

# Biomechanical and Clinical Evaluation of Rib Anchors

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# Current thoughts on management of kyphosis

*Papers roughly fall into 1 of 3 categories*

- “We got this”
- “We got this.....I’m not so sure”
- “We got this ....I don’t think so”

# Papers in your outline

- Positive papers generally deal with kyphosis in or near normal range
- “I’m not so sure “ papers focused on Growing Rods, increased kyphosis associated with worse results
- “I don’t think so” papers more associated with VEPTR

# “Normal” thoracic kyphosis in children

- 20-50 degrees, *Boseker, Moe et al, 2000*
- Average 39.9 degrees in children 8-19, *Ghandhari et al, 2013*



# Evaluating the Extent of Clinical Uncertainty Among Treatment Options for Patients with Early-Onset Scoliosis

Jacqueline Corona, MD, Daniel J. Miller, MD, Jenny Downs, PhD, MSc, Behrooz A. Akbarnia, MD, Randal R. Betz, MD, Laurel C. Blakemore, MD, Robert M. Campbell Jr., MD, John M. Flynn, MD, Charles E. Johnston, MD, Richard E. McCarthy, MD, David P. Roye Jr., MD, David L. Skaggs, MD, John T. Smith, MD, Brian D. Snyder, MD, PhD, Paul D. Sponseller, MD, MBA, Peter F. Sturm, MD, George H. Thompson, MD, Muharrem Yazici, MD, and Michael G. Vitale, MD, MPH

*Investigation performed at Columbia University Medical Center, New York, NY*

**Results:** Collective equipoise was identified in numerous scenarios in the survey spanning a range of ages and magnitudes of scoliosis, and additional questions were identified during the nominal group technique. Areas that had the greatest clinical uncertainty included the management of patients who have finished treatment with a growing-rod, timing of rod-lengthening intervals, and indications for spine-based and rib-based proximal instrumentation anchors. The use of rib anchors compared with spine-based anchors was ranked highly for consideration in future clinical trials.

# The Rib Construct(RC) - How it started

*5 year old boy with VATER syndrome*



# Initial management single growing rod



Age 12, bone age delayed 2 years  
Rapid development lumbar curve, kyphosis

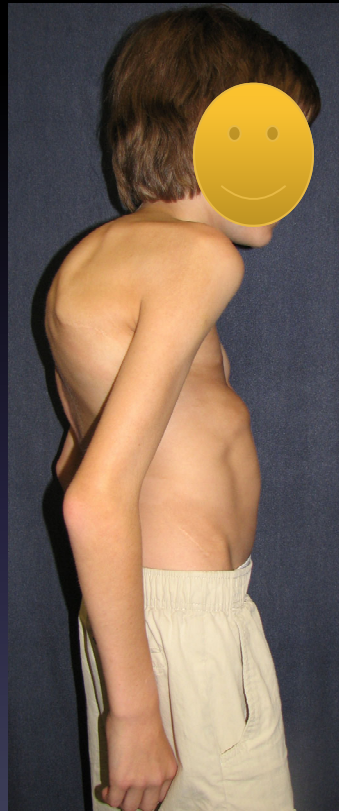


Rods extended to pelvis – good correction  
but a problem – he cried for 3 months until they were  
removed



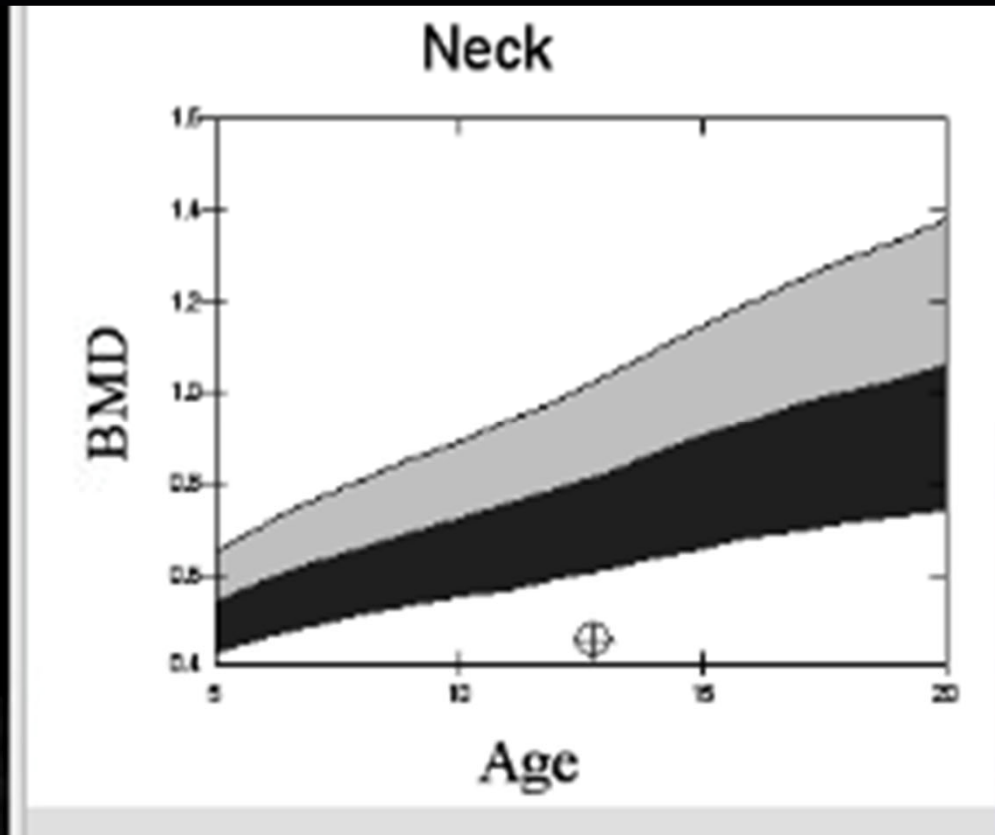


# Risser casts, brace unsuccessful now 6 months after instrumentation removed



Note sternum compressing stomach

I thought his radiographs looked pretty suggestive for osteoporosis



# Osteoporosis – an overlooked variable?

- Search for osteoporosis and growing rods, and osteoporosis and VEPTR, zero results
- “BMD has close relationship with the stability of pedicle screws in vivo” *Okuyama, et al*



# Development and Initial Validation of the Classification of Early-Onset Scoliosis (C-EOS)

Brendan A. Williams, MD, Hiroko Matsumoto, MA, Daren J. McCalla, BS, Behrooz A. Akbarnia, MD, Laurel C. Blakemore, MD, Randal R. Betz, MD, John M. Flynn, MD, Charles E. Johnston, MD, Richard E. McCarthy, MD, David P. Roye Jr., MD, David L. Skaggs, MD, John T. Smith, MD, Brian D. Snyder, MD, PhD, Paul D. Sponseller, MD, MBA, Peter F. Sturm, MD, George H. Thompson, MD, Muharrem Yazici, MD, and Michael G. Vitale, MD, MPH

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**TABLE II Variable Content Validity Rankings\***

Variable	Not Useful	Useful	Essential	CVR
Major curve angle	0	1	13	0.86
Etiology	0	3	11	0.57
Kyphosis	0	3	11	0.57
Age	5	0	9	0.29
Progression	3	5	6	-0.14
Curve flexibility	3	6	5	-0.29
Chest wall abnormalities	2	8	4	-0.43
Other comorbidities	3	8	3	-0.57
Pulmonary function	3	8	3	-0.57
Nutritional status	5	7	2	-0.71
Ability to walk	2	11	1	-0.86
Mental function	9	5	0	-1.00
Bone quality	10	4	0	-1.00

Fourteen surgeons participated in the primary survey of classification content. The participants rated the thirteen proposed variables included on the primary survey with a 3-point Likert scale used to assess the content validity ratio (CVR) as proposed by Lawshe<sup>26</sup>.



If everyone is thinking alike, then somebody isn't thinking.

(George S. Patton)

[izquotes.com](http://izquotes.com)

# Role of BMD in pedicle screw purchase

- “Understanding the the effects of pedicle morphology, **BMD**, pedicle screw design, insertion technique, and screw tapping is paramount to effectively correct spinal deformity” *Lehman et al, 2012*
- “For the same thread design and size, insertional torque is directly related to BMD, which, in turn, is directly related to pullout strength” *Cho et al, J Bone Joint Surg(Br), 2010;92-B: 1061-5*

# So, now what to do?

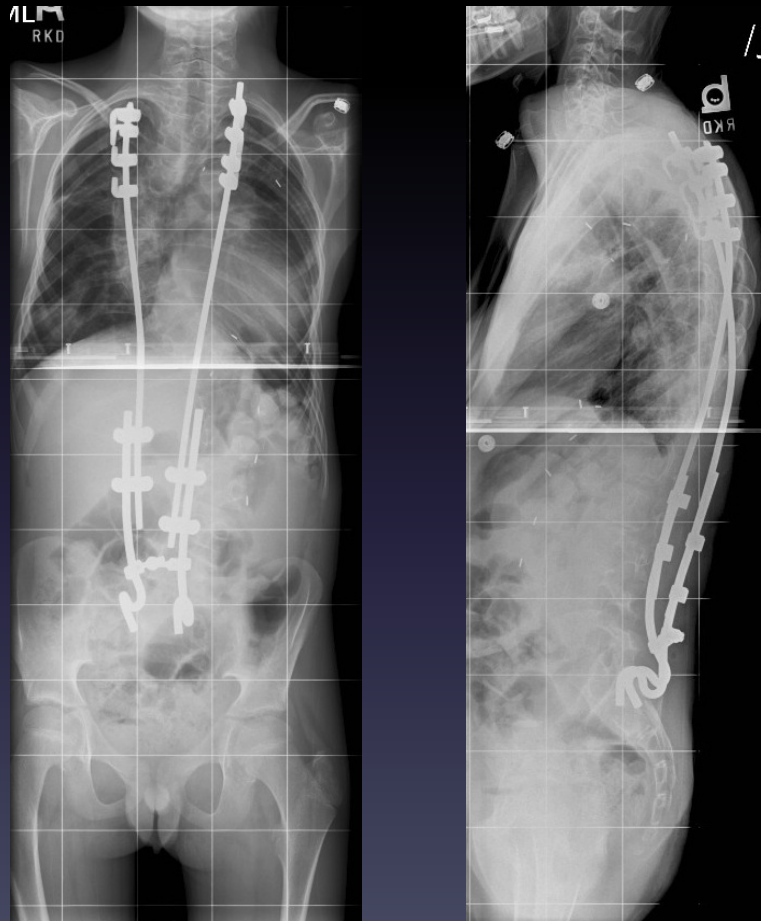
- I did not get very much help

# The rib construct



Gros

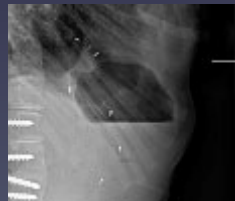
Condensing his course, Rib construct effective,  
4 additional procedures over 7 years



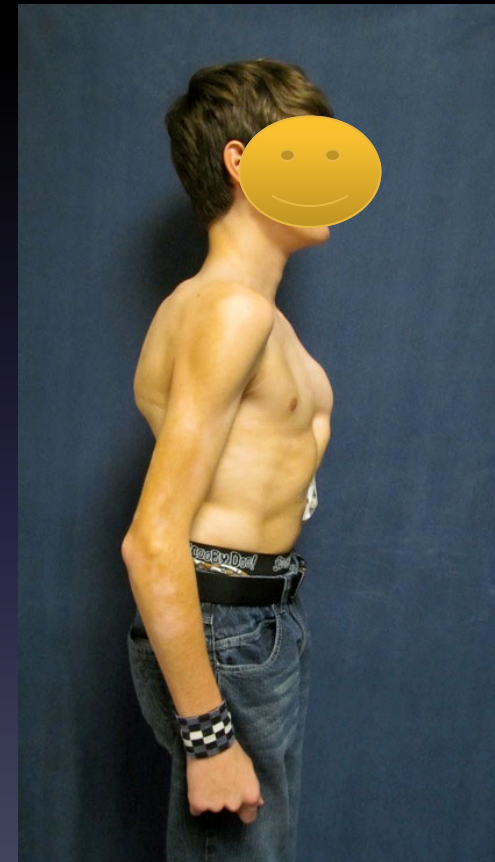
"S" rods consistently migrated into sacrum in patients with osteoporosis

# Current status

## 7 years postop initial procedure



Note sternal pressure  
on stomach relived -  
still has G tube



More on him a little later



# Clinical results – Thoracic Kyphosis

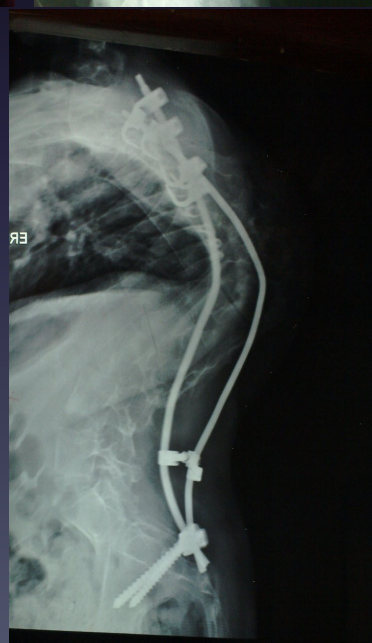
- 14 patients (7 syndromic, 4 neuromuscular, 3 congenital), age 4-21
- Treated in Charleston, SC or Nablus, Palestine
- Preop kyphosis average 107.8 degrees (71-145)
- Followup average 44.4 months (29-84)
- Postop average kyphosis 69.5 degrees (32-113)
- 4 Charleston patients had BMD studies, T scores ranged from -2.7 to -6.9, average -4.2



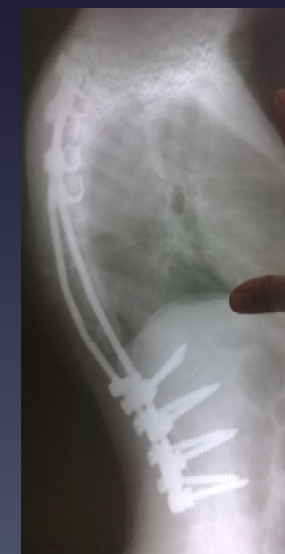
# Alaa



Diastematomyelia - 140  
degrees preop kyphosis, 85  
degrees postop



Neurofibromatosis – 134  
degrees preop, 55 postop after  
conversion to 5.5 rods



# Complications

- 2 patients died of unrelated causes
- 5 proximal loss of fixation, salvaged
- 2 proximal fixation failures, both osteoporosis, and early in series
- 2 delayed wound infections, 1 reinstrumented one year later with salvaged result

# Biomechanics of proximal kyphosis

*(Yongren Wu, PhD, Clemson)*



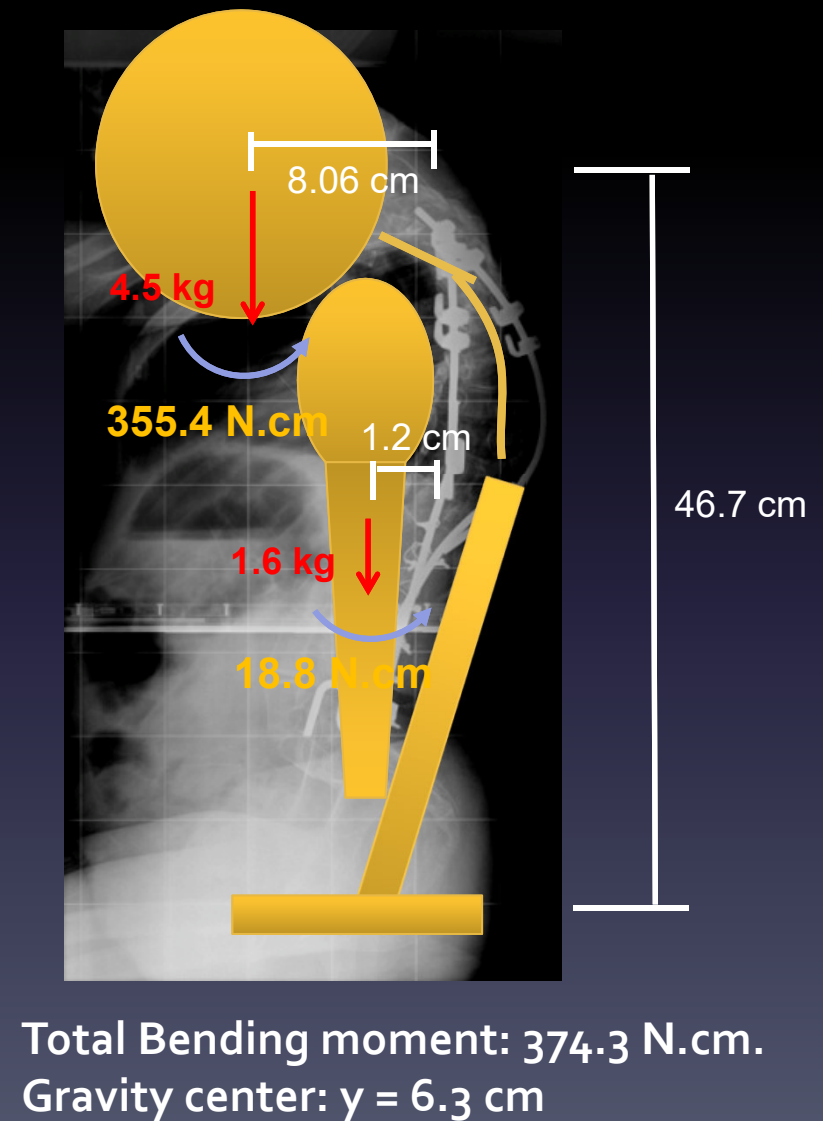
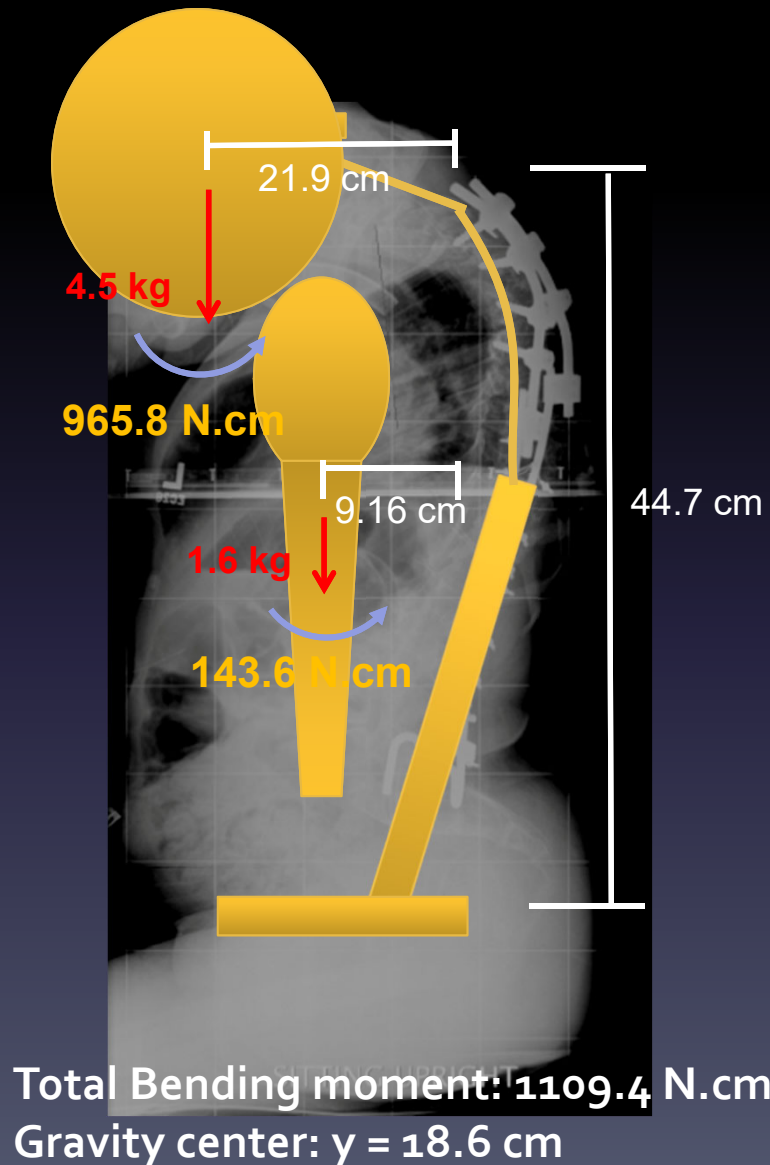


Ventilator  
dependent  
child. Kyphosis  
145 degrees,  
multiple failed  
procedures

Rib construct  
inserted. Kyphosis  
113 degrees despite  
displacement of 2  
superior hooks.  
Died 6 months after  
this radiograph.



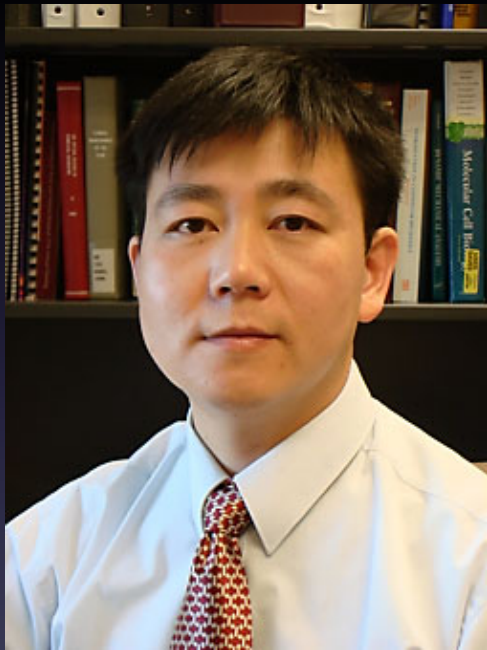
Deforming forces - which can be visualized as a force vector - were neutralized



# Resistance of pedicle screws and rib construct to kyphotic pullout forces

- 2011 SRS new investigator grant
  - Original submission designed to test rib construct, pedicle screws(growth rods), and VEPTR
    - Synthes spine refused to make VEPTRs available for study – could not even purchase

# Work done by.....



Hai Yao, PhD



Greg Wright, PhD Candidate



# Pedicle screws



As kyphotic deflection and force increased, there was a partial failure(arrow), then complete failure in all specimens

# Pedicle screws – all failed at remarkably consistent deflection angle

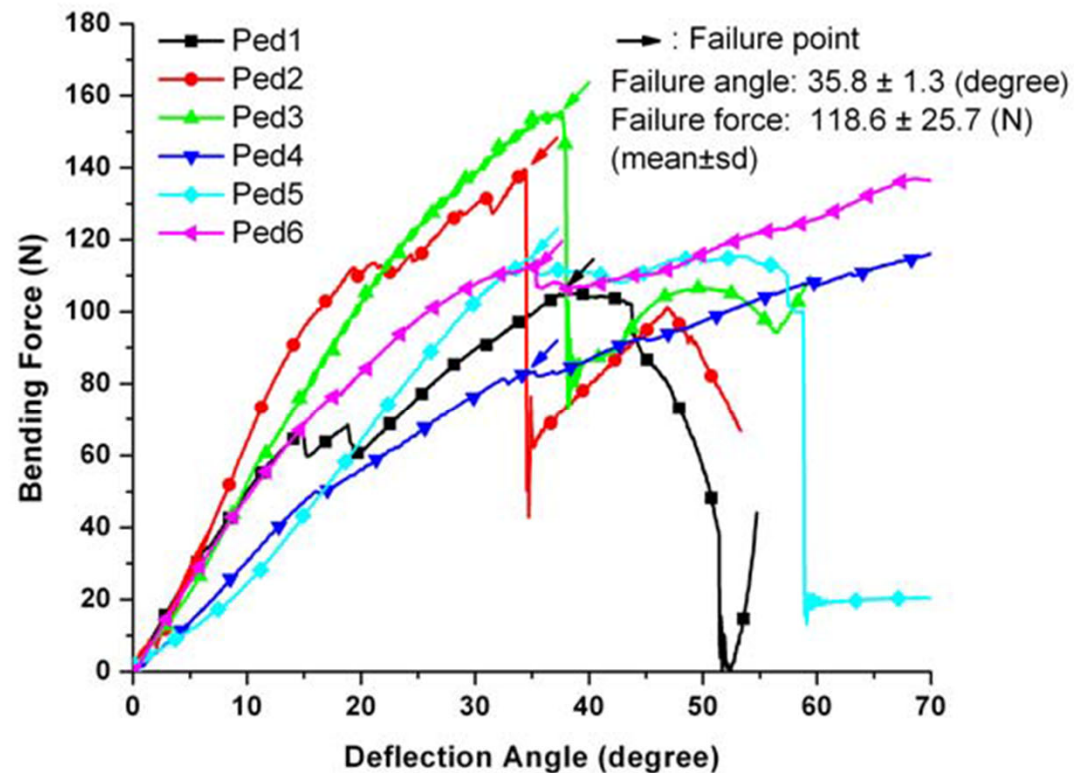
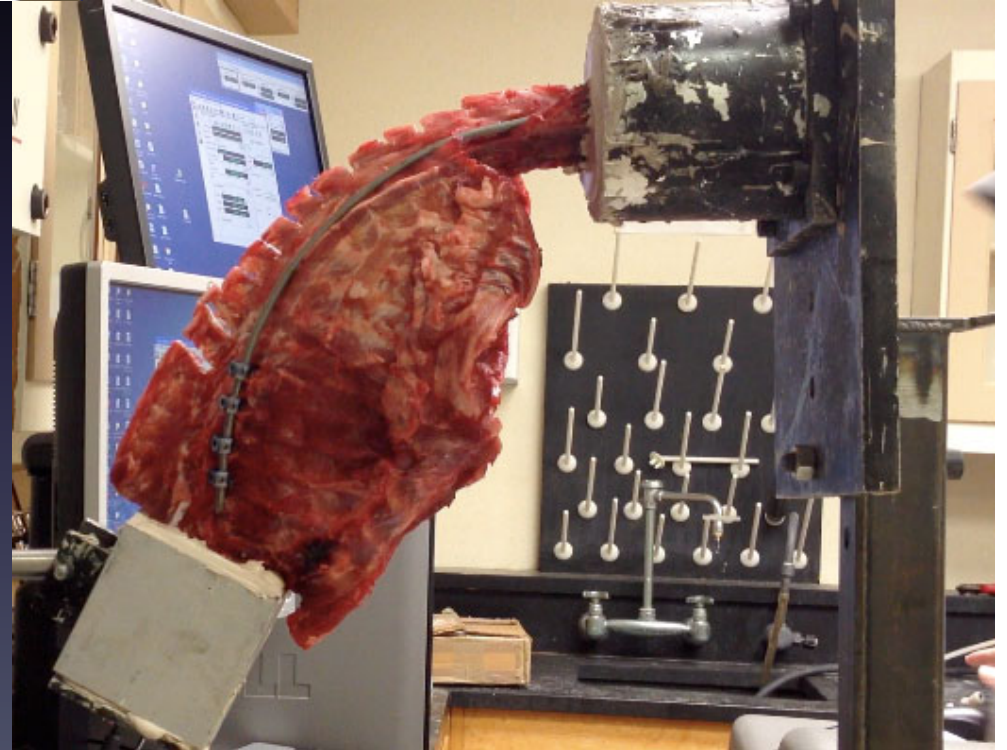


Figure 1. The pedicle screw group with failure.

# Rib construct



No failure in any of the  
6 constructs tested



# Rib Construct – no failures

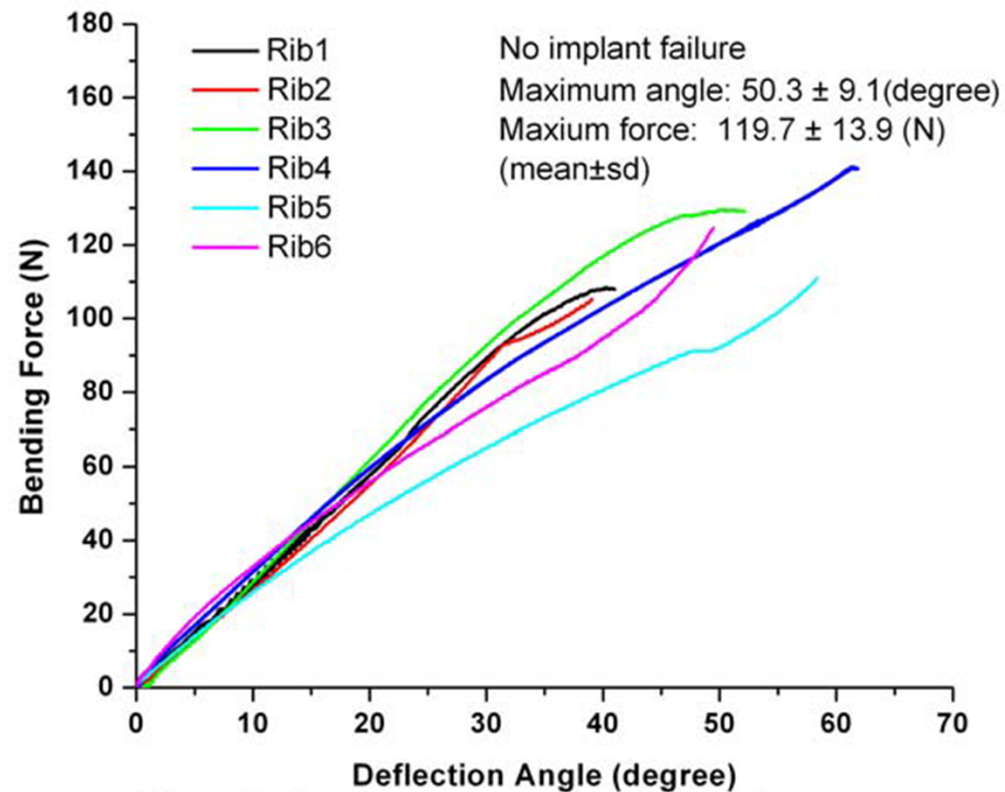


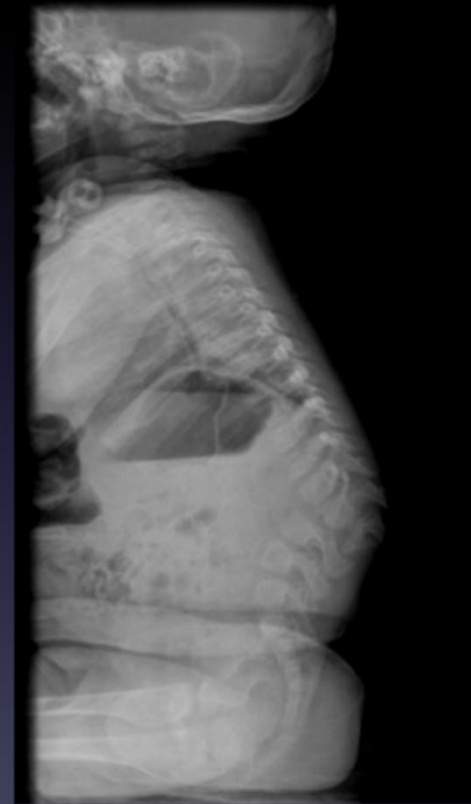
Figure 2. The rib construct group without failure.

# Practical applications

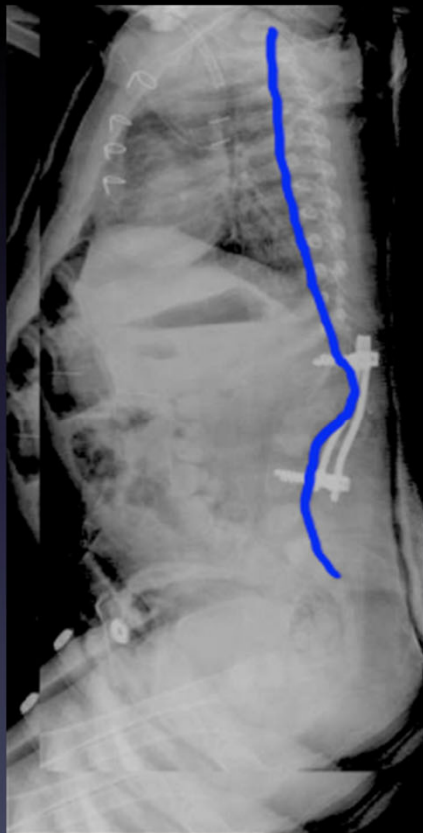


# Congenital Dislocation of Spine

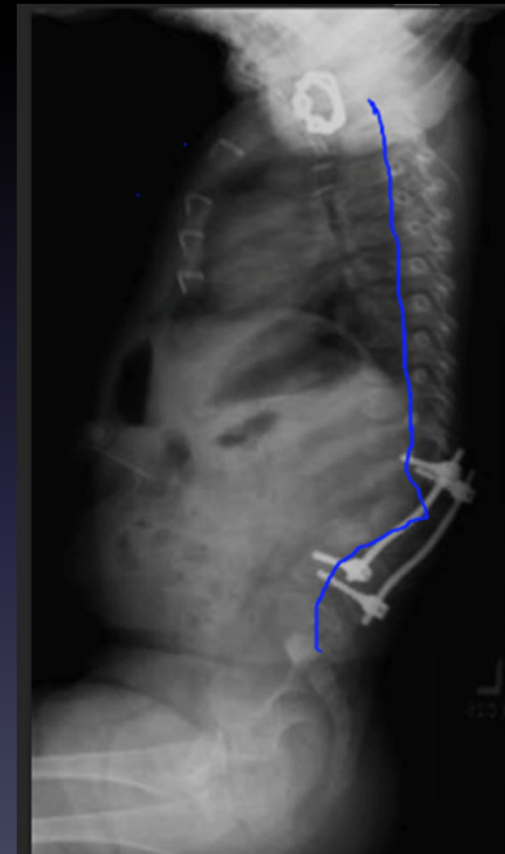
## 11 months old



# Resection of hemivertebra age 18 months

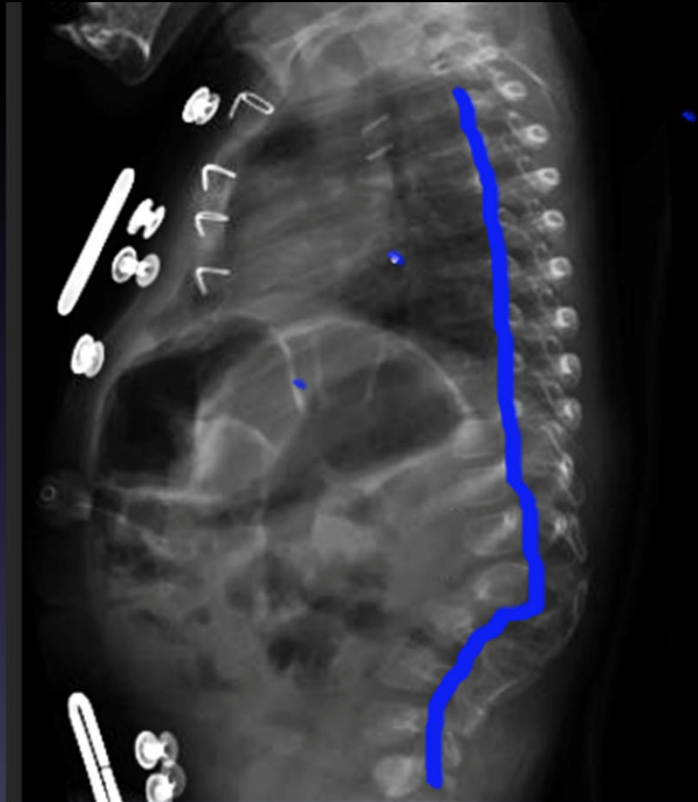


Initially after surgery



5 months later, pullout of superior screws

# Instrumentation removed



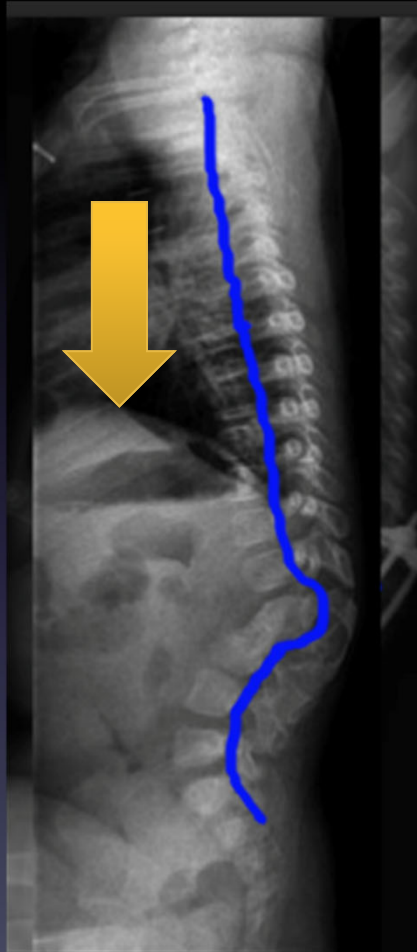
19 months



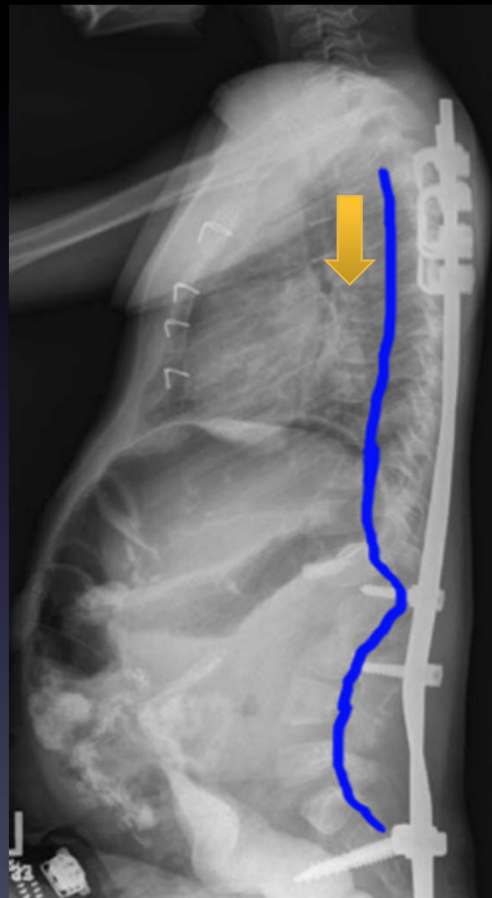
24 months



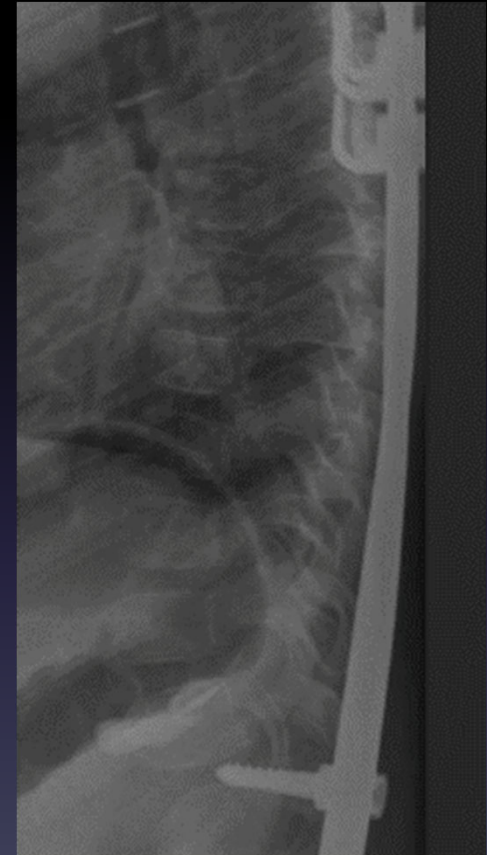
# First RC age 28 months



preop



Deforming force reduced



Subluxation above screw-  
not controlled

# Screws replaced 1 level superiorly



Now 41 months postop initial procedure –  
with 2 revisions



More anterior remodeling needed

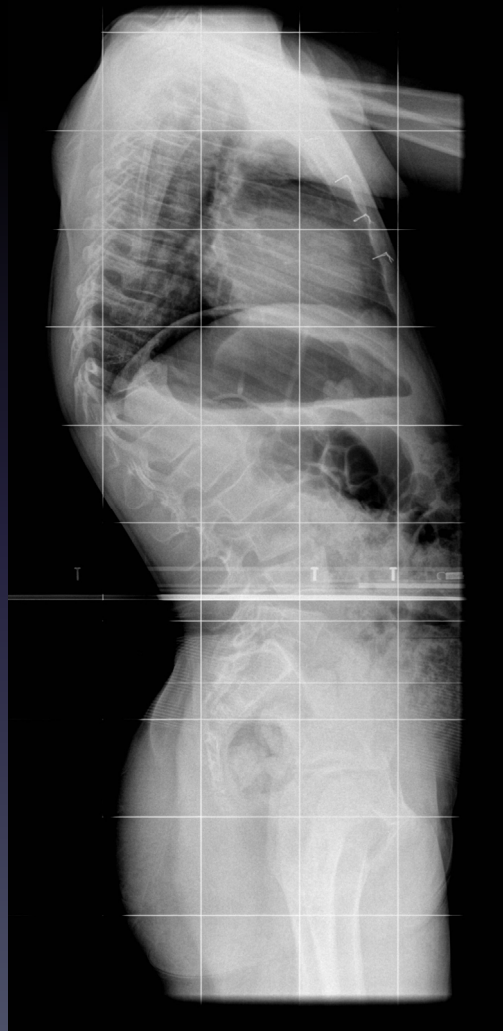
# Original and current



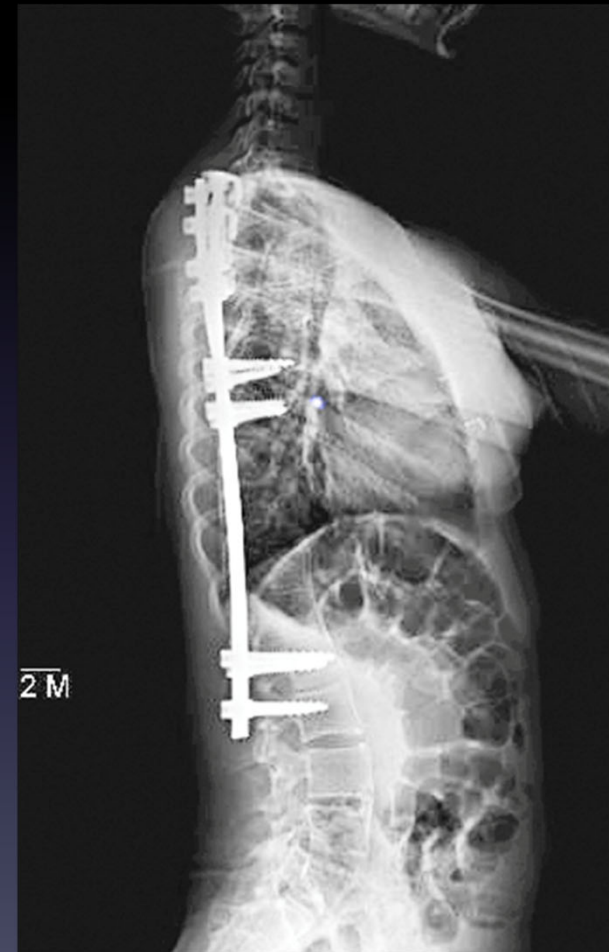


# Alternative to VCR

age 9+5



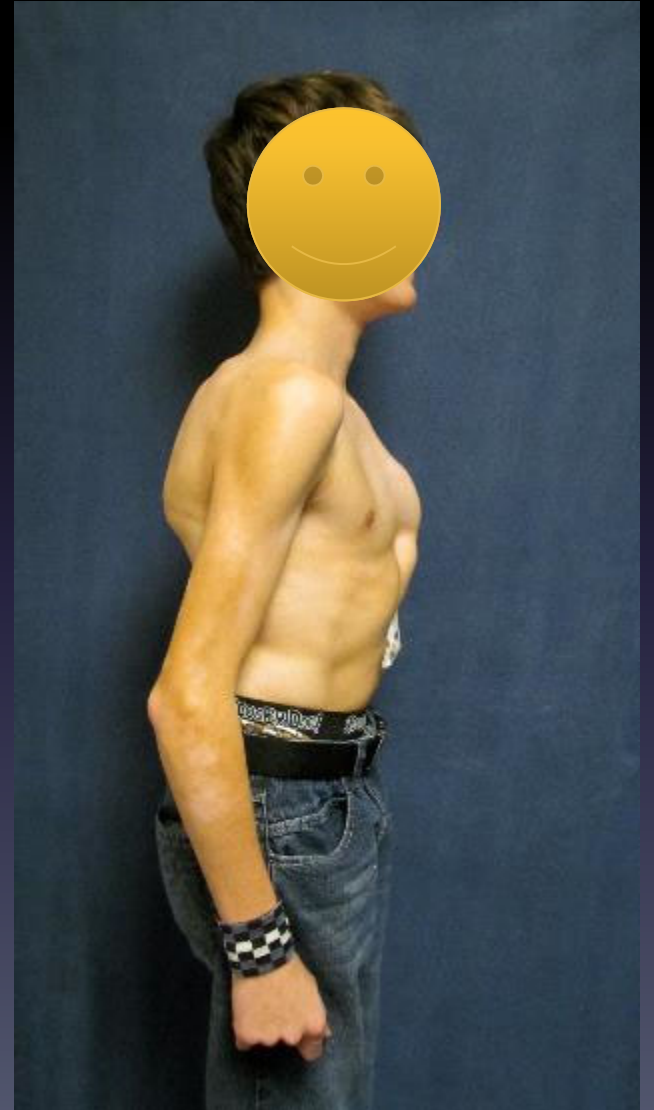
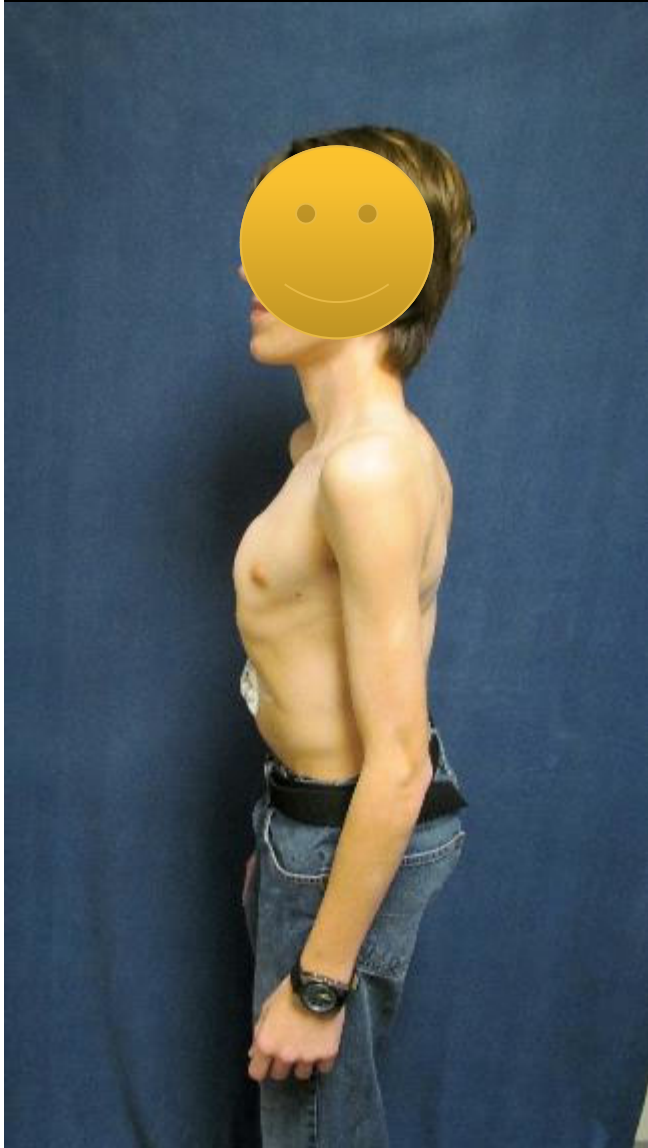
# Mini-thoracotomy, anterior release, RC, 2 revisions, now skeletally mature



Instrumentation did no bother her,  
Left in place



# The first case



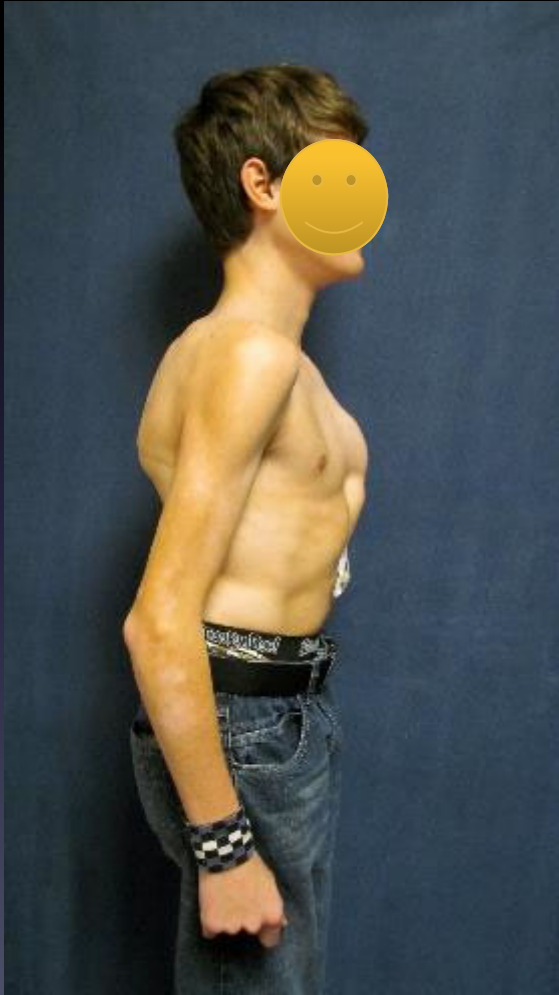
# What I did “Scapulopexy”



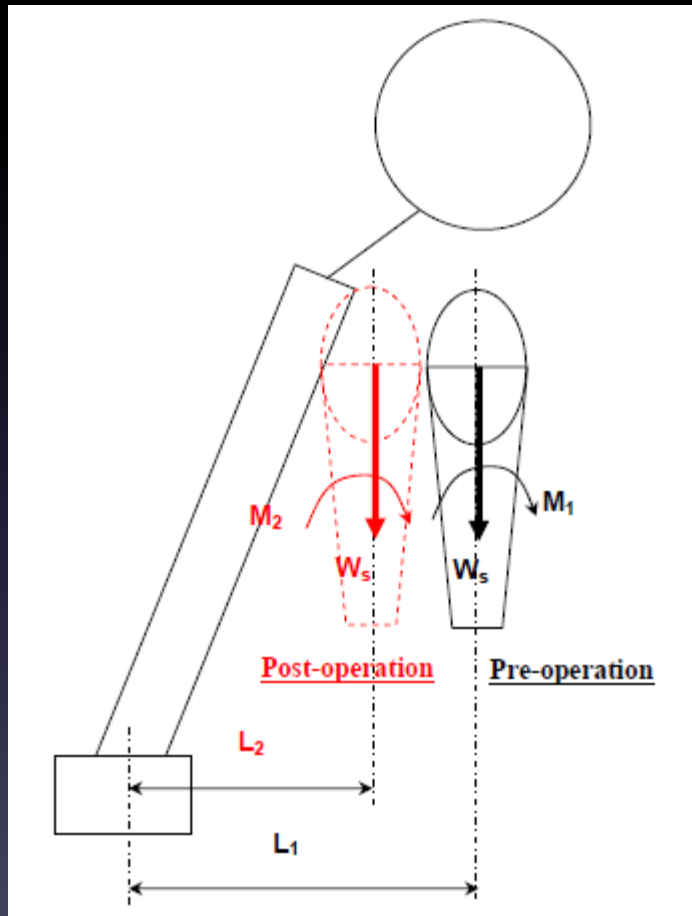
# Postop



# Preop and postop



# Effect of shoulder protraction on kyphosis



$W_s/W_s$ : weight of shoulder

$L_1$ : moment arm (pre-operation)

$L_2$ : moment arm (post-operation)

$M_1$ : kyphotic moment induced by shoulder (pre-operation)

$M_2$ : kyphotic moment induced by shoulder (post-operation)

Kyphotic moment induced by shoulder weight:

$$M = W_s \cdot L$$

$$\therefore L_2 < L_1$$

$$\therefore M_2 < M_1$$

# Preop motion





# Postop motion



# Alaa's technique for kyphosis associated with spina bifida







# postop



# Conclusion

The rib construct is versatile and reliable

# Thank you

