Clavicle Fractures in Children & Adolescents

Michael Busch, MD

Ben Heyworth - Boston
Cliff Willimon - Atlanta
State Medical Societies

• Advocacy
  – Healthcare policy – never more important than today
  – Trial lawyers, Hospitals, Insurance companies
  – If not you, then support those who do – PAC
  – Very partisan, in support of our patients!

• Backbone of AAOS
  – National lobbying
  – Credentialing, Licensing, Education, MOC, CME

• Join
  – Get involved
  – Support resident development
Doctors’ Day

Advocacy
Kay Kirkpatrick, MD

Advocacy/Relationships
Deborah Silcox, JD

Advocacy/Relationships
Secretary Tom Price, MD
Cloister @ Sea Island, GA

Relationships/Education
SAVE THE DATE
GOS Annual Meeting
September 19-22, 2019
Sea Island, GA

Relationships/Education
Disclosures

• None related to this subject
Outline

• Overview/basics
• Pediatric clavicle fractures
• Adolescents
  – Midshaft
  – Medial
  – Lateral
Clavicle Fx. Basics

Anatomy
- First to ossify
- Last to close (21-25 y/o)
- 80% of growth is medial
- Rotates 50° along its long axis
- Elevates 30°

Mechanism
- 90% direct blow

Ends
- Most medial injuries are physeal fractures until proven otherwise
- Lateral physeal fractures are often mistaken for AC joint injuries
Kids vs Adults

Kids
• 15% of all fx’s
• Most common UE fx

Adults
• 3% of all fx’s
• 40% of shoulder fx’s
Growth and Remodeling - Females

Growth of Clavicle in Females from birth - 18 years of age

- <1y Old = 37.8mm = 25.34%
- 4y 4m yr Old = 74.58mm = 50%
- 9y 3m yr Old = 119.33mm = 80%
- 18yr Old = 149.16mm = ~100%

8.49mm/yr from birth to 4y 4m
8.95mm/yr from 4y 4m to 9y 3m
3.41mm/yr from 9y 3m to 18y

McGraw, MA: JPO 2009
Growth and Remodeling - Males

Growth of Clavicle in Males from birth - 18 years of age.

- <1y Old = 37.61 mm = 23.32%
- 4y 8m yr Old = 80.65 mm = 50%
- 12y 1m yr Old = 129.03 mm = 80%
- 18yr Old = 161.29 mm = ~100%

McGraw, MA: JPO 2009
Allman Classification

subgroup

II

I

III

a

b

c

Distal

Proximal
Congenital Pseudarthrosis

When do you see it on the left side?
Deforming Forces

- Clavicular heard SCM, Subclavius, Pec minor
- Deltoid, Trapezius
- Figure of 8 opposes most of these
Rx: Childhood Clavicle Fx

- Sling / Figure of 8
- Comfort
- Not truly a reduction
- Most can be followed clinically
  - Educate the parents about callous and healing
  - Analogy to repairing a crack in a plaster wall
  - Activity recommendations
Case lessons: Not so bad, right?
Bit of a lump...
What about this view?
Look again at the asymmetry
Radiographic Views

Serendipity or lordodic view
45 Degree Tilt
So, what’s new in adolescents?

Plenty
Epidemiology: Adolescents & Adults

Robinson, CM: JBJS(B) 1998
Traditional View Begins to Change

• Classic studies
  – Complications began to be seen of this “invincible bone”
    • Neer
    • Rowe

• Outcome Metrics
  – Historical - Radiographic, Surgeon-based
  – Modern - Function, patient-reported
Paradigm Shift: Adult Clavicle Fractures

What changed?

• Poor functional outcomes
  – Hill, JM: JBJS(B) 1997

• Non-unions
  – Robinson, CM: JBJS 2004

• Mal-unions = Altered functional outcomes
  – McKee, MD: JBJS 2006

• Level 1 studies
Poor Outcomes

CLOSED TREATMENT OF DISPLACED MIDDLE-THIRD FRACTURES OF THE CLAVICLE GIVES POOR RESULTS

JAMES M. HILL, MICHAEL H. McGUIRE, LYNN A. CROSBY

From Creighton University, Omaha, USA

©1997 British Editorial Society of Bone and Joint Surgery

• 52 patients
  – Completely displaced fractures, non-operative treatment
  – Poor results not uncommon
    • 25% mild/moderate pain
    • 15% neurologic symptoms
    • 31% unsatisfied
    • 64% cosmetic complaint
  – Shortening > 2 cm → increased risk neurologic sx, unsatisfied
Poor Functional Outcomes

DEFICITS FOLLOWING NONOPERATIVE TREATMENT OF DISPLACED MIDSHAFT CLAVICULAR FRACTURES

By Michael D. McKee, MD, FRCS(C), Elizabeth M. Pedersen, MD, Caroline Jones, BSc, PT, David J.G. Stephen, MD, FRCS(C), Hans J. Kreder, MD, FRCS(C), Emil H. Schemitsch, MD, FRCS(C), Lisa M. Wild, BScN, and Jeffrey Potter, BSc

Investigation performed at the Division of Orthopaedics, Department of Surgery, St. Michael’s Hospital and the University of Toronto, Toronto, Ontario, Canada
Poor Functional Outcomes

McKee, MD: JBJS 2006
Nonoperative Treatment Compared with Plate Fixation of Displaced Midshaft Clavicular Fractures

A Multicenter, Randomized Clinical Trial

By the Canadian Orthopaedic Trauma Society

JBJS 2007
Canadian Study

Materials & Methods

• 8 centers,
  – 132 pts
  – “completely displaced” fxs
  – 87M, 24F
  – Mean age 33.5 (17-60)

• Randomized
  – ORIF vs. Sling x 6wks

• F/u
  – Loss to FU non-op > ORIF (23% vs. 8%, p=0.008)

• Results
  – Time to Union (XR):
    • ORIF: 16 wks (p=0.001)
    • Sling: 28 wks
Canadian Study

Constant Score Results

Dashed line = non-op
Solid line = operative rx.

DASH Results
### TABLE III Appearance of Shoulder

<table>
<thead>
<tr>
<th>Condition</th>
<th>Operative Group (N = 62)</th>
<th>Nonoperative Group (N = 49)</th>
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<tbody>
<tr>
<td>“Droopy” shoulder</td>
<td>0</td>
<td>10</td>
<td>0.001</td>
</tr>
<tr>
<td>Bump and/or asymmetry</td>
<td>0</td>
<td>22</td>
<td>0.001</td>
</tr>
<tr>
<td>Scar</td>
<td>3</td>
<td>0</td>
<td>0.253</td>
</tr>
<tr>
<td>Sensitive and/or painful fracture site</td>
<td>9</td>
<td>10</td>
<td>0.891</td>
</tr>
<tr>
<td>Hardware irritation and/or prominence</td>
<td>11</td>
<td>0</td>
<td>0.001</td>
</tr>
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<td>18</td>
<td>0</td>
<td>0.001</td>
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<td>Satisfaction with appearance</td>
<td>52</td>
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### Canadian Study

Advantage: Non-op

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## Canadian Study

Advantage: Surgery

### TABLE II Complications

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<th>Adverse Event</th>
<th>Operative Group (N = 62)</th>
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<tbody>
<tr>
<td>Nonunion</td>
<td>2*</td>
<td>7</td>
<td>0.042</td>
</tr>
<tr>
<td>Malunion requiring further treatment</td>
<td>0</td>
<td>9</td>
<td>0.001</td>
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<td>0</td>
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<td>0</td>
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<td>Transient brachial plexus symptoms</td>
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<td>7</td>
<td>0.690</td>
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<td>0</td>
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<td>Other</td>
<td>2</td>
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<td>0.784</td>
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<td><strong>Total</strong></td>
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*One patient who was randomized to operative fixation declined surgery. He had a nonunion of the fracture at one year. According to the “intention-to-treat” principle, the complication was included in the operative group as a nonunion. See text.*
## Canadian Study

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While we stress that our findings are applicable only to a specific subset of clavicular injuries, our data support primary plate fixation of completely displaced midshaft clavicular fractures in active adults.
Not so fast…

Sling Compared with Plate Osteosynthesis for Treatment of Displaced Midshaft Clavicular Fractures
A Randomized Clinical Trial

Kaisa J. Virtanen, MD, Ville Remes, MD, PhD, Jarkko Pajarinen, MD, PhD, Vesa Savolainen, MD, PhD, Jan-Magnus Björkenheim, MD, PhD, and Mika Paavola, MD, PhD

Investigation performed at Helsinki University Central Hospital, Helsinki, Finland

Single level-1 trauma center

- 28 ORIF, 32 Sling
  - 52M, 8F
  - 50% smokers
  - Mean age 37 (16-60)

- F/u = 3 mo & 1 yr
  - Lost: 7% ORIF, 22% Sling
Primary Results

– Non-Union:
  • ORIF = 0
  • Sling = 6 (24%)
– No sling pts elected ORIF for non-union
– No differences:
  • Constant
  • DASH
  • Pain
Conclusions
One year after displaced clavicle fracture
– Non-op had more non-unions
– Similar function and disability
Operative Versus Nonoperative Care of Displaced Midshaft Clavicular Fractures: A Meta-Analysis of Randomized Clinical Trials

Robbin C. McKee, Daniel B. Whelan, MD, FRCS(C), Emil H. Schemitsch, MD, FRCS(C), and Michael D. McKee, MD, FRCS(C)

Investigation performed at St. Michael’s Hospital and the University of Toronto, Toronto, Ontario, Canada
6 studies, 5 countries

- 412 pts
  - 212 ORIF vs. 200 non-op
  - Age range: 25-41
  - Mostly male

- Outcomes
  - Nonunion: ORIF 1.4% vs. Non-op 14.5%
  - Sx Malunion: ORIF 0% vs. Non-op 8.5%
  - Complications: ORIF 29% vs. Non-op 42%
  - Constant: ORIF 94 vs. Non-op 90
Pediatric/Adolescent Evidence

FACTS STUDY GROUP
Function after Adolescent Clavicle Trauma and Surgery

Boston Children’s Rady – UCSD
Texas Scottish Rite
U. of Michigan
Campbell Clinic

Children’s Healthcare of Atlanta
UCSF
Wash. U St. Louis
Non-union in Adolescents?

Adolescent clavicle nonunions: potential risk factors and surgical management

Andrew T. Pennock, MD,*, Eric W. Edmonds, MD, Donald S. Bae, MD, Mininder S. Kocher, MD, MPH, Ying Li, MD, Frances A. Farley, MD, Henry B. Ellis, MD, Philip L. Wilson, MD, Jeffrey Neppe, MD, J. Eric Gordon, MD, Samuel C. Willimon, MD, Michael T. Busch, MD, David D. Spence, MD, Derek M. Kelly, MD, Nirav K. Pandya, MD, Coleen S. Sabatini, MD, MPH, Kevin G. Shea, MD, Benton E. Heyworth, MD

Risk of Non-union

8 pediatric referral centers
– Age = 14.5yrs (10-18)
– 13 years (2003-2015)
– 25 cases = 1 every 4 years/center

**no non-unions in prospective group...

Pattern?
– 68% displaced
– 21% partially displaced with angulation
– 11% non-displaced/minimally displaced

32% were re-fractures
Rx for Non-union?

- All underwent ORIF/plate
- 24/25 bone grafting
- 24/25 cases (96%) = uneventful healing

So, if non-union is a much smaller problem in adolescents, are there other reasons we need to be fixing them?
2-Year Functional Outcomes of Operative vs. Non-Operative Treatment of Completely Displaced Midshaft Clavicle Fractures in Adolescents

The FACTS Study Group
Enrollment/Demographics

Screened/Enrolled

- 302, 35% Enrolled
- 550, 65% Not enrolled

Reasons for Failed Screening/Non-enrollment

<table>
<thead>
<tr>
<th>Reason</th>
<th><em>(%)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-diaphyseal fracture</td>
<td>4%</td>
</tr>
<tr>
<td>&lt;10 or &gt;18 years old</td>
<td>5%</td>
</tr>
<tr>
<td>Pathologic fracture</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>SC joint injuries/proximal fracture</td>
<td>5%</td>
</tr>
<tr>
<td>AC joint injuries/distal fracture</td>
<td>11%</td>
</tr>
<tr>
<td>Neurologic/neurocognitive disorder</td>
<td>1%</td>
</tr>
<tr>
<td>Metabolic bone disorder</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>&gt;90 days or no X-ray</td>
<td>7%</td>
</tr>
<tr>
<td>Would not participate</td>
<td>65%</td>
</tr>
</tbody>
</table>

*Percentages sum to >100% because subjects may have been excluded for multiple reasons
Enrollment/Demographics

Age at Enrollment

Sex Distribution

- Female: 21%
- Male: 79%
Pediatric Clavicle Epidemiology

Activity of Injury

- Sports: 66%
- Motor vehicle accident: 5%
- Horseplay (not during sports): 6%
- Fall/trip from standing height: 1%
- Fall/trip from height > standing: 12%
- Bicycle: 3%
- Other: 8%
Enrollment/Demographics

% Athletes

- Yes, Competitive: 68%
- Yes, Non-Competitive: 20%
- No: 12%

Primary Sport Played

- Soccer: 29%
- Baseball: 22%
- Ice Hockey: 8%
- Basketball: 8%
- Lacrosse: 7%
- Skateboarding: 5%
- Others (<10 each): 18%
Pediatric Clavicle Epidemiology

**Mechanism of Injury**

- Direct blow to collar bone/chest: 24%
- Direct blow to shoulder/upper arm: 11%
- Fall onto outstretched hand: 60%
- Other: 5%

FACTS STUDY GROUP POSNA
2017
Laterality, Hand Dominance

**Side of Fracture**
- Left: 42%
- Right: 58%

**Dominant Side Injury?**
- Yes: 44%
- No: 56%
Shortening

Completely Displaced Fractures

Distance (mm)

Measuring Method
Op vs. Non-Op Treatment

83% Non-surgical
17% Surgical

VS

Children’s Healthcare of Atlanta
Treatment

Completely Displaced Fractures

- Op: 32%
- Non-op: 68%
ORIF vs. Non-op

Methods
• All pts 10-18 yrs, 2013-2018, 8 centers (n=909)
  – Completely displaced, ≥ 2 yrs, adequate PRO’s = 151 pts
  – 55 ORIF (36%) vs. 96 non-op (64%)
    • No difference in gender (76% male), competitive athletic participation, fracture pattern
    • Differences: age, fracture shortening (ORIF older, greater)

Results
• Greater percentages of operative patients reported suboptimal outcomes
  – ASES: 15% vs. 5% (p=0.07)
  – Satisfaction: 11% vs. 5 (p=0.06)
• Sensory loss
  • ORIF: 17% Sling: 8%
• Hardware
  • 9% pain
  • 4% ROH
Conclusions

• No apparent benefit to ORIF:
  – Complications
  – Patient satisfaction
  – Functional outcomes

• Need more data/time to be more definitive
  – Probably need to better identify the group who does benefit
20 patients – 10 operative, 10 non-operative

Matched series

Biodex isokinetic testing

No difference between groups

- PRO’s
  - Both showed less endurance than other shoulder
  - Maybe just underpowered to show a difference
How to measure shortening?

- **End to End**
- **Cortex to Cortex**
- **Clavicle to Clavicle**
Other Level 4 & 5 Pearls

• Repeat films at first visit, and then in 2 weeks if non-op
  – Displacement can occur
  – Spasm may diminish
  – Upright vs. Supine films

• Beware of anterior angulation
  – Re-fracture risk high

• Use clavicle specific plates
  – Contoured
  – Low profile
Clavicle Fx Rodding – Josh Murphy

- 24 Patients
- Age: 15.5 years (11-17 years)
- Male: 87%
- Healing
  - 96% periosteal bridging
- One non-union
  - Low grade infection?
- One hardware removal – easy
- One slightly bent rod
- All fx patterns
Clavicle Fx Rodding – 24 Patients

- DASH (return to sport)
  - 80% Excellent
  - 6% Mild limitations
  - 13% Limited by pain

- Conclusions
  - Load sharing alternative
  - ± Smaller incision
  - No prominence
  - Few removals
  - Few complications
  - Viable alternative for the right cases
Summary: Mid-shaft Clavicle Fx’s

- Majority: Non-op
- Look hard at both planes
- Parental expectations
- Non-unions are rare
  - Beware of congenital psuedarthrosis
- Improved gadgets, but when?
- Some indications for ORIF in kids
Indications for ORIF

- Open fracture
- Tented skin
- Multi-trauma
- Brachial plexus compromise
- ± Severe shortening
- ± Dominant shoulder in an UE athlete
- Option
- Tuition due…
Neer Classification - Distal
Distal Clavicle Fractures

- “My son separated his shoulder...”

- Distal clavicle ruptures through periosteum

• Treatment
  - Non-op vs operative
    ● Age
    ● Displacement
    ● Fx pattern

(Adapted from Sarwark et al.)
Lateral Clavicle Fractures

• Often mistaken for AC joint injuries
• Periosteum & CC ligaments intact
• Fixation is the challenge
  – Distal Plates
  – DogBone®
Case: 13yo M Cirque performer

March Injury X-Ray
Shoulder Pain

4 months later . . . Persistent shoulder pain
Distal Clavicle Plate Button (AR-2658)
Stainless steel plate button is designed to seat flush in any compression slot

15° divergent screw pattern
“Double DogBone®”

- Beach chair position
- C-arm
- Arthroscopic or open approach to coracoid
- Mobilize periosteum to allow reduction within periosteal sleeve

Willimon, SC. Techniques in Shoulder and Elbow Surgery: 2012
“Double DogBone®”

- Double cortical button suture fixation system
“Double DogBone®”
Post-op Protocol

- Sling x 6 weeks
- PROM shoulder at 2 weeks
- AROM at 6 weeks
- Strengthening at 12 weeks
- Return to sport 4-5 months
- No planned hardware removal
Medial Clavicle

- Medial clavicular epiphysis
  - Last to fuse 23-25 yrs

- Most injuries are Salter-Harris type I or II, but true dislocations may occur
  - Important to differentiate, as treatment differs
Medial Clavicle Fracture

• Often confused for SC dislocation, usually posterior

• Tremendous remodeling capacity
Medial Clavicle Fracture

- Rule-out vascular/tracheal/esophageal/neurological compromise
  - Brachiocephalic vein compression
  - Dysphagia
  - Dysphonia
  - Odynophagia

- CT vs MRI
  - Availability
  - Urgency
Treatment

• Non-operative
  – Tremendous remodeling capacity
  – Re-examine in 5-7 days
  – Sling 4-6 weeks

• Operative Treatment
  – Closed reduction often unstable, but best <24hrs
  – ORIF acute- suture
  – Pins → migration
Medial Clavicle - ORIF Pearls

• Cardiovascular Surgery available or perform exposure if needed
• Rolled Sheets or IV bag between scapula
• Wide drape exposure
• Large bore IV access
• Bone holding clamp to reduce
• Drill holes and suture fixation
• Meticulous periosteal and capsular repair
Meagan Fernandez, DO
John Erickson, DO & John Deegan, DO
See you in Atlanta next year!

Michael Busch
@CHOA.org