Expert Consensus for a Principle-Based Classification in Treatment of Diaphyseal Pediatric Femur Fractures

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Background

- Pediatric Diaphyseal Femur Fractures (PDFF) are common
- Disagreement exists in optimal treatment for this common entity
- AAOS working groups have been convened
- Recommendations given have lacked specificity and are largely not followed
- PDFF heal routinely well, as such the goal of treatment is to promote optimal healing with the least intervention and cost.
- We performed a two stage study with a survey of experts in the field, and secondarily an analysis of institutional data to assess success of the classification/

Methods

- Arm 1
  - Survey designed with 15 PDFF cases
  - Classification developed apriori but not given to raters
  - Survey given to orthopedic fellows to work out any issues prior to distribution
  - Survey given via RedCap to 17 thought leaders in PDFF
  - Thought leader defined by >20 years call experience and publication of seminal papers in PDFF literature
  - No information available to the raters as to other raters ratings or the classification itself
- Arm 2
  - 2 raters assessed 289 consecutive institutional PDFF
  - Fractures classified as "over" "under" or "ideal" treatment
  - Outcomes including complications, reoperations and cost assessed within each group as rated
  - Analyzed in terms of each classification level

Results (Expert Arm)

- 100% response rate
- Substantial Agreement for Classification (K 0.7)
- Near Perfect for Operative vs Non Operative (K 0.93)
- Flexible fixation vs Rigid near perfect (K 0.83)
- Damage control Substantial agreement (K 0.64)

Results (Institutional Arm)

- Suboptimal results found in 43% of undertreated patients 18.8% in those treated as recommended, and 14.3% of overtreated patients. (p value <0.01)
- Family burden increased as more aggressive fixation was pursued.
- Charges trended higher as more invasive treatment was pursued.

Results- Family Burden

Group	Class 1 Median (IQR)	Class 2 Median (IQR)	Class 3 Median (IQR)	Class 4 Median (IQR)	Class 5 Median (IQR)	P value
Length of Inpatient Stay (Days)	1 (1-1)	1(1-2)	1.5 (1-3)	2 (1-4)	7 (3.1-38.25)	<0.01
Total Number of Outpatient Visits	2.5 (2-3)	4 (3-5)	5 (4-6)	4 (3-6)	5.5(3.25-6.75)	<0.01

Classification

Class 1 "Protect Until Healed"

- Age <6M: **Pavlik Harness /Soft Padding**
  - All type of fractures
  - High index of suspicion for abuse
- Ages 6M- 4Y: **Preferably Walking Spica Cast**
  - Incomplete fractures
  - Complete, strict non-displaced fractures
- Neuro-muscular non-ambulant patient: **Spica Cast/ Splint Cast/ Knee Brace**

Class 2 "Active Cast Treatment"

- Ages 6M- 4Y: **Walking / Regular Spica Cast, Close and Early Follow-up (within 10 days)**
  - Complete fractures with any displacement or shortening (in cases of modest shortening Walking Spica is preferred)
  - Prepare for cast-wedging during follow-up

Class 3 "Flexible Fixation"

- Ages 4-9 years: **Elastic Nailing**
  - All simple fractures (2 parts)
- Age 9 years-until skeletal maturity: **Elastic Nailing**
  - Simple fractures (2 parts) plus:
    - Length stable fractures (transverse, short oblique pattern)
    - Low energy trauma
    - Weight<50 Kg

Class 4 "Rigid Fixation"

- Ages 4-9 years: **Sub-muscular Plate** or **External Fixation**
  - Complex (>2 parts) or comminuted fractures
- Age 9 years- until skeletal maturity: **Trochanteric-entry Rigid Nail** or **Sub-muscular Plate** or **External Fixation**
  - length unstable fractures (long spiral/oblique pattern)
  - High energy trauma
  - Weight >50 Kg
- After skeletal maturity: **Trochanteric-entry Rigid Nail** or **Sub-muscular Plate** or **External fixation**

Class 5 "Limb/Life Preservation"

- All ages: **Appropriate Early Care (Rigid Fixation)** VS. **Damage Control Orthopedics (Staged Approach Usually with Temporal External Fixation)**
  - Systemic hemodynamic instability
  - Multi-trauma injuries
  - Mangled extremity
  - Open fractures with high energy trauma or severe contamination
  - Vascular injury

Results (Costs)

Table 4. Reported Charges for A Random Small Sample of Patients

Group	Median charges	IQR	P value
Conservative Treatment (Classes 1-2)	$168,141	$42,782 - $201,784	<0.001
Surgical Treatment (Classes 3-5)	$700,554	$432,520 - $999,630	
Class 1 Imaging (Radiology) Charges	$19619	$16,106.5- $34,840.5	<0.001
Class 2 Imaging (Radiology) Charges	$20796.5	$3,656- $29,371.5	
Class 3 (Flexible Fixation) Total Charges	$416,122	$323,748 - $822,954	0.047
Class 4 (Rigid Fixation) Total Charges	$510,538	$344,404 - $714,122	
Class 3 Surgical and Adjunct Supply Charges	$11,773.5	$9,845 – $11,774	0.001
Class 4 Surgical and Adjunct Supply Charges	$39,136	$14,429 –$ 39,135	
One Stage Procedure (Classes 3-4)	$471,529	$339,084 - $724,332	0.024
Two Staged Procedures (Class 5)	$1,113,846	$700,554 - $4,610,244	

*IQR= interquartile range

Complications by treatment

	Under-Treated	Treated Appropriately	Over-Treated
Radiographic Malunion	20/56 (35.7%)	31/191 (16.2%)	4/42 (9.5%)
Return to operation room (ROR)	4/56 (7.1%)	11/191 (5.7%)	1/42 (2.3%)
Loss of reduction (LOR)	3/56 (5.3%)	6/191 (3.1%)	1/42 (2.3%)
Residual limb length discrepancy (LLD)>2 cm	2/56 (3.5%)	1/191 (0.5%)	1/42 (2.3%)
Surgical site infection (SSI).	0/56	2/191 (1%)	1/42 (2.3%)

Discussion

- This classification was developed by the senior author over 20 years
- This study has shown the classification system to be reliable and has validated the classification for usage with 17 leading pediatric orthopedic trauma experts.
- Reliability estimates were high exceeding many commonly used fracture classification systems
- Usage of less surgically invasive means than recommended by the classification system results in more complications and less optimal outcome
- Usage of more surgically means than recommended by the classification results in greater costs, length of stay and doctors visits on average.
- The concept of the role of "Damage Control" orthopedics is poorly understood with respect to children, and likely has less to do with the polytraumatized child than the child with a vascular injury.
- Strengths include a sample of experts from across the country with >20 years of experience and a large institutional sample for the validation arm and perfect response rate
- Weaknesses include small survey size, and low numbers of certain arms of the classification including small numbers of patients for damage control

Conclusions

- This PDFF classification has been shown to be reliable and predictive of outcome via this study
- The guiding principle has been to provide the optimal outcome at the least possible cost and inconvenience to the family.
- This classification can be used as a reliable framework for community orthopedists pediatric orthopedists and fracture surgeons to guide selection of a treatment strategy for pediatric diaphyseal femur fractures.

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