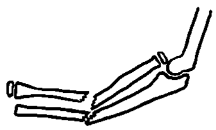
A. Type 1—Anterior dislocation of the radial head
- Failure to maintain satisfactory ulnar reduction can be managed with IM k-wire
- If closed reduction of radial head is blocked, open reduction is through posterolateral (Kocher) approach
- Repair of annular ligament in the acute setting is rarely necessary



B. Type 2—Posterior dislocation of the radial head
- Reduction held by casting in extension—if this fails, IM k- wire in the ulna may stabilize, allowing immobilization with the elbow flexed



C. Type 3—Lateral dislocation of the radial head
- 10-20% may fail closed treatment
- If after reduction and casting, the radial head subluxates with recurrence of ulnar varus, an IM k-wire can hold the ulnar alignment



D. Type 4—Dislocation of the radial head with a fracture of the radius
- *Most likely Monteggia fracture to require operative treatment*
- Difficult to reduce the radial head with nearby radial shaft fracture
- Attempt closed reduction first. If this fails, IM fixation of one or both bones (as necessary) is preferable
  - Stabilize radius first, then reduce radial head, then stabilize the ulna, if necessary
  - In adolescents, plating of the radius is recommended

E. Complications
- Missed radial head dislocation
- Re-dislocation of the radial head
- Nerve injuries (particularly radial nerve)
- Loss of motion
- Heterotopic ossification

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ELBOW FRACTURES: AVOIDING THE PITFALLS

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SUPRACONDYLAR FRACTURES

- 70% of all elbow fractures in children
- Average age 6 years
- Anatomic predisposition
  - Ligamentous laxity
  - Metaphyseal "remodeling"
  - Thin cortex
- 97% extension "injuries"
  - most posteromedially displaced
- Classification
  - Type I - nondisplaced
  - Type II - displaced, posterior cortex intact
  - Type III - displaced, no cortical contact
- Treatment - general
  - Type I - posterior splint or long-arm cast, 3 weeks
  - Type II - reduction, percutaneous pinning for severe varus or valgus impaction
  - Type III - reduction, splint or cast, traction
    - CLOSED REDUCTION + PERCUTANEOUS PINNING PREFERRED
    - open reduction, internal fixation
- Treatment - type III fractures
  - Closed reduction, splint or cast
    - Problems: vascular status, increased cubitus varus
  - Traction
    - Generally effective, but requires 2-3 weeks in hospital
    - Indications: patient unable to tolerate general anestheisa, multiple burns or large soft tissue injuries, 3+ edema at initial evaluation, comminuted fracture
  - *Closed reduction, percutaneous pinning - TREATMENT OF CHOICE*
    - General anesthesia
    - Image intensification
    - Power drill, smooth 0.062 K-wires or 5/64" pins
      - .062 < 5 years of age
      - 5 / 64" > 5 years of age
  - Open reduction
    - Irreducible fracture or unacceptable reduction
    - Open fracture
    - Suspected nerve or artery "entrapment" after reduction
    - Anteromedial or anterolateral approach probably best for posterolateral or posteromedial displacement

COMPLICATIONS AND PITFALLS

Vascular

- Probably most serious sequelae - 0.5%-1% brachial artery occlusion, laceration
- Permanent sequelae rare - < 0.5% (Volkmann's, compartment syndrome)
- Radial pulse unreliable as "danger sign"
- Most frequent vascular complication when distal fragment is displaced posterolaterally
- Complete rupture of brachial artery more likely with open injury
- Vascular monitoring may be useful in children; Doppler, pulse oximeter - reliability ???

- Signs of vascular compromise -> direct surgical exploration: morbidity very low with surgery, may be very severe with procrastination
- Rely on clinical exam!!! - pale, non-viable hand vs pink, viable hand
- Arteriogram not mandatory - in OR if necesasary
- Open reduction - anteromedial or anterolateral. for posterolateral. or posteromedial. displacement, respectively
- Reduce and pin fracture - repair or vein graft brachial artery

Neurologic

- Overall incidence of nerve injury approximately 7%
- Radial nerve
  - Most commonly affected
  - Posteriormedial displacement of distal fragment most common
- Median nerve
  - Posterolateral displacement of distal fragment
  - Three possible combinations of artery and nerve involvement
    1. Brachial artery and median nerve tented anteriorly over medial spike of humerus
    2. Artery dissociated from nerve, artery tented anteriorly and nerve coursing posterior to spike
    3. Artery and nerve lying posterior to medial spike -attempts at reduction may rarely compress both between fracture fragments

Anterior interosseous nerve
May be isolated nerve injury - FPL thumb, profundus of index loss
Easily overlooked - absent sensory and minimal motor deficits
Posterolateral displacement compresses nerve against other structures
Ulnar nerve
Uncommon with extension type fracture
Most common with overhead olecranon pin traction, secondary to medial pin ??
Most resolve spontaneously; reports of delayed recovery because of nerve incorporation in fracture callus
Complete transection of nerve occasionally reported in radial nerve injuries
Observation usually adequate treatment
Rarely, consider exploration for persistent nerve dysfunction > 6 months

Angular deformities:
type II fractures and cubitus varus
Beware Type II fracture, medial impaction fracture

Angular deformities in coronal plane will not remodel - rare growth arrest of trochlea secondary to avascular necrosis
Cubitus varus or valgus deformity
Use of percutaneous pinning has reduced incidence
Treat like type III fracture
Cubitus varus most common (5%-10%) and produces worst cosmetic deformity
Malreduction probably primary factor
Only treatment is surgical (osteotomy)
Clinical presence of cubitus varus deformity
Three major types of osteotomy
Lateral closing wedge
Dome
Step-cut – preferred
Pearls
Osteotomy within 4 cm of joint
Adequate fixation - screws in older adolescent
Supracondylar humeral osteotomy – complications
Recurrence of varus deformity
Nerve injury (ulnar nerve)
Stiffness
Scar formation
Infection
Cubitus vaIgus - occurs most often with posterolateral fracture pattern
Tardy ulnar nerve palsy - possible, but rare

Late presentation
Correct or accept position ?
Closed reduction by manipulation almost impossible in fracture > 1 week old
Open surgical intervention > 96 hours after injury -> myositis ossificans increased
Corrective osteotomy later if deformity cosmetically objectionable
May remodel to signficant degree (exception: posterior angulation, cubitus varus/valgus)

Myositis ossificans
Rare
Reported after open and closed reduction
Vigorous repeated manipulation and passive physical therapy during rehabilitation phase should be avoided

Loss of mobility
Rare from anatomically reduced fractures
Loss of flexion can occur with posterior angulation, posterior translocation, or rotation with protruding medial spike anteriorly
Hyperextension. deformity if fracture heals > 30° anterior angulation

Ipsilateral fractures
Reported incidence ranges from 1% - 13%
Cubitus varus more frequent, neurovascular complications no more frequent
Distal radius should be examined carefully in patient with supracondylar fracture
Supracondylar fracture should be stabilized first, then distal radius when both are displaced

LATERAL CONDYLAR FRACTURES
- 15% of all elbow fractures in children
- Average age 5-6 years
- Classification
  - Type I - <2 mm displacement
  - Type II - 2-4 mm displacement
  - Type III - completely displaced, rotated
- Treatment
  - Type I
    - Splint and check weekly until union
    - ? Percutaneous pinning
    - ? Arthrography
    - ? Stress radiograph

      Risk of late displacement/nonunion approx. 5%-10%
  - Type II - ORIF, percutaneous pinning ?; percutaneous pinning alone has been advocated recently
  - Type III - ORIF, percutaneous pinning

SYMPOSIA

- Complications
  Nonunion -> cubitus valgus -> tardy ulnar nerve palsy
  Treatment of nonunion
    Benign neglect - treat tardy ulnar nerve
    Late "modified" ORIF, bone grafting
  Nonunion in “good position” - extraarticular ORIF, bone graft
    Displaced < 1 cm from joint
    Physis open
    Good motion
    Large metaphyseal fragment
  Nonunion in “poor position” - benign neglect - treat tardy ulnar palsy
    (anterior transposition)
  Avascular necrosis
    Excessive soft tissue dissection
    Loss of blood supply at time of injury
    If union occurs, AVN will resolve like LCPD - may lose motion
  “Fishtail” deformity is common radiographic finding
    No clinical significance

MEDIAL EPICONDYLAR FRACTURES
- Approximately 11% of injuries to distal humerus
- Peak age 9-12 years, 4 times more frequent in boys than in girls
- Approximately 50% associated with elbow dislocation
- Mechanism: acute avulsion caused by overpull of forearm flexor tendon or ulnar collateral ligament, direct blow, elbow dislocation
- Classification
    Acute injuries
      Displacement
      Entrapment of fragment in joint
      Fracture through epicondylar apophysis
    Chronic tension stress injuries
    (Little League elbow)
  Treatment
    Immobilization for comfort
    (minimal or no displacement)
    Closed reduction + cast
    Open reduction indicated
      Rotation and displacement > 1 cm
      Persistent entrapment of fracture fragment (5%-10%)
        -possible up to 6 weeks after injury
      Ulnar nerve dysfunction
      VaIgus instability
      High-performance athlete

RADIAL HEAD AND NECK FRACTURES
- Rare - < 57o of all elbow fractures
- Most caused by falls
- Treatment - nonoperative if possible
    Accept angulation of 25°-50°, displacement < 50%
    Manipulation - traction + varus force, direct pressure to radial head
    “Percutaneous” manipulation with image intensifier, Metizeau technique or blunt Steinmann pin
  Open reduction
    Angulation > 45°, displacement > 50%
    Lateral ORIF, fixation with:
      Transcapitellar K-wire - try to avoid
      Oblique K-wires - preferred
      - remove at 2-3 weeks
      Try percutaneous or retrograde manipulation before ORIF
- Complications
  Avascular necrosis
  - appears to remodel with growth
  Synostosis - common after severe injury and surgical treatment

MONTEGGIA FRACTURE-DISLOCATIONS
- Pronation injury
- Anterior and lateral dislocations most common
- Treatment
    Closed manipulation in most
    Reduce ulnar fracture and radial head dislocation
    Cast in stable position 6-8 weeks
    Line through radial head/lateral condyle must be concentric on all views
    ORIF: irreducible radial head
    (soft tissue interposition)
      May require fixation of ulnar fracture with plate or IM device
      Avoid transcapitellar pin
    Special problems - undetected, untreated Monteggia lesion
      No treatment - excise symptomatic radial head at skeletal maturity
      Late reconstruction, lengthening - angulation osteotomy of ulna
      Experience required
      Modification of Bell-Tawse procedure by Ham Peterson is superb
- Complications
  Posterior interosseous nerve palsy
  - most recover spontaneously
  Transcapitellar pin - migration or breakage

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OPERATIVE MANAGEMENT OF PEDIATRIC FEMUR FRACTURES

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I. General Principles

A. Indications

- *Whether* to operate is based on
  - *associated injuries*
  - *age/size*
- *Type* of operation based on
  - *Age and surgeon experience*

Other relative indications for surgery

- Open injury
- floating knee
- polytrauma
- closed head injury

B. Type of Operative Fixation

– Preferences by Age

- 0-5:
  - early spica
  - traction then spica
- 6-10:
  - flexible nails
  - external fixation
- 11-14:
  - reamed nail through trochanter
  - external fixator
- >15:
  - reamed nail through piriformis

II. Specific Operative Techniques

A. External Fixation

- Works much better in kids than adults
- 4-pin frame usually satisfactory
- Early weight bearing allowed
- Time to union is longer

External Fixator Results (Blasier, Turski & Aronson JPO 1997)

- 139 patients ages 2-17
- return to school by 4 weeks
- average time in fixator = 11 weeks
- 3 required IV antibiotics; 2 required I&D
- 3 refractures; 1 through pin, 2 through original fracture site
- pin scars "acceptable"

Refracture after External Fixation

- Reported rates range from 2-12%
- May occur through fracture site or pin site
- Increased risk if:
  - low *Fracture Index* (ratio of fracture width to bone width)
  - callus seen bridging < 3 cortices on AP and Lateral
  - minimize risk at time of removal by simple spica for 1 month, if quality of healing is questionable

B. Plate Fixation

(Results –Ward, Sturm)

- No nonunions/25 patients
- No limb length discrepancy > 1 cm
- 1 plate fracture and one stress fracture (both over 10 years old)
- Long incision

C. Intramedullary Rods

– advantages

- Automatic alignment
- Nothing to see/feel (big advantage for kids)
- Early return to activity

– Disadvantages

- Rigid rods not feasible for small kids
- Flexible rods don't control length, angulation
- Rigid rods risk AVN
- What to do with implant? Remove or leave in??

– Avascular Necrosis

- 1-2% after reamed piriformis IM rod
- Occurs in children ages 10-14; none reported in older teens
- Symptoms develop at 6-12 months after surgery
- None reported after flexible nails
- ? Caused by injury to ascending cervical artery (Huurman 1996)

1. Flexible Nails

- Feasible in kids because of:
  - smaller canal diameter
  - lower body weight
  - faster healing
- Retrograde (usually) or antegrade
- Ideal for ages 6-11, transverse or short oblique pattern

-Technique: flexible nails
- Fluoro table or fracture table
- Entry 2 cm above physis
- Drill hole larger than rod
- Select rod 40% width of isthmus
- Gentle bend in plane of the hook
- Implant options:
  - – AO titanium nails
  - – Rush Rods
  - – Enders rods, others
- Insert both to fracture site
- Use F-tool to reduce
- Insert to full-length
- Cut off ~1.5cm outside bone

-Flexible nails: aftercare
- No cast if:
  - – transverse or short oblique
  - – good canal fill
  - – not too proximal or distal
- otherwise simple 1-leg spica
- remove after 3–6 months

-Complications of flexible nails:
- Angulation > 5o: 10%
- Malrotation: 5-10%
- Infection:1-2%
- pin irritation/revision: 5-10%
- Refracture
- Delayed union

2. Rigid Nails
- Age >11
  - – 11-14: insert through trochanter
  - – >15: insert through piriformis
- Trochanteric nail:
  - – standard
  - – tibial
  - – pediatric
- Removal?

III. Cost Factors

Charge Comparison (Stans, Morrissy 1997)

Early Spica:	$6,000
Traction + Spica:	$16,000
External Fixation	$17,000
Flexible IM nail	$14,500
Reamed IM nail	$16,500
Plate	$17,000

Charge Comparison-Conclusions
- Early spica is most cost-effective when it can be used (Costs shifted to family)
- Surgical methods not cheaper than traction
- All surgical methods cost about the same
- Charges do not equal costs
- Pressure to contain costs varies by region

IV. Conclusion
- Many different methods are effective
- Differences = a matter of degree
  - – Ease of care, appearance
- Pick several methods and perfect them

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FRACTURES THROUGH BONE CYSTS: UBCs, ABCs AND NON-OSSIFYING FIBROMAS

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SYMPOSIA

Pathologic fracture
- Intrinsic - osteopenia or replacement of bone with tumor.
- Extrinsic - weakness caused by something lessens structural integrity, eg bone biopsy hole.

Pathologic bone fails in 2 ways:
- **Microfracture:** MC in trabecular bone. Undisplaced, unrecognized, heal without consequence. Energy may be small. Multiple micro-fractures may result in deformity, "shepherd's crook".
- **Complete Fracture**

Quantification of risk of pathologic fracture:
- Hipp et al 1995 "factor of risk" - load applied to bone divided by load required for failure.
- Retrospective studies have failed to find predictive methods based on radiographic findings that can accurately forecast fracture in most situations.

Radiographs - most helpful in establishing cause of pathologic fracture. Majority of tumors and tumor-like processes are recognizable by radiographic appearance; location of the lesion can also be helpful.
Biopsy is sometimes needed to determine cause of fracture. Ensure that biopsy is representative. Healing fracture mistaken for osteosarcoma has been reported.

Treatment of fractures associated with tumors and tumor-like lesions

Priority for Treatment	Tumor/Tumor-Like Lesion
Fracture	Eosinophilic granuloma* Fibrous cortical defect** Unicameral bone cyst** (lesion may heal spontaneously sooner *, or later **)
Fracture, then lesion (If necessary)	Unicameral bone cyst Aneurysmal bone cyst Eosinophilic granuloma Nonossifying fibroma Fibrous dysplasia Enchondroma Chondromyxoid fibroma
Fracture and lesion (simultaneous)	Giant cell tumor Angiomas of bone Malignant bone tumors
Lesion (fracture may heal with lesional treatment)	Metastatic lesions such as neuroblastoma Leukemia Selected chemosensitive malignant bone tumors

Benign bone tumors can be classified according to aggressiveness.

Stage 1, Latent Benign
- Asymptomatic
- Often discovered incidentally
- Seldom associated with pathologic fracture

PEDIATRICS

Stage 2, Active Benign
- Majority
- Tend to grow steadily
- May be symptomatic.

Stage 3, Aggressive Benign
- Generally symptomatic
- Discomfort, usually tender
- May be associated with **pathologic fracture**
- Growth rapid

Benign but locally aggressive tumors
- Chondroblastoma
- ABC
- Chondromyxoid fibroma
- Giant cell tumor
- Osteoblastoma
- Chordoma
- Adamantamona

1) Fractures and UBCs

UBCs: fluid-filled cystic lesions; most commonly in metaphysis. "Unicameral" suggests single-chamber; often multiloculated with septa. Contain yellow serous fluid. Fibrous lining.
Location: proximal humerus, proximal femur, proximal tibia, distal tibia, distal femur, calcaneus, distal humerus, radius, fibula, ilium, ulna, and rib. (70% found in proximal humerus or femur).
Usually diagnosed within 1st 2 decades of life
UBCs evolve from an accumulation of interstitial fluid in bone; ? A defect in venous or lymphatic drainage?

Xray: centrally located, radiolucent, slightly expansion (width of lesion seldom exceeds that of adjacent physis)
Occasionally diaphyseal UBCs (physis has migrated away). "Fallen fragment sign"

Differential dx: ABC, fibrous dysplasia (cystic), enchondroma, GCT, LCH.

Natural history - variable - tendency for gradual improvement.
Most persist into adulthood; others disappear at puberty.
Cysts are described as
- Active if adjacent to physis
- Latent if lesion is > than 0.5 cm from physis.

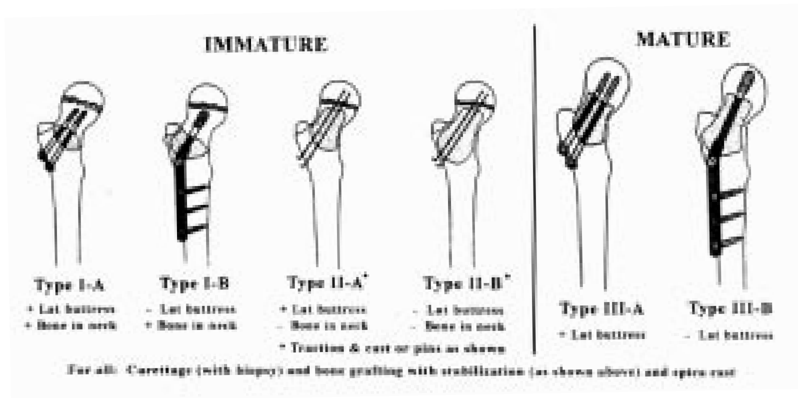
Kaelin and MacEwen "cyst index."
- Low cyst index = low risk for fracture = no treatment
- Cyst index = Area of the cyst/(Diaphysis diameter)2

Pathologic fracture: 75% present with fracture - most incomplete or minimally displaced.
Fracture heals within 6 wks, UBC usually persist, often with further fracture.
10-15% of cysts heal after fracture.
Ahn and Park noted that pathologic fracture occurred when transverse diameter of cyst was 85% or greater.
Others - chance of fracture high if cyst wall was < 5 mm in width.
Complications after fracture: malunion, growth arrest, and AVN of femoral head.

Fracture treatment—UBC
Fractures invariably heal with simple immobilization
Cyst persist in nearly 85%; additional fractures common.
Neer et al observed an additional 2.5 fractures per patient during observation periods after initial injury.

Displaced pathologic fractures of proximal femur. If significant loss of bone, high risk of a coxa vara without internal fixation. Both location of UBC and bone loss dictates whether fixation can stabilize fracture after grafting and what type of fixation would be best to use. The goal is to prevent coxa vara; with malunion, osteotomies may be necessary.

CHOP classification of pathologic fractures of proximal femur



Upper extremity fractures (and small UBCs, stable fractures in lower extremity):
Commonly seen, especially upper humerus.
Displacement is usually minimal.
Treatment:
- Minimally displaced, stable fractures - simple immobilization 4-6 wks.
- Sling for stable fractures of proximal humerus; once healed, options discussed.

After fracture, most authors advocate at least a 6 wk delay in treatment to allow fracture to heal before curettage, bone graft. Delaying treatment until cyst converts from an active to latent - advocated, but 2 yr period may be necessary. Some suggest that response to tx may be same for latent as compared with active cysts.
Due to fact that incomplete healing & recurrence are common after injection of corticosteroid and that multiple injections may be necessary, in majority of patients, new grafting materials are being used.

Surgical Treatment - Many techniques

1) Curettage and Bone Grafting
Out of favor for UE and smaller LE UBCs
Significant persistence and recurrence rates
Popular for larger UBCs of proximal femur (recurrence 10% to 40%).

Calcaneal UBC present with pain -micro-fracture.
May not respond to methylprednisolone injections (Glasser et al).

2) Aspiration and Injection
1974, Scaglietti. Empiric injection of UBCs with methylprednisolone.
By 1979, reported healing rates (radiographic improvement of the cyst) of 96% in series of 72 pts.
Some suggest cyst healing occurs through decompression of fluid pressure by trephination.
Injection for UBCs became popular (low morbidity, apparent effectiveness).
More recently: incomplete healing and recurrence more common. Other techniques have been developed.
Aspiration and Injection - Operative Technique
2 needle technique most common. Initial dose of methylprednisolone can vary from 40 to 200 mg.
Cystogram - fibrous septa found in 92% of lesions-may prevent filling of cyst by steroid.
Pathologic fractures through cysts are allowed to heal before corticosteroid is injected.

With C arm, thin cortex is identified, 2 needles passed into cyst; needle tips are at opposite ends of cyst. Serous fluid indicative of UBC. A cystogram with Renografin to confirm fluid-filled nature and ascertain whether cyst is unicameral. If dye does not fill cavity, diagnosis of UBC should be questioned. If cyst is multiloculated, needles can be used to break up septations. Methylprednisolone injected - dose from 80 to 150 mg. Arm protected in sling for 2 to 6 wks; x-rays taken every 6 wks. Persistence of cyst addressed through additional injections.

Steroid injection can also be done for UBCs of LEs, but if cyst is unstable and risk of malunion (varus of femoral neck) one should consider a different treatment (see below).
Recurrent and Persistent Cysts
15-39%; some require no further treatment.
80% of recurrences are evident 2 years after initial injection; once healing is obtained,
annual x-rays sufficient.

Complications
Persistence, recurrent fractures, AVN of femoral head
In one series, growth disturbance was a problem in 20% of 141 patients with bone cyst treated by corticosteroid injection.
Systemic reactions to corticosteroid (eg corticosteroid flush or increased appetite, weight gain) are rare.

3) Newer methods

Relieving pressure of interstitial fluid.

Chigira et al - 6 pts. Punctured cyst with multiple K wires, left in place. Recurrence rate 33%.

Santori et al decompressed with Enders nails or Rush pins. Short term f/u: healing in all 11pts.

Roposch et al JBJS 82A, Oct 2000. 32 pts (30 with patho #). All responded, 14 healed completely, 9 required change of nails.

New grafting materials:

DBM or Grafton® - 100 to 500 um particles in glycerol base.

Treatment of UBCs (Killan, Kresler, Rougraff).

Killan et al used DBM for 11 pts and were able to obliterate cysts in 9 of 11 by using a single injection within 4-5 months and at 2 years' follow-up, no cysts were deemed active or recurrent.

Calcium sulfate - Plaster of Paris pellets - Peltier 1978.

Osteoset® Pellets medical grade calcium sulfate.

Radiopaque. Injected percutaneously.

Biodegradable; pellets resorbed in 30-60 days. Not intended to provide structural support – contraindicated where device is intended as structural support.

Adjuvants :liquid nitrogen for UBCs (Schreuder1997) most prefer to avoid.

2) Fractures and ABCs

ABCs: Eccentric or central, expansile, osteolytic, in metaphyseal of long bones

(65%: tibia, femur, humerus, fibula, ulna, and radius) or posterior elements of spine

(12% to 27% -lumbar vertebral bodies MC - posterior elements with frequent extension into vertebral body).

Age: 75% <20 years old, 50% between 10 and 20 yrs

Rare, prevalence of 1.5% of all primary bone tumors.

Not true cysts - sponge-like collection of fibrous tissue, blood spaces.

Tend to be destructive. Elevated periosteum; maintain thin osseous shell.

Etiology unknown. Some primary, others secondary with UBCs, NOF, fibrous dysplasia, OGS, et al.

Also been seen in a/w fractures of long bones.

Symptoms -pain of < 6 mos duration, stiffness with juxta-articular.

Radiographic Findings

Eccentric or central. Lytic. Septations common, ie "soap bubble". (Extension beyond cortex uncommon).

Initially, frank osteolysis, periosteal elevation. With growth, progressive destruction.

A stabilization phase next follows with formation of a bone shell with septa. Later, with further ossification, a bony mass begins to form

Campanacci et al - 3 groups:

Aggressive - reparative osteogenesis with ill-defined margins; no periosteal shell.

Active - incomplete periosteal shell; defined margin between lesion and host bone.

Inactive - periosteal shell complete and sclerotic margin between cyst and bone.

MRI often helpful:

Demonstrating septations, fluid-fluid levels (characteristic but not pathopneumonic of ABC)

Epiphyseal involvement

Natural history

ABCs benign but locally aggressive.

Pathologic fractures - 11% to 35% long bones.

Humerus, femur are most commonly fractured

Treatment

Conservative treatment - inappropriate definitive treatment.

Pathologic fracture heal, but ABC will persist and enlarge - recurrent fracture.

Although cases of cyst healing after simple biopsy have been reported, does not occur often and observation not recommended - usually locally aggressive.

Simple curettage and bone grafting has been associated with high recurrence rates (20% to 30%).

Higher rate of recurrence in patients < 15 yrs of age.

Selective arterial embolization - definitive or preoperatively with other procedures.

Used most commonly in spine, pelvis and proximal portion of extremities.

Cryotherapy in conjunction with curettage recurrence rate of between 8 and 14%. Cementation described as adjuvant. Ozaki et al cementation in 35 patients.

Complete en bloc resection - reserved for active or recurrent ABCs; most feasible in proximal fibula, distal ulna, ribs, pubic ramus, metatarsals, and metacarpals.

Irradiation - avoid

Author's Preferred Treatment—ABC

1st step - confirmation of lesion - biopsy and frozen section; done at same surgical setting as definitive procedure. Remember, ABC can be secondary!

Treatment asap after dx. Adequate exposure, preparation for blood loss, internal fixation, grafting material and in selected cases, preoperative embolization.

Thorough extended curettage is a key. High speed burr - systematic intralesional extended excisional curettage. A dental mirror to inspect for residual. Adjuvants reserved for aggressive or recurrent ABCs (phenol, liquid nitrogen and cementation). Bone grafting for all larger lesions (autograft, allograft, bone substitutes or a combination).

Stabilization when appropriate (see UBC).
Hip spica cast or "walking" hip spica (unilateral hip spica cast with the hip and knee in 20 to 30 degrees of flexion) is sometimes appropriate for young children in lieu of internal fixation.

3) **Fibrous cortical defects (FCDs) and Non-ossifying Fibromas (NOFs)**
   FCDs: Small (1 to 2 cm). Metaphyseal. Distal femur, proximal tibia, fibula. Eccentric with thinned cortex. Seen in lower extremity in 25% of pediatric patients. Usually asymptomatic.

   NOFs: 5 cm. or more. Similar age, distribution as FCDs. Multiple lesions in one-third. Eccentric, metaphyseal, radiolucent, uniloculated or multiloculated. In small bones may occupy entire width of shaft. Usually asymptomatic.

   Both lesions contain fibrous tissue, foam cells, and multinucleated giant cells.
   Both regress spontaneously - average duration of lesions ranges from 29 to 53 months.
   Some pathologic fractures are micro-fractures. The larger the lesion, greater chance for fracture.

Risk of fracture:
Fractures - excellent healing potential; Lesion usually persists after healing of fracture. Incidence of refracture is low. Fracture union takes place normally, but often radiolucencies remain.

Arata et al: all pathologic fractures associated with NOF in LEs occurred through lesions > than 50% of transverse cortical diameter. "Large lesions" = > than 50% cortical involvement and height measurement of > than 33 mm. Recommended observation of these large NOFs, but suggested "prophylactic curettage and bone grafting be considered if there is a reasonable chance of impending fracture." Their series does not include any large lesions meeting their size criteria that did not fracture, This hypothesis has never been tested in any published series.

Easley and Kneisel et al:while absolute size parameters were helpful, they do not imply a requirement for prophylactic curettage and bone grafting. In their series, 13 (59%) large NOFs had not fractured despite exceeding previously size threshold. In nine (41%) patients with fracture, healing was uneventful and no cases of refracture were observed.

Authors preferred method
Many with large NOFs can be monitored without intervention, as spontaneous resolution occurs in majority. Fractured NOFs heal favorably. It may be reasonable to limit activity with large NOFs. Absolute size parameters useful in predicting fractures, but do not imply requirement for prophylactic surgery. Most fractures successfully managed nonoperatively. Many incidentally-discovered large NOFs do not fracture. Many large NOFs remain unidentified and nonproblematic.

After fracture: Most stable fractures- conservative immobilization until healing.
Surgery only if residual lesion is of significant size to predispose to further fractures or doubt about identity of lesion. Larger lesions, (ie diameter > 50% of width of bone on AP and lateral, are believed prone to fracture and may be best managed with curettage and bone, but should be approached individually.

Displaced pathologic supracondylar fractures of distal femur - open reduction, bone grafting, IM fixation.

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RECOGNITION AND MANAGEMENT OF TRAUMATIC GROWTH ARREST

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I. Types of Physeal Injury

Salter Harris Classification:

Type I: complete separation without metaphyseal of epiphyseal involvement

Type II: fracture plane extends a variable distance through the physis and exits through the metaphysis on the side opposite the initiation point of the fracture plane

Type III: an intra-articular fracture of the epiphysis that prorogates to the physis and dissects to its periphery

Type IV: vertical splitting of the epiphysis, the physis, and into the metaphysis

Type V: crush of physis

Type VI (Rang modification): perichondrial ring injury

(Weber Classification)
(Aiken Classification)
(Odgen Classification)

Apophyseal Injury
Acute disruption
Fatigue (Osgood Schlatter Disease , Sever Disease)

II. Physeal response to injury:

a. Hueter-Volkman Law: physis adjacent to a malunited fracture tend to realign perpendicular to the resultant force that acts through then (Heuter 1862, Volkman 1863)
b. overgrowth
c. inhibition/closure (angulation and/or shortening)
d. Partial growth arrest
   Types of Partial growth arrest
   - peripheral
   - central
   - combined

III. Treatment of physeal fractures

a. reduce the physeal fracture within three days of injury (seldom after five days)
b. stabilize the physis until healed
c. try to avoid physeal transfixion

IV. Evaluation of the physis after injury

a. radiographs; Harris line
   1. center over physis
   2. perpendicular to the plane of the physis
   3. two views at 90 degree to each other
   4. varus and valgus stress radiographs
b. tomography
c. Magnetic Image Resonance (eight months after initial injury)

V. Treatment of physeal injury

a. observation (near maturity)
b. epiphysiodesis
c. physeal stapling
d. resection of physeal bar (with or without osteotomy)
   - at least two years of remaining growth
   - less than 50 percent cross sectional surface involvement
   - not associated with infection
e. lengthening (with deformity correction)

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