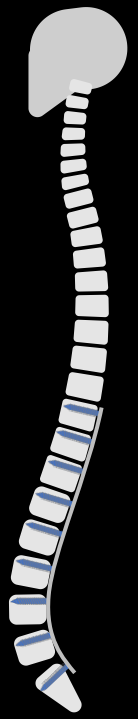
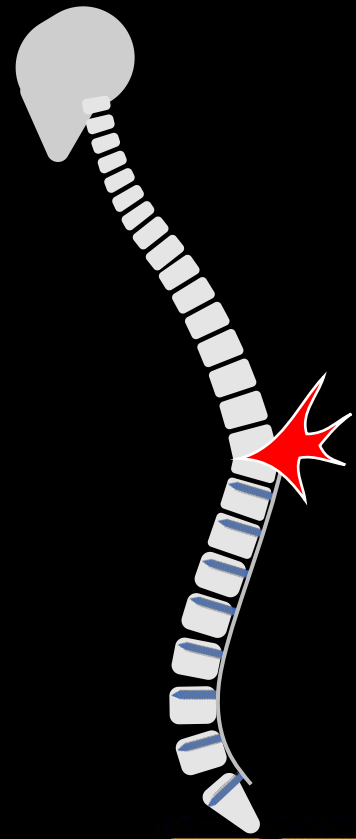
A Patient-Specific Approach to Alignment & Proximal Junctional Kyphosis Risk in Adult Spinal Deformity Patients





Jeff Hills, MD

UT Health San Antonio

Co-Authors: Benjamin Weisenthal, MD

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Jackie Pennings, PhD

Byron Stephens, MD

UT Health San Antonio Orthopaedics

Study conducted at Vanderbilt University Medical Center, Nashville, TN

Current Understanding of PJK and Risk for PJK

Spine Deformity

A Comprehensive Review of Complication Rates After Surgery for Adult Deformity: A Reference for Informed Consent

Daniel M. Sciubba, MD[a,*], Alp Yurter, BS[a], Justin S. Smith, MD, PhD[b], Michael P. Kelly, MD[c], Justin K. Scheer, BS[d], C. Rory Goodwin, MD, PhD[a], Virginie Lafage, PhD[e], Robert A. Hart, MD[f], Shay Bess, MD[g], Khaled Kebaish, MD[h], Frank Schwab, MD[e], Christopher I. Shaffrey, MD[b], Christopher P. Ames, MD[i], The International Spine Study Group (ISSG)

PJK Rate 10-40%

Proximal Junctional Kyphosis and Failure After Spinal Deformity Surgery

A Systematic Review of the Literature as a Background to Classification Development

Darryl Lau, MD,* Aaron J. Clark, MD, PhD,* Justin K. Scheer, BS,† Michael D. Daubs, MD,‡ Jeffrey D. Coe, MD,§ Kenneth J. Paonessa, MD,¶ Michael O. LaGrone, MD,‖ Michael D. Kasten, MD,** Rodrigo A. Amaral, MD,†† Per D. Trobisch, MD,‡‡ Jung-Hee Lee, MD,§§ Daniel Fabris-Monterumici, MD,¶¶ Gurpreet Anand, MD,‖‖ Andrew K. Cree, MD,*** Robert A. Hart, MD,††† Lloyd A. Hey, MD, MS,‡‡‡ Christopher P. Ames, MD,* and the SRS Adult Spinal Deformity Committee

What Factors Predict the Risk of Proximal Junctional Failure in the Long Term, Demographic, Surgical, or Radiographic?

Results From a Time-dependent ROC Curve

Jingyan Yang, MHS,*† Marc Khalifé, MD,‡ Renaud Lafage, MS,* Han Jo Kim, MD,* Justin Smith, MD,§ Christopher I. Shaffrey, MD,§ Douglas C. Burton, MD,¶ Christopher P. Ames, MD,* Gregory M. Mundis Jr., MD,** Richard Hostin, MD,†† Shay Bess, MD,‡‡ Eric O. Klineberg, MD,§§ Robert A. A Hart, MD,¶¶ Frank J. Schwab, MD,* and Virginie Lafage, PhD*, International Spine Study Group (ISSG)

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Age-Adjusted Alignment Goals Have the Potential to Reduce PJK

Renaud Lafage, MS,* Frank Schwab, MD,* Steve Glassman, MD,† Shay Bess, MD,‡ Bradley Harris, JD,‡ Justin Sheer, MS,§ Robert Hart, MD,¶ Breton Line, BSME,‖ Jensen Henry, BS,‡ Doug Burton, MD,** Han Jo Kim, MD,* Eric Klineberg, MD,†† Christopher Ames, MD,‡‡ and Virginie Lafage, PhD*, International

Orientation of the Upper-most Instrumented Segment Influences Proximal Junctional Disease Following Adult Spinal Deformity Surgery

Renaud Lafage, MS,* Breton G. Line, MD,† Sachin Gupta, MD,‡ Barthelemy Liabaud, MD,* Frank Schwab, MD,* Justin S. Smith, MD,§ Jeffrey L. Gum, MD,¶ Christopher P. Ames, MD,‖ Richard Hostin, MD,** Gregory M. Mundis Jr., MD,†† Han Jo Kim, MD,* Shay Bess, MD,‡‡ Eric Klineberg, MD,§§ and Virginie Lafage, PhD*, International Spine Study Group (ISSG)¶¶

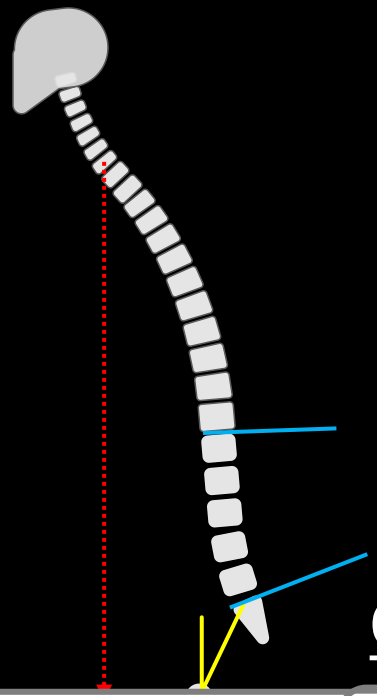
Effective Prevention of Proximal Junctional Failure in Adult Spinal Deformity Surgery Requires a Combination of Surgical Implant Prophylaxis and Avoidance of Sagittal Alignment Overcorrection

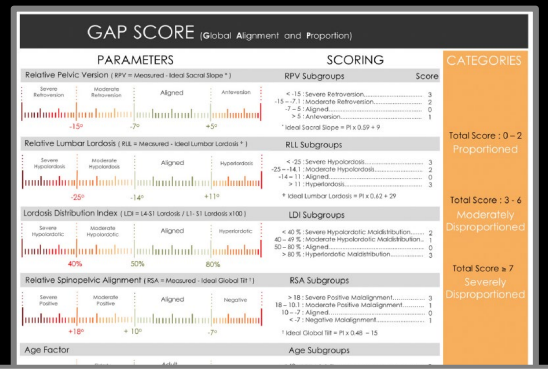
Breton G. Line, BS,* Shay Bess, MD,* Renaud Lafage, BS,† Virgine Lafage, PhD,† Frank Schwab, MD,† Christopher Ames, MD,‡ Han Jo Kim, MD,† Michael Kelly, MD,§ Munish Gupta, MD,§ Douglas Burton, MD,¶ Robert Hart, MD,‖ Eric Klineberg, MD,** Khaled Kebaish, MD,†† Richard Hostin, MD,‡‡ Gregory Mundis, MD,§§ Robert Eastlack, MD,§§ Christopher Shaffrey, MD,¶¶ and Justin S. Smith, MD, PhD¶¶, International Spine Study Group

Risk Factors Commonly Reported:

- ***Age & frailty***
- ***Osteoporosis***
- ***Implants***
- ***Degree of Deformity Correction/Surgical Alignment***

What is the Optimal Sagittal Alignment?





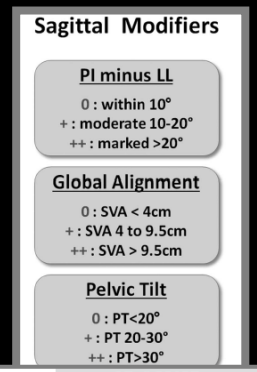
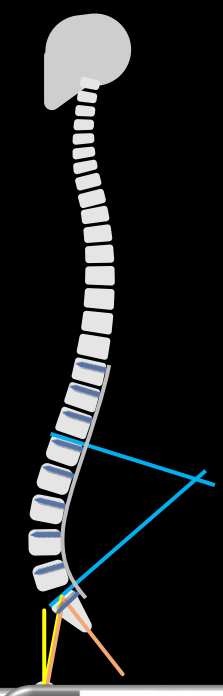


TABLE 1. Ideal Age-Specific Alignment Criteria

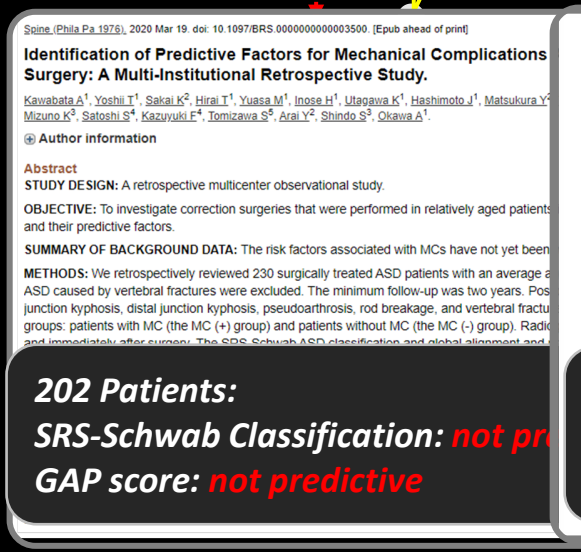
Age Group (yr)	PT (°)	PI–LL (°)	SVA (mm)
<35	11.0	−10.5	−30.5
35–44	15.4	−4.6	−5.5
45–54	18.8	0.5	15.1
55–64	22.0	5.8	35.8
65–74	25.1	10.5	54.5
≥74	28.8	17.0	79.3

LL indicates lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis.

PT OFFSET		
<40	40–65	≥65
PI-LL OFFSET		
<40	40–65	≥65
SVA OFFSET		
<40	40–65	≥65



Classify Alignment as:



Spine (Phila Pa 1976). 2020 Mar 19. doi: 10.1097/BRS.0000000000003500. [Epub ahead of print]

Identification of Predictive Factors for Mechanical Complications Surgery: A Multi-Institutional Retrospective Study.

Kawabata A[1], Yoshii T[1], Sakai K[2], Hirai T[1], Yuasa M[1], Inose H[1], Utagawa K[1], Hashimoto J[1], Matsukura Y[2], Mizuno K[3], Satoshi S[4], Kazuyuki F[4], Tomizawa S[5], Arai Y[2], Shindo S[3], Okawa A[1].

Author information

Abstract

STUDY DESIGN: A retrospective multicenter observational study.

OBJECTIVE: To investigate correction surgeries that were performed in relatively aged patients and their predictive factors.

SUMMARY OF BACKGROUND DATA: The risk factors associated with MCs have not yet been

METHODS: We retrospectively reviewed 230 surgically treated ASD patients with an average a ASD caused by vertebral fractures were excluded. The minimum follow-up was two years. Pos junction kyphosis, distal junction kyphosis, pseudoarthrosis, rod breakage, and vertebral fractu groups: patients with MC (the MC (+) group) and patients without MC (the MC (-) group). Radio

202 Patients:
SRS-Schwab Classification: not pr
GAP score: not predictive

Ability of the Global Alignment and Mechanical Failure Following A Surgery—Validation in 149 Patients

Tanvir Johanning Bari, MD[a,*], Søren Ohrt-Nissen, M Benny Dahl, MD, PhD, DMSc[b], Mart

[a]Spine Unit, Department of Orthopedic Surgery, University Hospital
[b]Department of Orthopedics and Scoliosis Surgery, Texas Children's Hospital a

Received 4 June 2018; revised 27 July 2018;

Abstract

Study Design: Retrospective analysis of prospectively collected data.
Objectives: To validate the Global Alignment and Proportion (GAP) score patients.
Summary of Background Data: Surgical treatment for ASD is associated wit surgery. To improve prediction of mechanical complications, the GAP score was on the assumption that not all patients would benefit from the same fixed morphological parameter that greatly influences the sagittal curves of the spin

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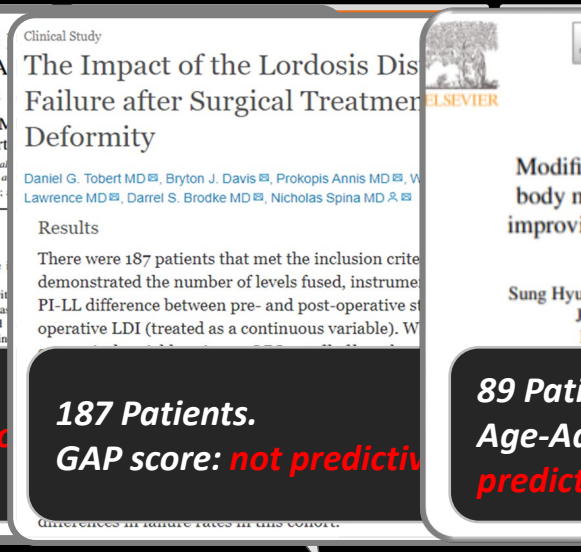
149 Patients.
GAP score: not predictive c
Complications



Clinical Study

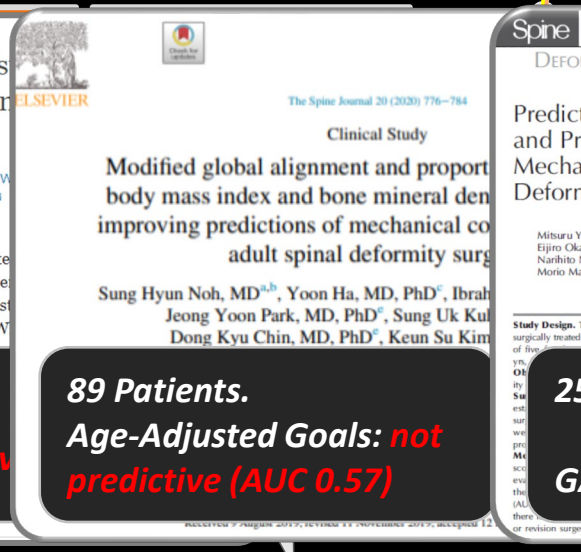
The Impact of the Lordosis Dis Failure after Surgical Treatmer Deformity

Daniel G. Tobert MD, Bryton J. Davis, Prokopis Annis MD, W Lawrence MD, Darrel S. Brodke MD, Nicholas Spina MD

Results

There were 187 patients that met the inclusion crite demonstrated the number of levels fused, instrume PI-LL difference between pre- and post-operative s operative LDI (treated as a continuous variable). W

187 Patients.
GAP score: not predictiv



ELSEVIER

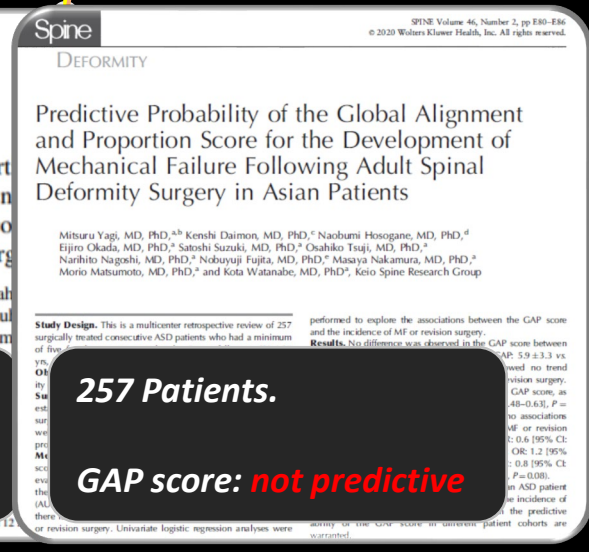
The Spine Journal 20 (2020) 776–784

Clinical Study

Modified global alignment and proport body mass index and bone mineral den improving predictions of mechanical co adult spinal deformity surg

Sung Hyun Noh, MD[a,b], Yoon Ha, MD, PhD[c], Ibrah Jeong Yoon Park, MD, PhD[c], Sung Uk Ku Dong Kyu Chin, MD, PhD[c], Keun Su Kim

89 Patients.
Age-Adjusted Goals: not predictive (AUC 0.57)



Spine

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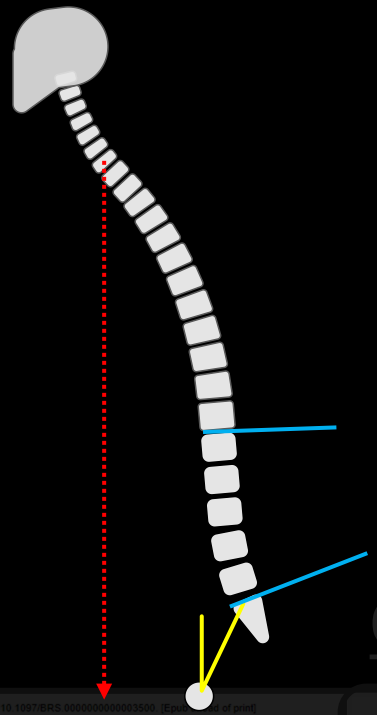
Predictive Probability of the Global Alignment and Proportion Score for the Development of Mechanical Failure Following Adult Spinal Deformity Surgery in Asian Patients

Mitsuru Yagi, MD, PhD,[a,b] Kenshi Daimon, MD, PhD,[c] Naobumi Hosogane, MD, PhD,[d] Eijiro Okada, MD, PhD,[a] Satoshi Suzuki, MD, PhD,[a] Osahiko Tsuji, MD, PhD,[a] Narihito Nagoshi, MD, PhD,[a] Nobuyuji Fujita, MD, PhD,[a] Masaya Nakamura, MD, PhD,[a] Morio Matsumoto, MD, PhD,[a] and Kota Watanabe, MD, PhD[a], Keio Spine Research Group

257 Patients.

GAP score: not predictive

What is the Optimal Sagittal Alignment?



Patient Factors

Planned Alignment

Probability Model

Patient-Specific Risk of Complication

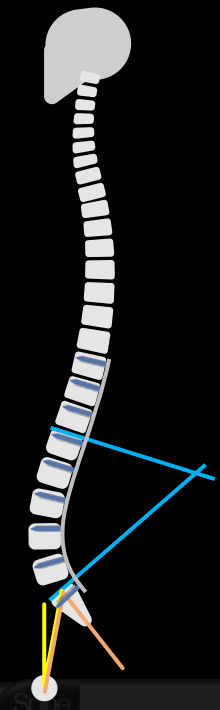
Additional Considerations

Surgeon & Patient

Nonoperative

Optimize Patient

Surgery



Improved Decision Making

Summary of Current State

PJK Risk is Multifactorial.

Patient-Specific alignment targets & risk assessment is lacking.

Objective

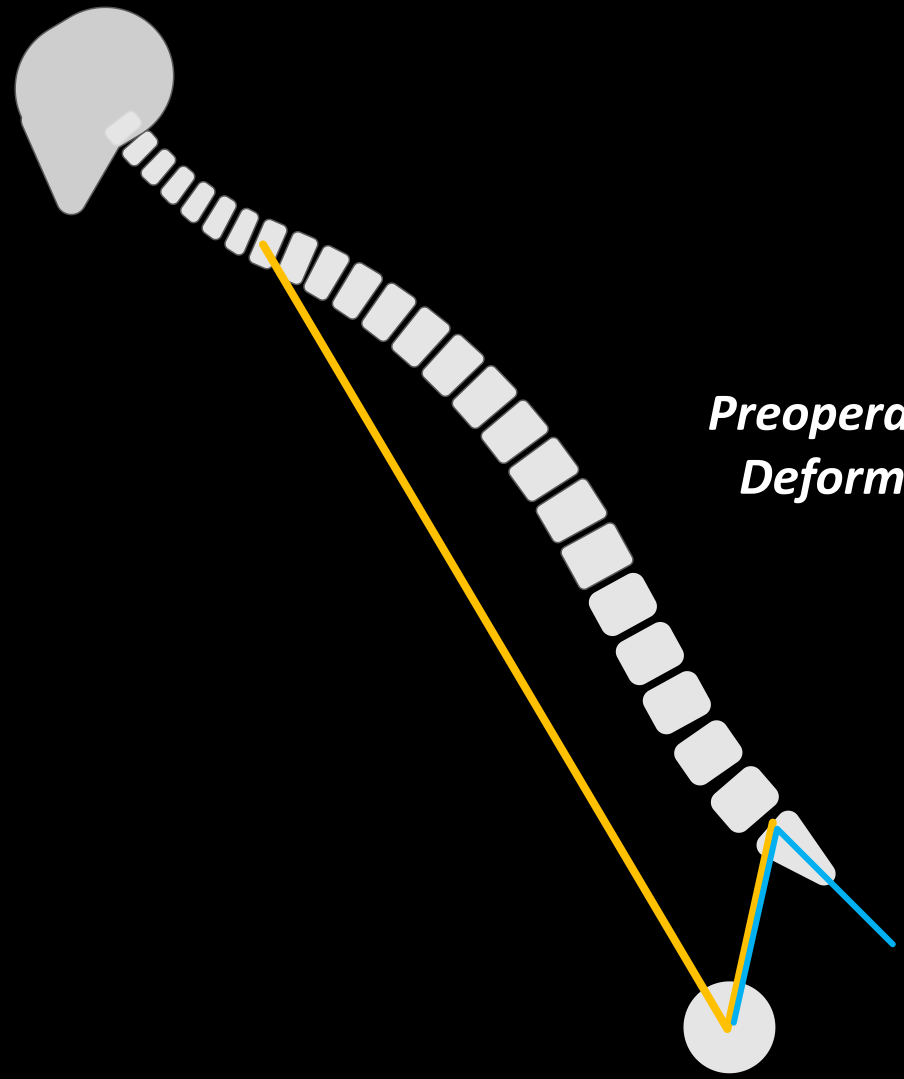
Develop a PJK risk probability model using variables that are either known preoperatively or directly modifiable.

Hypothesis

Comorbidity
Burden / Frailty

Hypothesis

Comorbidity
Burden / Frailty

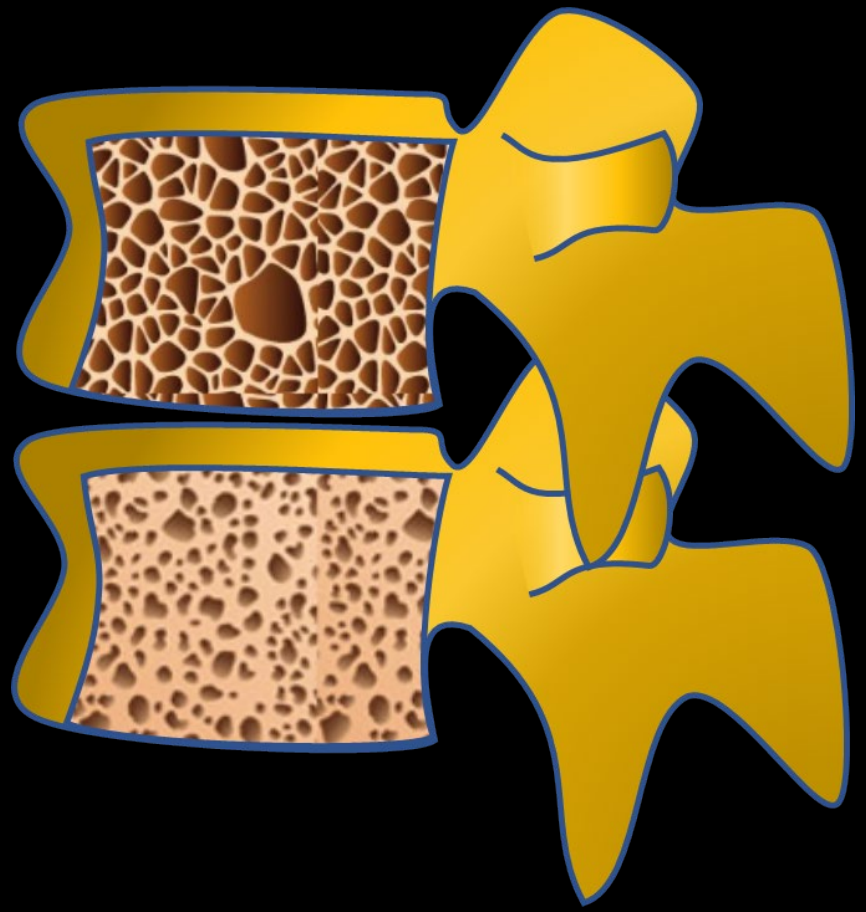


Preoperative
Deformity

Hypothesis

Comorbidity Burden / Frailty

Preoperative Deformity



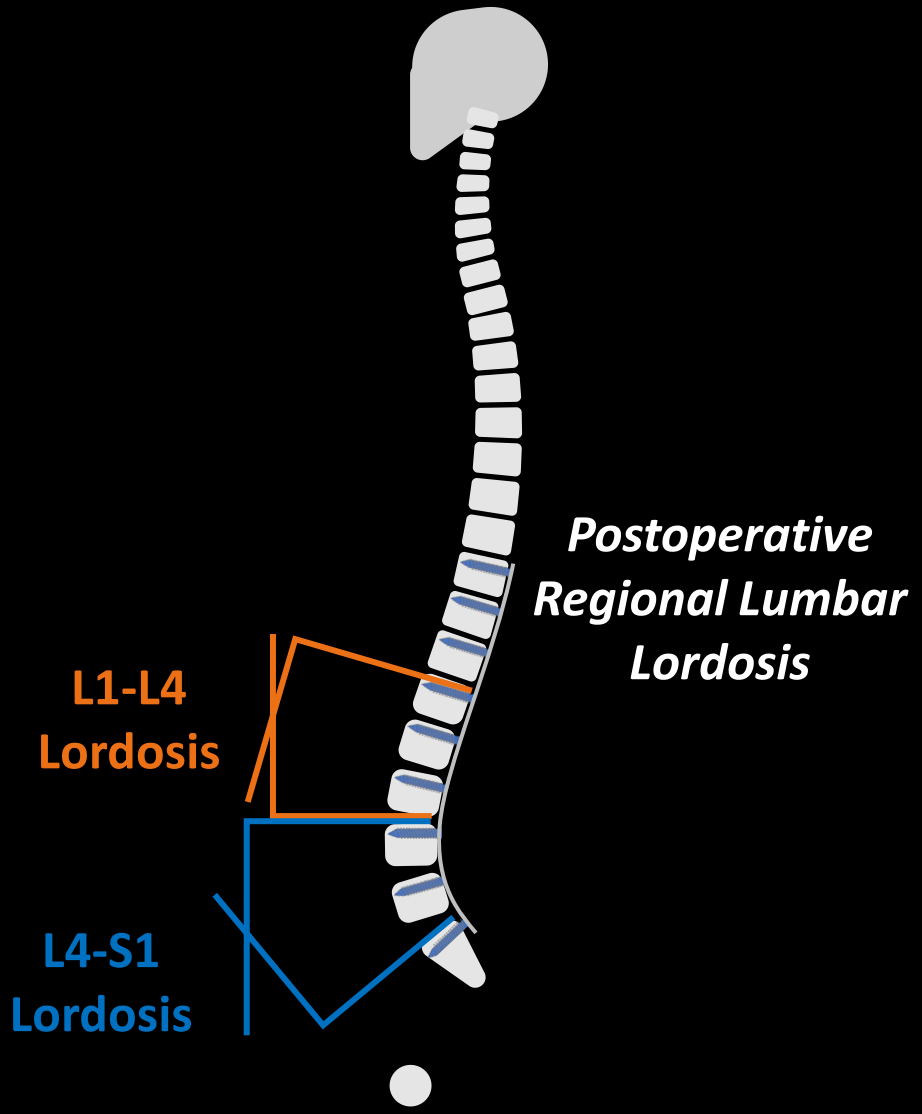
Vertebral Bone Density

Hypothesis

Comorbidity Burden / Frailty

Preoperative Deformity

Vertebral Bone Density



Postoperative Regional Lumbar Lordosis

Hypothesis

Comorbidity Burden / Frailty

Preoperative Deformity

Vertebral Bone Density

L1-L4 Lordosis

L4-S1 Lordosis

Postoperative Regional Lumbar Lordosis

Proximal Junctional Kyphosis & PJK Severity

Study Design & Cohort

Retrospective Cohort of Adult Deformity Surgical Patients (2009 to 2017)

Inclusion:

- **>18rs**
- **Fusion > 5 vertebral levels**
- **SVA ≥ 5cm, Pelvic tilt ≥ 25°, Thoracic Kyphosis ≥ 60°, or Coronal Cobb >20°**

Exclusion:

- **< 2yr follow-up**
- **Undergoing surgery for infection or tumor**
- **Prior fusion > 5 levels**

Methods

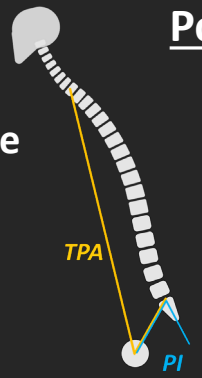
Outcome, Predictors & Statistical Approach

Predictor Variables → ***Outcome: PJK Severity Score (ordinal)***

Preoperative Predictors

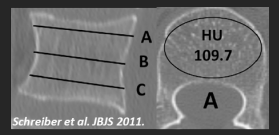
Alignment:

- Pelvic Morphology: Pelvic Incidence
- Global Deformity: T1 Pelvic Angle



Patient Factors:

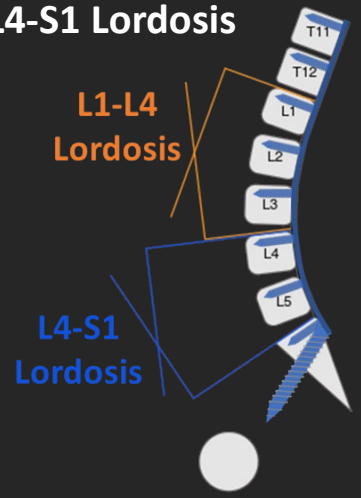
- Comorbidity Burden:
  - Charlson Comorbidity Index
- Vertebral Bone Density:
  - Hounsfield Units at UIV +/- 4 vert



Postoperative Predictors

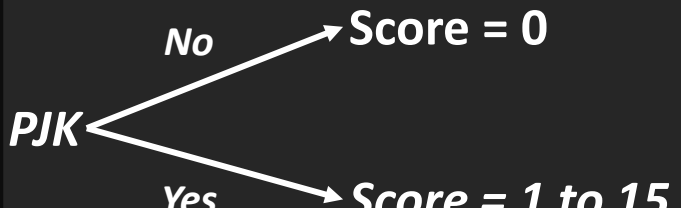
Surgical Alignment:

- L1-L4 Lordosis
- L4-S1 Lordosis



Primary Outcome:

- Hart ISSG-PJK Severity Score:



Characteristic	Points
Neurologic Deficit	0-4
Focal Pain	0-3
Instrumentation Problem	0-2
Change in Kyphosis/PLC Integrity	0-2
UIV/UIV + Fracture	0-3
Level of UIV	0-1
Total:	

Statistical Approach:

1. Proportional Odds Ordinal Regression Model
   - Assess Predictor Effects
   - Develop Predictive Tool
   - Internally Validate Model via Bootstrap Resampling

Results

Descriptive Summary

204 meeting inclusion criteria

59 Excluded
- 18 lost to f/u
- 41 prior long fusion or tumor/infection

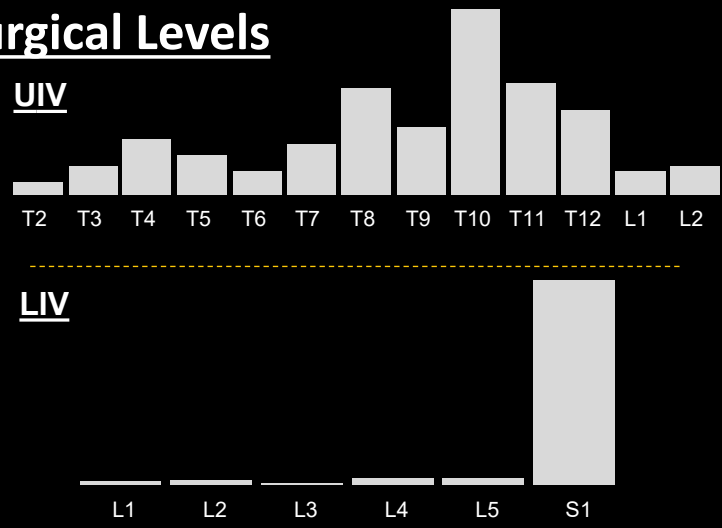
145 Included

Patient Characteristics	Study Cohort n = 145
Age, median (IQR)	66.2 (59.8 to 71)
Female Sex, n (%)	118 (81.4)
Charlson Comorbidity Index, mean (IQR)	2 (0 to 3)
Hounsfield Units, median (IQR)	139.3 (120.6 to 180.1)
Follow-up (mo), median (IQR)	26.8 (24 to 48.7)

Pre- & Postoperative Alignment

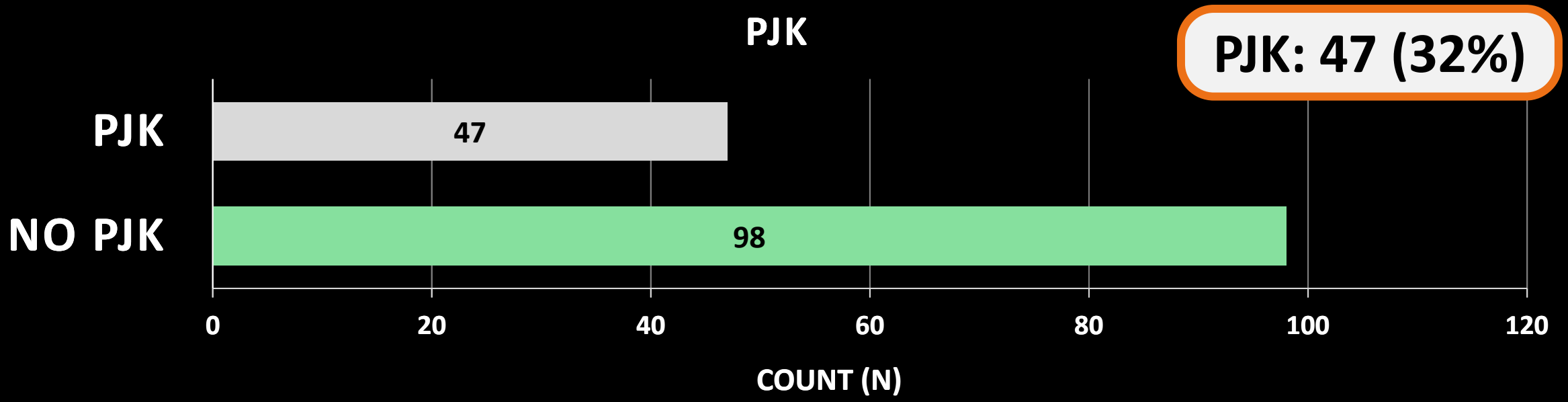
Measure, median° (IQR)	Preoperative	Postoperative	P-value
PI-LL	20.3 (9.2 to 35)	9.9 (0.5 to 19.2)	< 0.001
TPA	25.4 (17.6 to 36.5)	20.3 (14.8 to 28)	< 0.001
L1-L4 Lordosis	1.0 (-9.3 - 14.3)	11.9 (5.1 to 21.7)	< 0.001
L4-S1 Lordosis	30.4 (21.0 - 37.0)	29 (21.6 to 34.8)	0.23

Surgical Levels



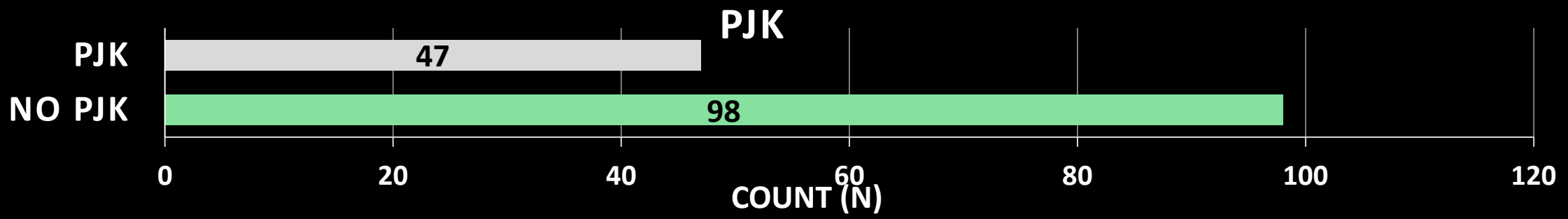
Results

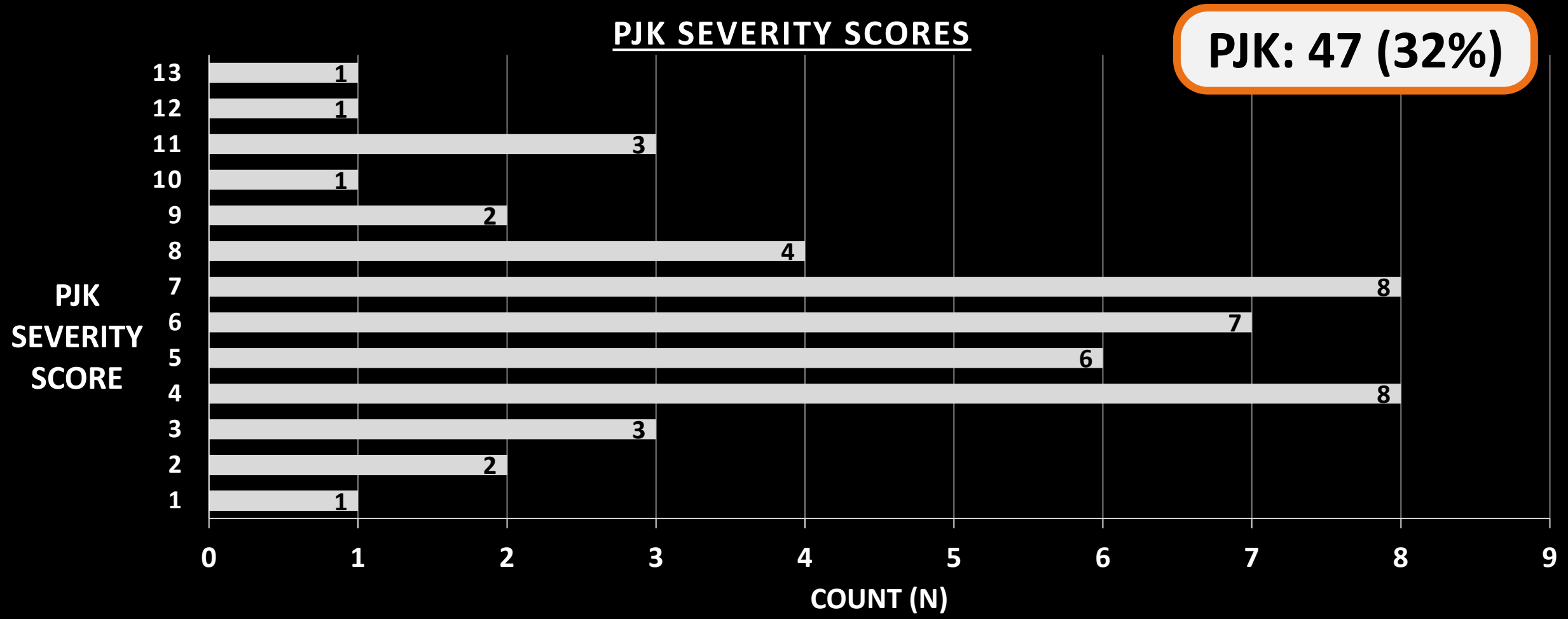
PJK & Revision Surgery



Results

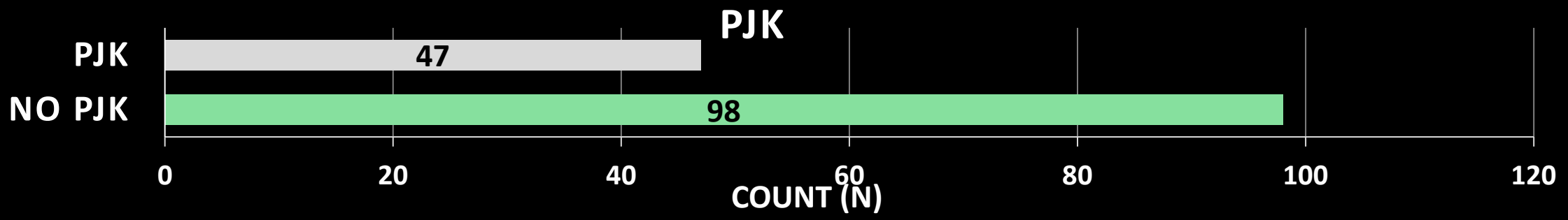
PJK & Revision Surgery

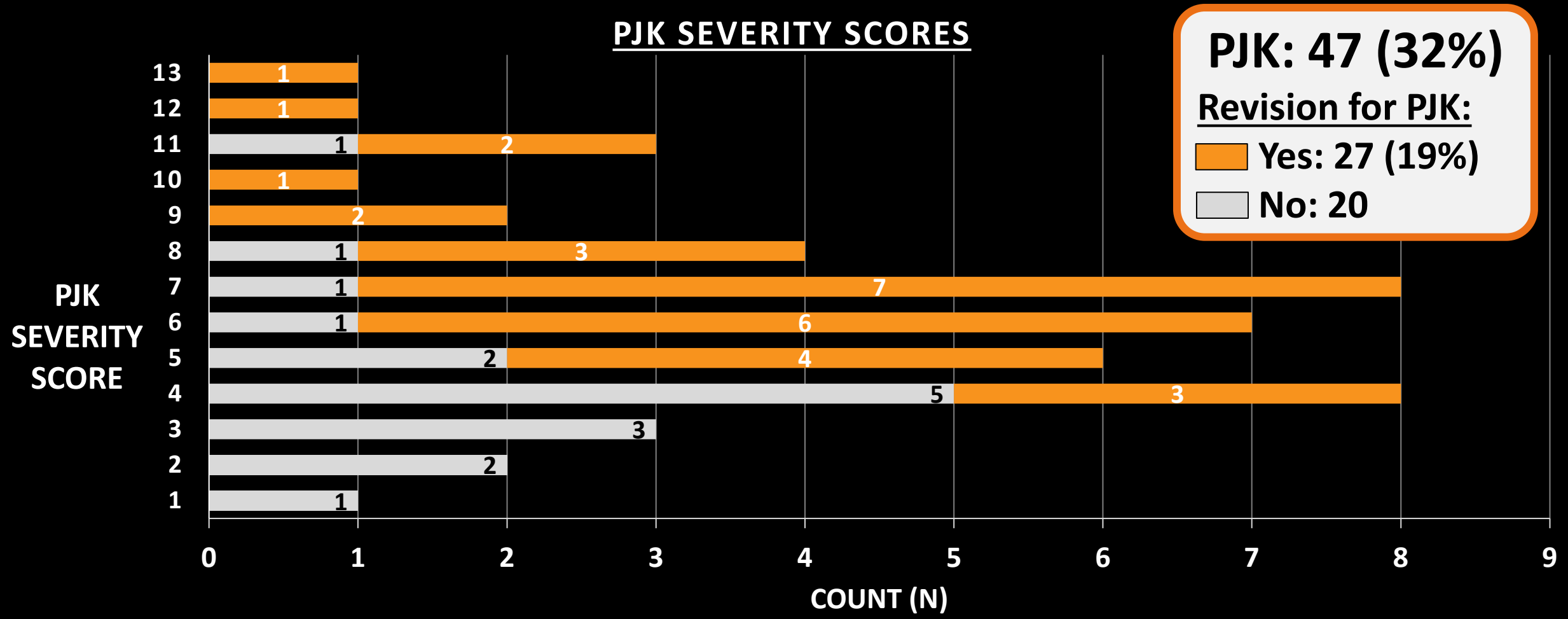




Results

PJK & Revision Surgery

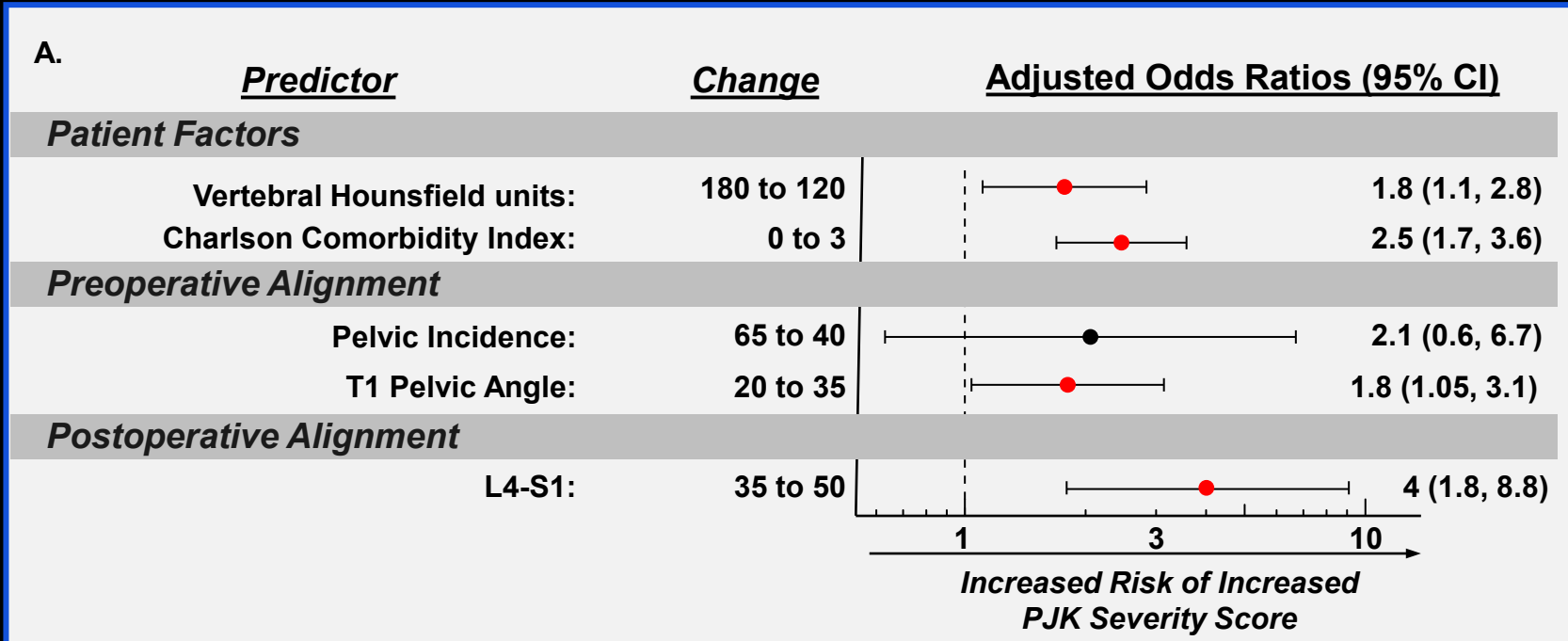




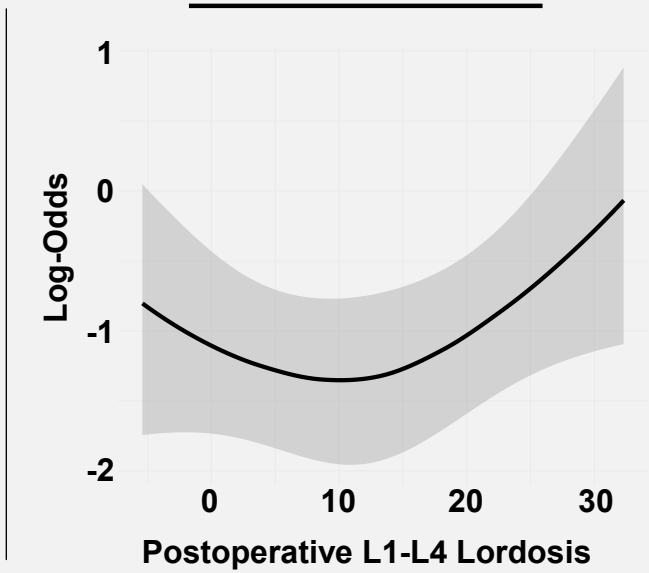
Predictor Effects

Adjusted odds of an increase in PJK Severity Score associated with a change in each predictor

A.

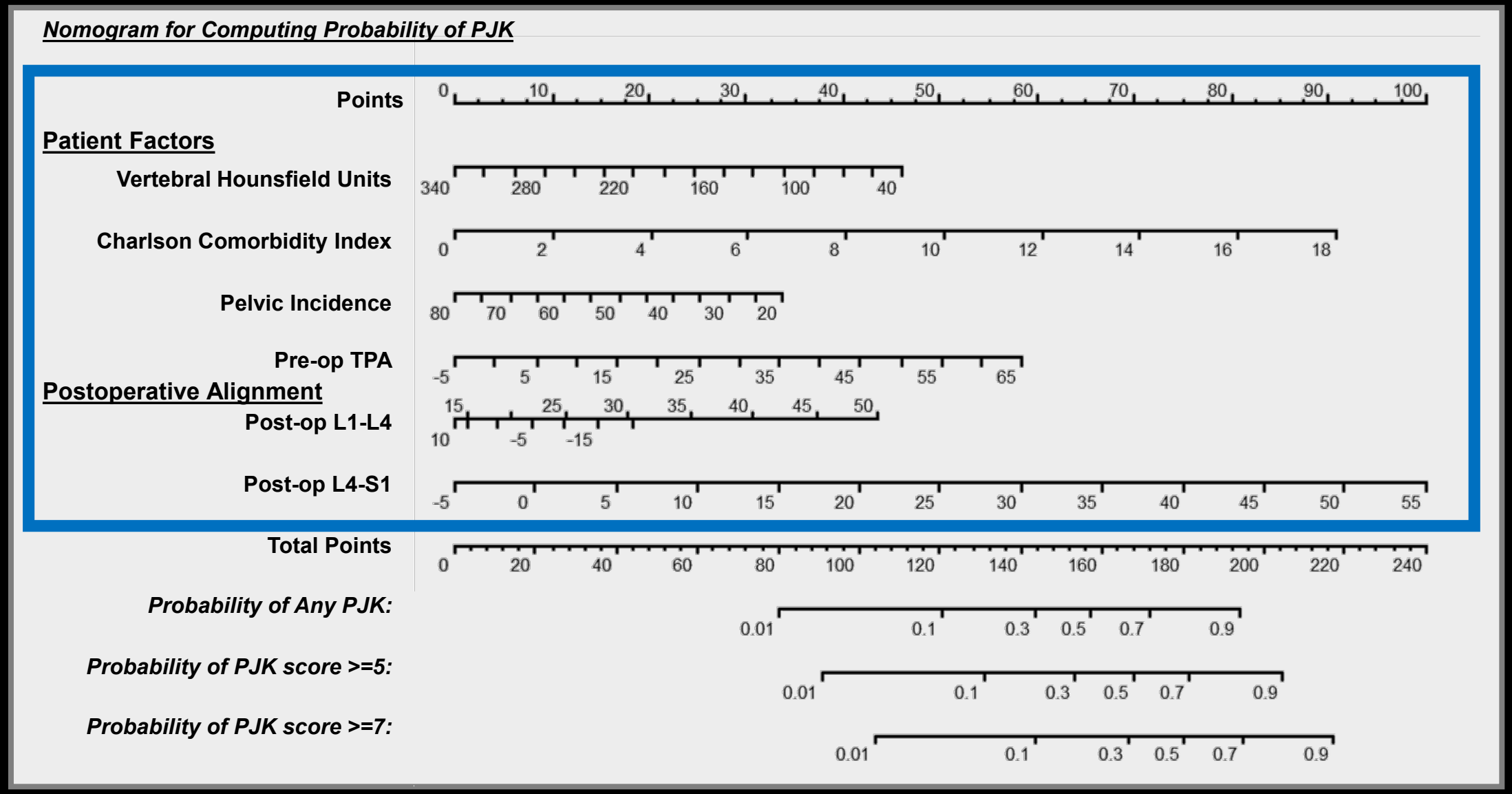


B.



L1-L4 Lordosis was modeled nonlinearly & thus, adjusted odds ratios not computed.

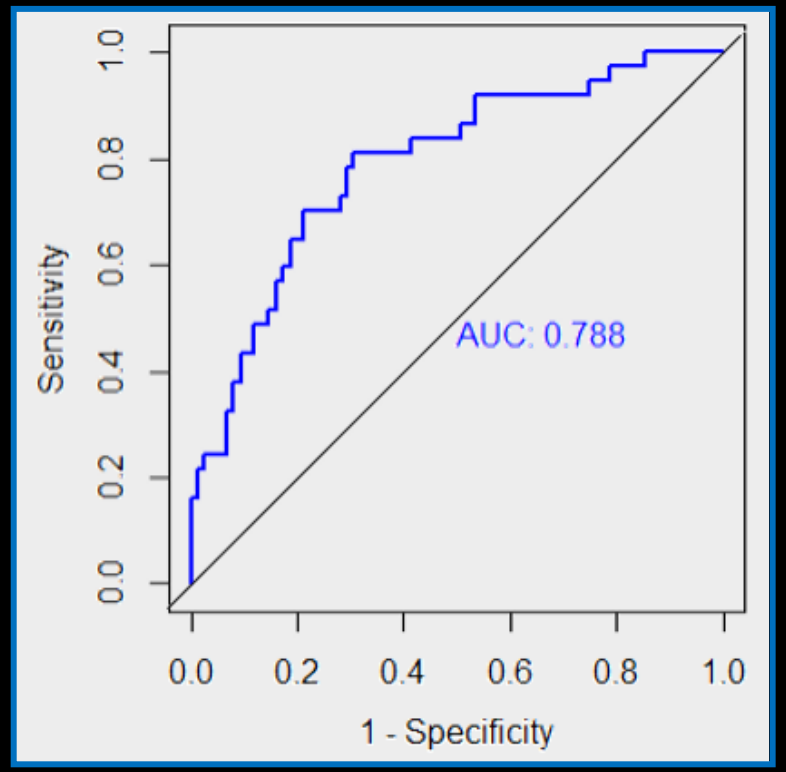
Nomogram


Nomogram for Computing Probability of PJK
Points
0 10 20 30 40 50 60 70 80 90 100
Patient Factors
Vertebral Hounsfield Units
340 280 220 160 100 40
Charlson Comorbidity Index
0 2 4 6 8 10 12 14 16 18
Pelvic Incidence
80 70 60 50 40 30 20
Pre-op TPA
-5 5 15 25 35 45 55 65
Postoperative Alignment
Post-op L1-L4
15 25 30 35 40 45 50
10 -5 -15
Post-op L4-S1
-5 0 5 10 15 20 25 30 35 40 45 50 55
Total Points
0 20 40 60 80 100 120 140 160 180 200 220 240
Probability of Any PJK:
0.01 0.1 0.3 0.5 0.7 0.9
Probability of PJK score >=5:
0.01 0.1 0.3 0.5 0.7 0.9
Probability of PJK score >=7:
0.01 0.1 0.3 0.5 0.7 0.9

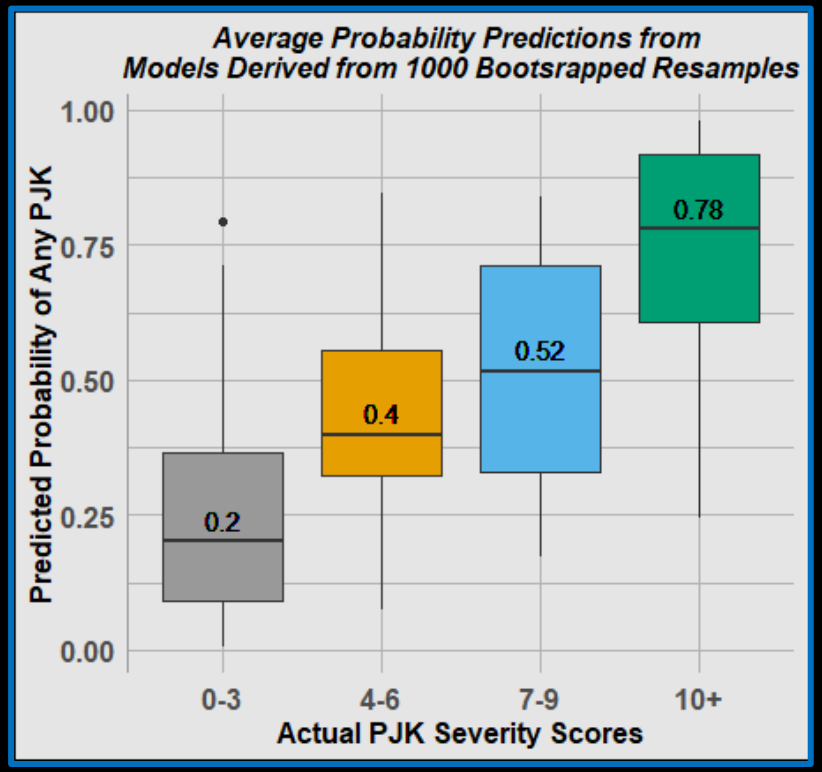
Internal Validation: 1000 Bootstrapped Resamples

Performance Metrics:

Discrimination
(Ability to distinguish high from low risk)



Overall Predictive Accuracy
(Mean squared error in probability estimates)



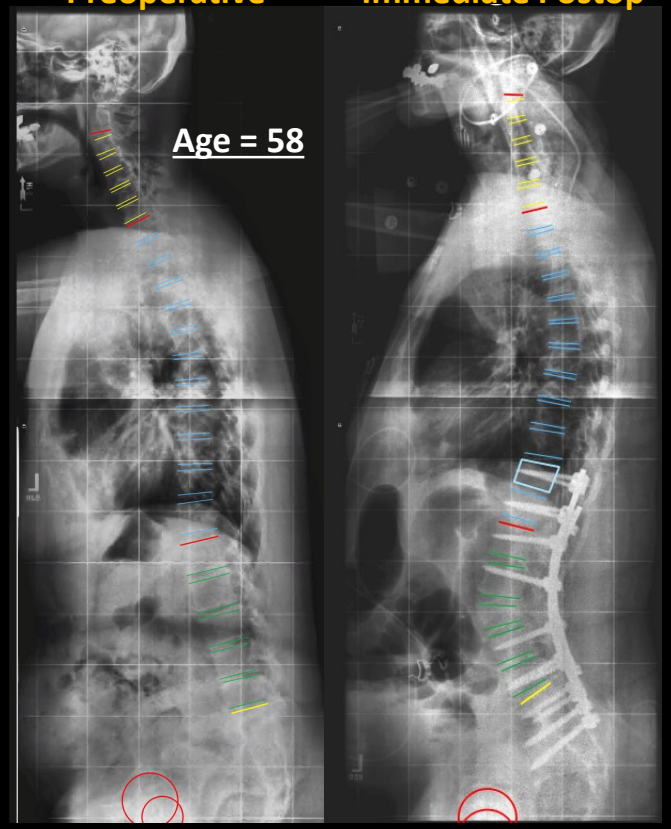
After Adjusting for Optimism (overfitting):

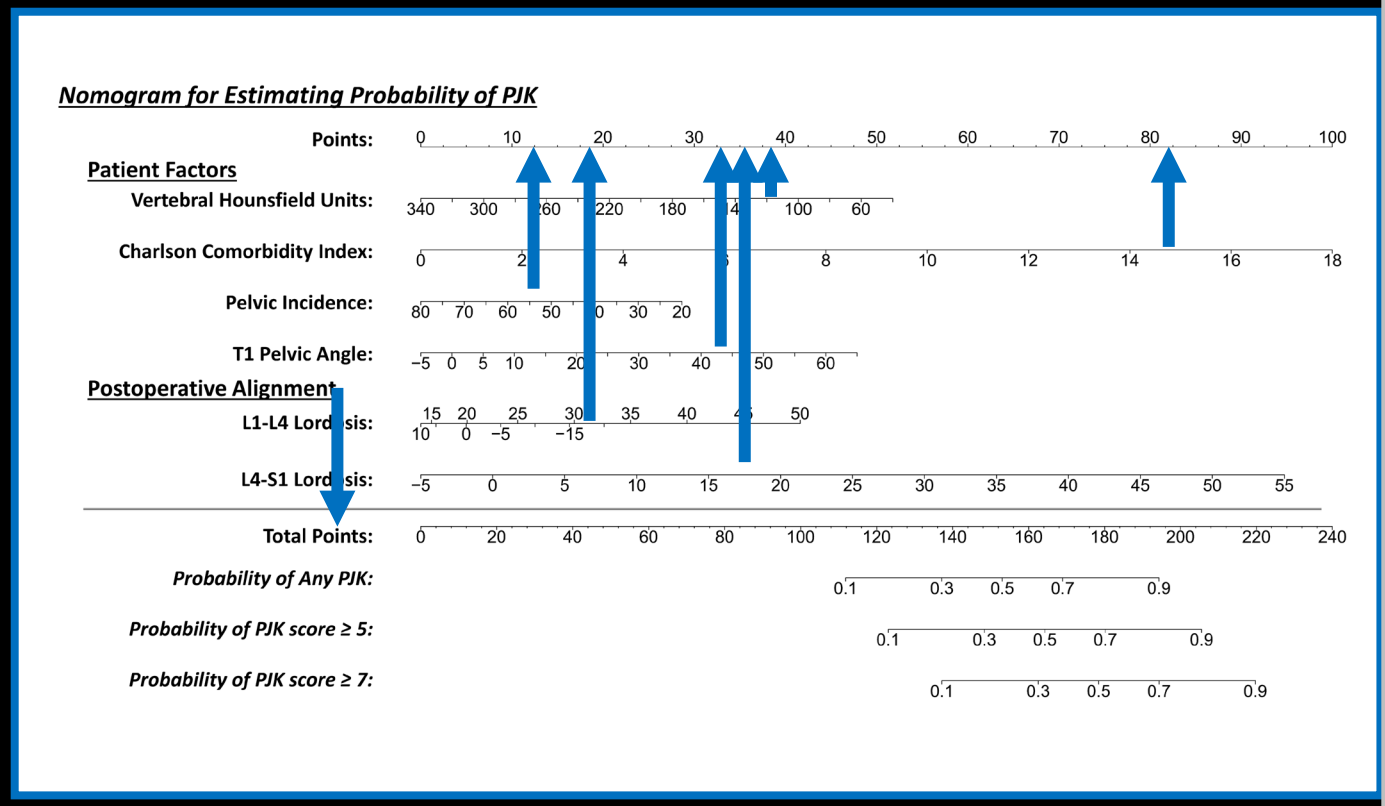
C statistic (AUC) = 0.73

Brier Score = 0.10

Case Example

Preoperative **Immediate Postop**



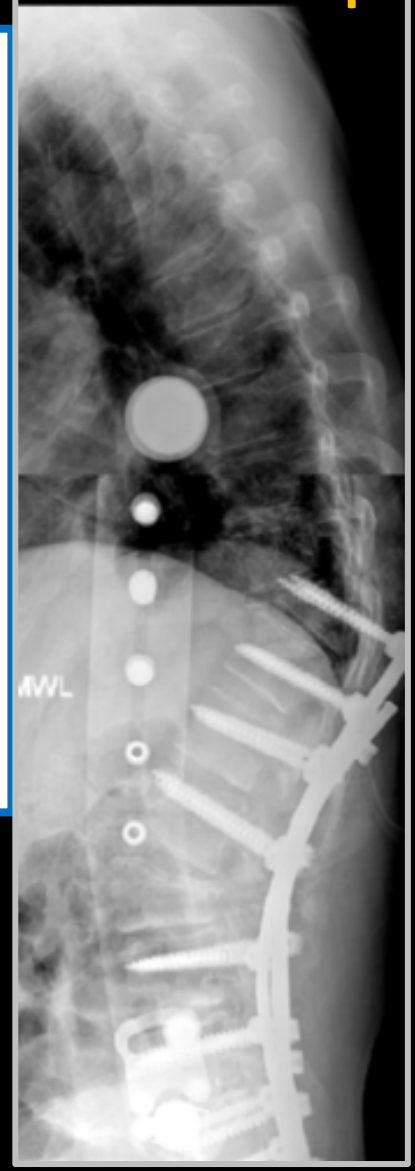


Alignment Classifier	Value	Interpretation
GAP Score:	4	*"Moderate-Risk"*
Schwab Sagittal Modifier Total:	+	*Minimal Malalignment*
Age-Adjusted Target Offsets		
PI-LL:	1	
Pelvic Tilt:	0.3	*'At Goal'*
TPA:	2	

Probability of Any PJK = 97%

Probability of PJK Score ≥ 7 = 91%

4wks Postop



Conclusion

Limitations

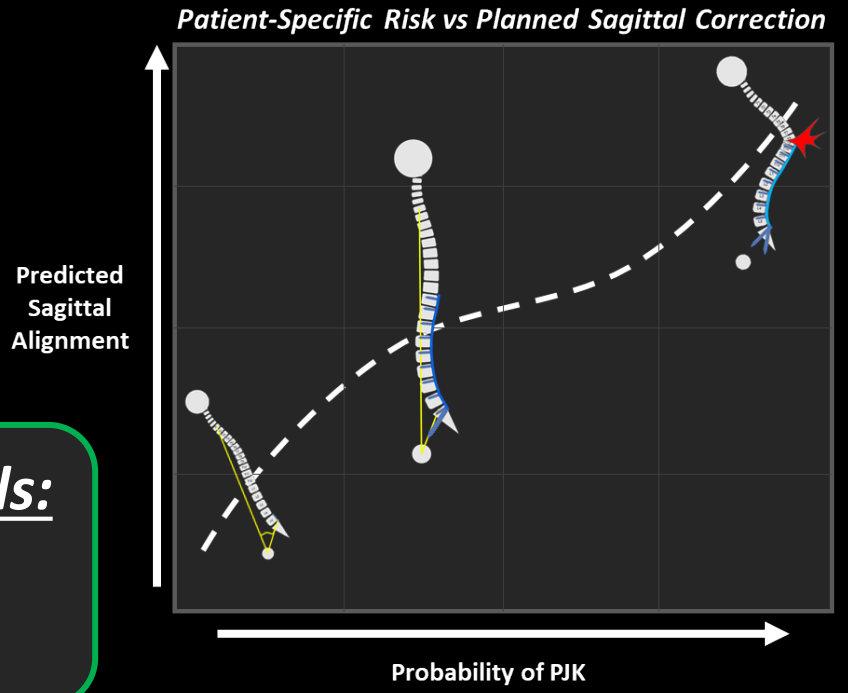
- Retrospective
- Sample size & single center
- Strictly an assessment of PJK risk

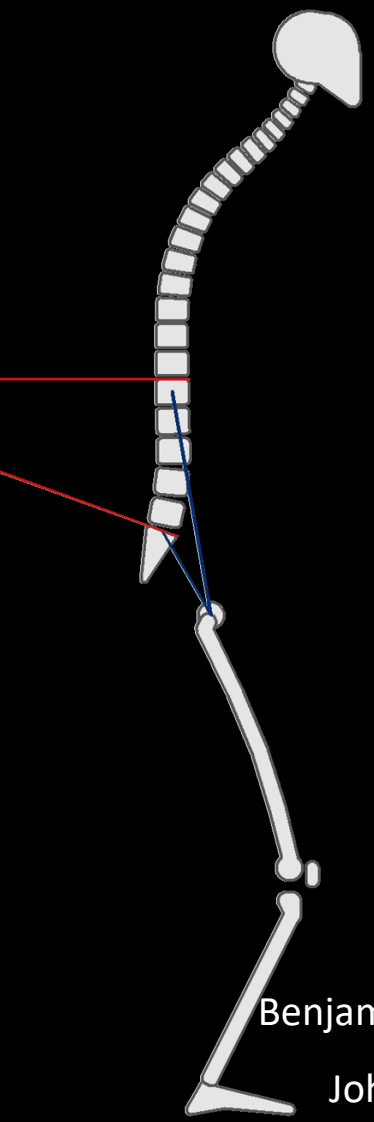
Future Directions

Multicenter → Updated Models

Additional Predictors:
- UIV, LIV
- PJK prophylaxis
- Prior Fusion
- Paraspinal M. atrophy
- Surgeon
- Etc.

Patient Specific Alignment Goals:
- ***Minimize Risk***
- ***Maximize HRQOL's***





Thank You!

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UT Health Science Center San Antonio

September 30, 2021

NASS 36th Annual Meeting

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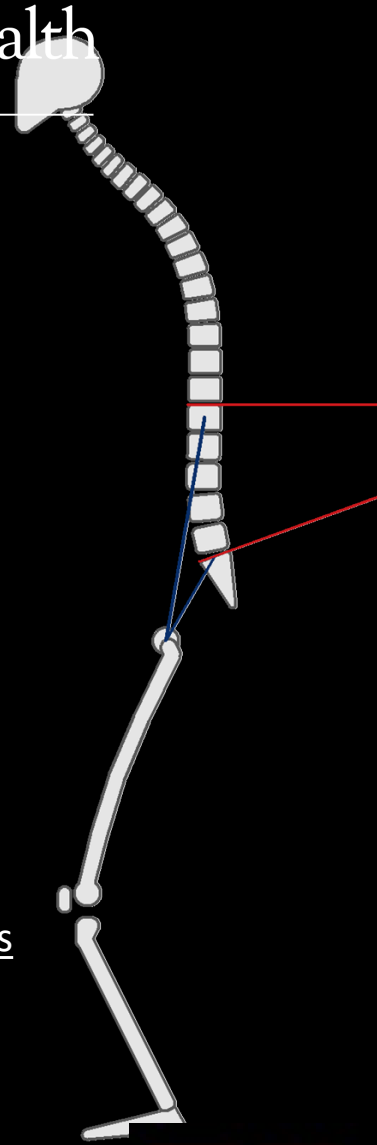

Study conducted at Vanderbilt University Medical Center, Nashville, TN