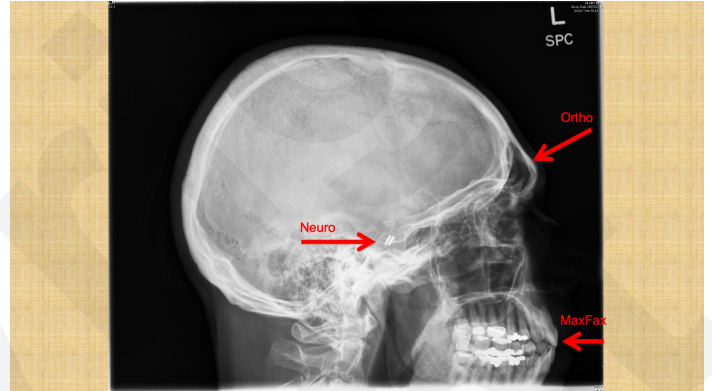


Adult Spinal Deformity – Surgical Planning and Interbody Fusion Techniques

Mr Michael J H McCarthy
Consultant Spinal Surgeon



What we will be covering today:

- Adult spinal deformity – surgical planning and interbody fusion techniques
- Pre-operative evaluation
- Surgical planning (radiological parameters, spinopelvic alignment etc)
- Goals of correction
- Decision making in direct/indirect neural decompression
- Selection of interbody fusion technique
- Requirement for osteotomies

• BUT NOT IN THAT ORDER

Some Basics First then the Complicated Stuff!



The 7 Ps

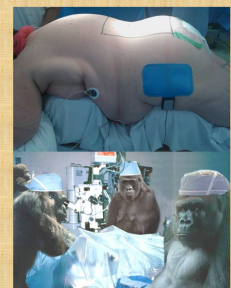
- Proper
- Planning and
- Preparation
- Prevents
- P
- Poor
- Performance



Attention to detail
Never let your guard down

The other 3 Ps

- Personality - Patient
- Personality - Pathology
- Personality - Practitioner



Indications for Surgery - DRS

- **Decompression**
 - Spinal cord / nerve roots
- **Realignment**
 - Correct deformity
- **Stabilisation**
 - Prevent / Treat
 - Neurological deficit / deformity / pain
 - (Non fusion technology form of "stabilisation")

All may require fusion
Require Instrumentation
Instrumentation increases fusion

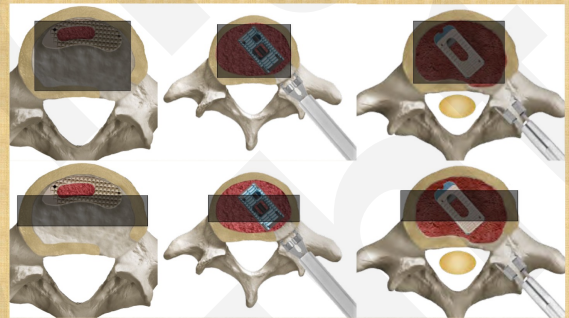
Indications for Surgery

- **What are you trying to achieve?**
 - Non-maleficence - "first, do no harm" (primum non nocere).
- **DO THE APPROPRIATE OPERATION FOR THE PATIENT AND THEIR PATHOLOGY AND YOUR SKILL / ABILITY**

Fusion

- Fusion – think:
 - $\propto$ contact surface area (1/ $\propto$ subsidence)
 - $\uparrow$ compression $\downarrow$ tension
 - autograft > allograft > synthetic
 - vascular > avascular
 - structural graft > non structural
 - Biologics
 - And unfortunately fusion may not be a clinical outcome
- **BUT, joints are designed to move**
 - Fusion is abnormal
 - Beware – nature against you!

Fusion Footprints



Interbody Fusion

- Is an interbody fusion required?
 - Restore foraminal height (up / down)
 - Improve fusion
 - Revision of failed posterolateral fusion
 - Restore lordosis / correct deformity
 - Biomechanics – shear / large disc height / entire facet removed / long construct involving L5/S1
- Types:
 - Auto / allograft
 - Threaded / Cylindrical cages
 - Banana cages
 - Oblique cages
 - Articulated cages
 - Expandable cages

Indications ALIF

- (L2/3) 3/4 4/5 5/1 levels
- Restore foraminal height (up / down) ✓
- Improve fusion ✓
- Revision of failed posterolateral fusion ✓
- Restore lordosis / correct deformity ✓
- Biomechanics – shear / large disc height / entire facet removed / long construct involving L5/S1 ✓

Indications TLIF

- All lumbar levels
- Restore foraminal height (up / down) ✓
- Improve fusion ✓
- Revision of failed posterolateral fusion ✓
- Restore lordosis / correct deformity ?
- Biomechanics – shear / large disc height / entire facet removed / long construct involving L5/S1 ✓

Indications LLIF

- All lumbar levels except L5/1
- Restore foraminal height (up / down) ✓
- Improve fusion ✓
- Revision of failed posterolateral fusion ✓
- Restore lordosis / correct deformity ✓
- Biomechanics – shear / large disc height / entire facet removed ✓

Advantages

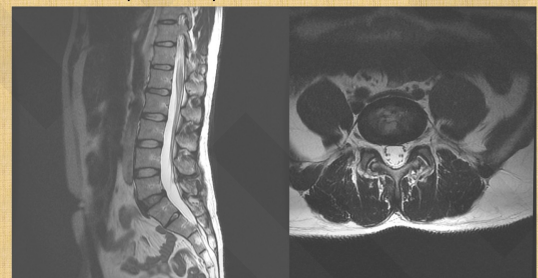
PLIF	Bilateral access to canal, restores lordosis
Mini Open and MIS PLIF	Less painful, low infection, less blood loss, faster recovery
Open TLIF	Access, fusion
Mini Open TLIF	Less painful, low infection, fusion, less blood loss
MIS TLIF	Even less pain, low infection, avoids paraspinal muscle damage, less blood loss, faster recovery
LLIF + Perc Post	Good fusion, less painful, low infection, T5-L5, avoids canal, less visceral vessel injury then ALIF, avoids paraspinal muscle damage, less blood loss, faster recovery
ALIF + Perc Post	Best fusion, best restoration lordosis, less painful, low infection, avoids canal, avoids paraspinal muscle damage, mostly less blood loss than a TLIF

Disadvantages

Painful, infection, neural / dural injury scarring, limited higher up
Fusion?, neural / dural injury scarring, limited higher up
Painful, infection, neural / dural injury scarring, endplate damage / subsidence
Neural / dural injury scarring, disc preparation, endplate damage / subsidence
Fusion?, neural / dural injury scarring, disc preparation, endplate damage / subsidence
L4/5?, L5/S1 – No, endplate damage / subsidence, plexus injury, diaphragm injury, pneumothorax
Access Surgeon, ilio-lumbar vein, visceral vessel injury, ileus, not above L3

ALIF Limitations

- VESSELS / OBESITY / ELDERLY

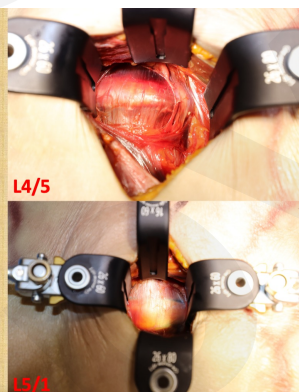
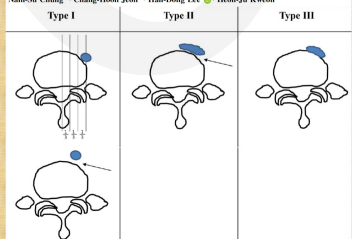


Eur Spine J (2017) 26:2797–2805
DOI 10.1007/s00586-017-5176-6

ORIGINAL ARTICLE

Preoperative evaluation of left common iliac vein in oblique lateral interbody fusion at L5–S1

Nam-Su Chung¹ · Chang-Hoon Jeon¹ · Han-Dong Lee² · Heon-Ju Kwon¹



Spine ANATOMY

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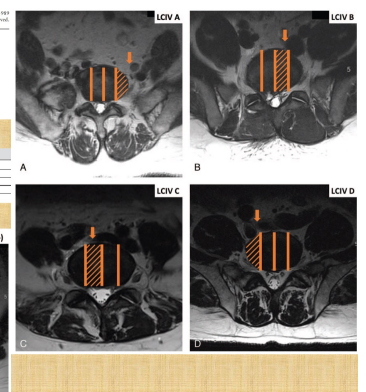
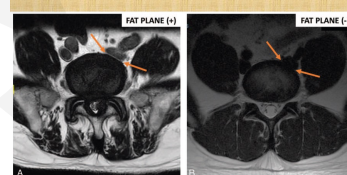
The Feasibility of Anterior Spinal Access

The Vascular Corridor at the L5–S1 Level for Anterior Lumbar Interbody Fusion

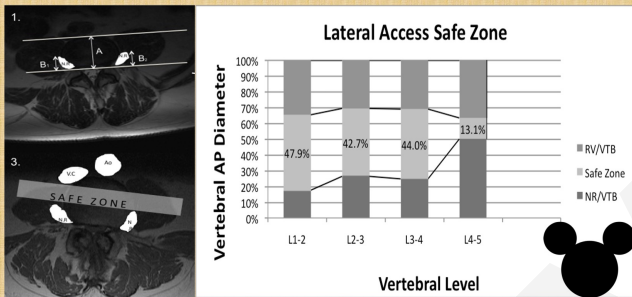
Julia Poh-Hoeng Ng, MRCG^a, Matthew Soon-Yang, FRACS, M^a, Daniel Siew-Chi Chan, FRCS^a, and Jacob Young-Lewing, FRCS^a

	Easy	Advanced	Difficult
Vascular corridor	Wide	Fails left criteria for easy OR	Narrow
L5/S1 position	A	Difficult	C or D
Fat plane	Yes	No	No
Number (%)	188 (37.30%)	231 (46.10%)	17 (3.40%)

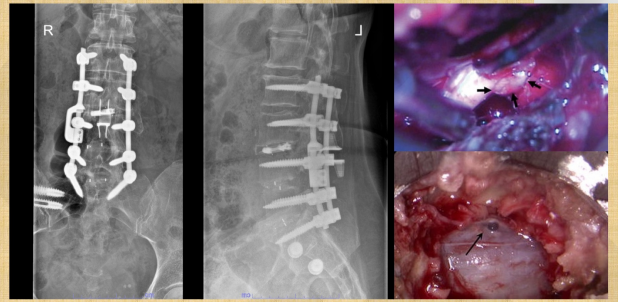
OR, open reduction.



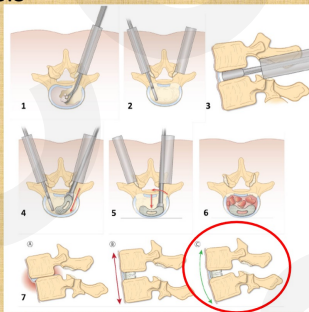
LLIF Limitations



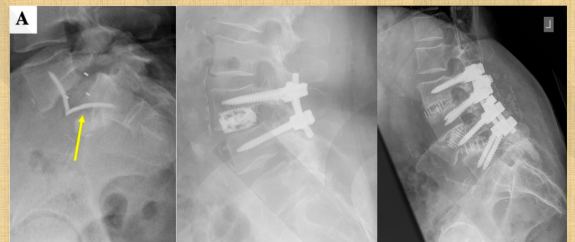
TLIF Limitations



TLIF Lordosis



They can all subside - endplate damage



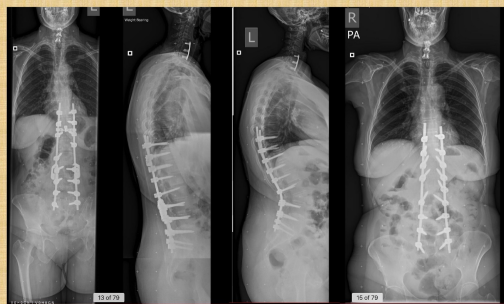
It's like removing your bendy spine..

and replacing it with a metal pole!

Deformity – ALL release - ALIF



Deformity – Osteotomy - PSO



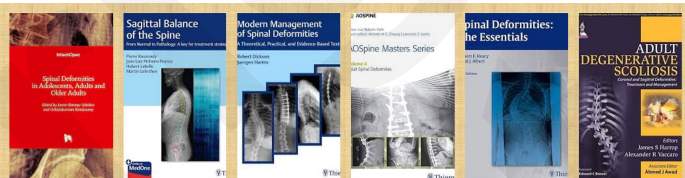
Type	Description	Diagram	Reference
1	Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc		Ponte
2	Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging of the disc posteriorly and opening of the disc anteriorly		Smith-Petersen
3	Posterior-based transpedicular decancellation of the vertebral body with realignment through controlled fracture of the anterior column		Heinig
4	Posterior-based intraosseous wedge resection of the vertebral body with realignment through osteoclasts of the proximal third of the anterior vertebral body		Thomasen (PSO)
5	Posterior-based wedge resection with extension of the osteotomy into the supra-adjacent disc and realignment hinging on the anterior column at the intervertebral space		Mod Thomasen (Ext PSO)
6	Posterior-based vertebral column resection including one or more vertebra with adjacent discs		Suk (VCR)

Osteotomy vs ALL Release

- Osteotomy - PSO**
 - Direct canal decompression
 - Direct foraminal decompression (but no height restoration)
 - Shortening procedure
 - "Bone on bone" fusion if performed correctly
 - Correction = per level
 - Typically up to 30 degrees
- ALL release + Cage**
 - Indirect canal decompression
 - Indirect foraminal decompression
 - "Lengthening" procedure
 - Fusion through a cage
 - Requires additional posterior procedure
 - Correction = per level
 - Depends on cage lordosis and facets at back

27

Assessing and Classifying Adult Spinal Deformity



Causes of Coronal Malalignment

- Any cause of (untreated) childhood scoliosis
- Degenerative (de novo) adult scoliosis
- Iatrogenic
- Neuromuscular / Paralytic

	Idiopathic (residual)	Degenerative (de novo)
Curve pattern	Follows classic curve patterns	Lack classic curve patterns
Vertebral segments	Involves more vertebral segments	Involves fewer vertebral segments
Curve location	Thoracic spine	Lumbar spine
Curve magnitude	Larger curves	Smaller curve magnitude

Table 1. SRS Adult Deformity Classification

Primary curve types

- Single thoracic (ST)
- Double thoracic (DT)
- Double major (DM)
- Triple major (TM)
- Thoracolumbar (TL)
- Lumbar "de novo" idiopathic (LI)
- Primary sagittal plane deformity (SP)

Adult spinal deformity modifiers

Regional sagittal modifier includes only if outside normal range as listed:

- (PT) Proximal thoracic (T2-T6) $\geq 10^\circ$
- (MT) Main thoracic (T5-T12) $\geq 10^\circ$
- (TL) Thoracolumbar (T10-L2) $\geq 10^\circ$
- (LL) Lumbar (T12-S1) $\geq 10^\circ$

Lumbar degenerative modifier (include only if present)

- (DDO) L disk height and facet arthropathy based on x-ray include lowest disk level between L1 and L5
- (LLS) L5/S6 retroversion, lateral antero, retro ≥ 2 mm include lowest level between L1 and L5
- (LCT) junctional L5-S1 curve $\geq 10^\circ$ intersection angle superior angulation L5 and S1

Global balance modifier (include only if imbalance present)

- (CSB) sagittal C7 plumb ≥ 3 cm anterior or posterior to sacral promontory

SRS definition of regions

- Thoracic spine: T2-T12
- Thoracolumbar: spine T12-L1
- Lumbar: spine L1-S1

Criteria for specific major curve types

- Thoracic curve
 - Curve $\geq 40^\circ$
 - T1 tilt or coronal angle $\geq 10^\circ$ upper thoracic curves
- Thoracolumbar and lumbar curves
 - Curve $\geq 30^\circ$
 - Sagittal vertebral body lateral to CSVL
- Primary sagittal plane deformity
 - No major coronal curve
 - One or more regional sagittal measurements (PT, MT, TL, L) outside normal range

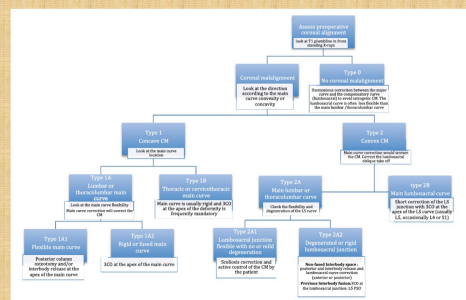


Fig 1 Type 1 This case is an example of concave CM. The central T1 plumb line falls in the concave of the main curve. The correction of the main curve shows no global effect, resulting in correction of the central malalignment.

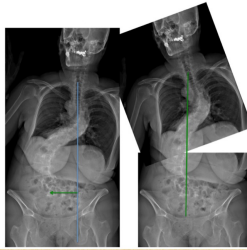
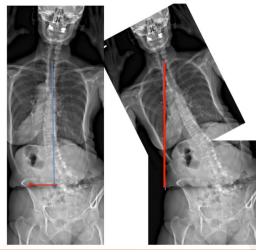


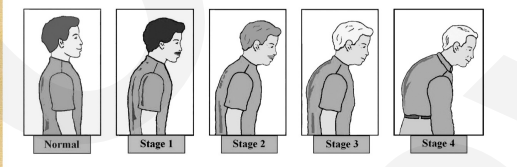
Fig 2 Type 2 Example of convex CM. The central T1 plumb line falls in the convex of the main curve. The correction of the main curve shows no global effect, resulting in correction of the central malalignment.



Causes of Sagittal Malalignment

- Congenital anomaly
- Ankylosing spondylitis
- Iatrogenic:
 - Flatback Syndrome
 - Kyphotic Decompensation Syndrome
 - Adjacent segment pathology
- Post-traumatic
- Infectious
- Neoplastic
- Osteoporotic Compression Fractures
- Degenerative Spinal disorders

Life is a Kyphosing Event!



Iatrogenic Causes

- Posterior distraction instrumentation
- Anterior compression instrumentation
- Poor sagittal alignment in the instrumented segment
- Breakdown above long fusion



Sagittal Balance Parameters

- Pelvic Incidence
- Pelvic Tilt
- Sacral Slope
- Lumbar Lordosis
- Thoracic Kyphosis
- Cervical Lordosis
- Centre of Gravity
- C7 Plumb Line
- Sagittal Vertical Axis
- Chin Brow Vertical Angle
- Kyphosis Tilt Angle
- Sacro Femoral Distance
- T9 Tilt (body centre mass level)
- T1 Spino Pelvic Inclination
- T1 Pelvic Angle
- T1 Sagittal Angle
- Global Tilt
- GAP Score
- Etc etc...



First - Lumbar Lordosis

ORIGINAL ARTICLE

LUMBAR LORDOSIS: A STUDY OF ANGLE VALUES AND OF VERTEBRAL BODIES AND INTERVERTEBRAL DISCS ROLE

LUZ HELENIE FONSECA DAMASCENO¹, SILVIO RICARDO GUARNIER CATARINI², ANTONIO DORNAL CAMPOS³, HELTON LUIS APARECIDO DEFRIG⁴

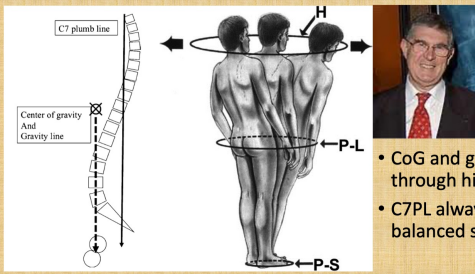
	Mean Angle (°)	Standard Deviation	Range (°)	% participation in curvature L1S1 (range)
L1-L2	-4.99 *	2.79	4.0 to -12.0	8.16 (-8.57 to 24.00)
L2-L3	-6.89 *	2.73	0.0 to -15.0	11.35 (0.00 to 27.27)
L3-L4	-9.25 *	2.54	-2.0 to -20.0	15.38 (3.03 to 30.95)
L4-L5	-12.29 *	3.39	-2.0 to -26.0	20.43 (3.81 to 42.86)
L5-S1	-15.58 *	5.43	-4.0 to -35.0	26.07 (5.80 to 56.52)

(*)Averages different from each other with p<0.001

Tabela 2 - Intervertebral discs measurements

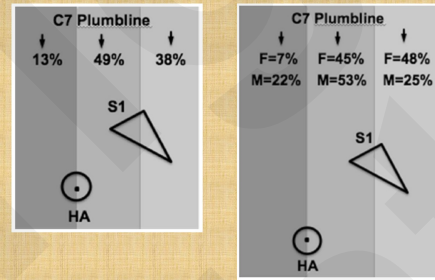
>50% LL @ L4-S1
(21deg vs 28deg)

Cone of Economy



- CoG and gravity line goes through hips
- C7PL always behind CoG in a balanced spine

Normal Distribution



Eur Spine J (1998) 7:99–103
© Springer-Verlag 1998

ORIGINAL ARTICLE

J. Legaye
G. Duval-Beaupère
J. Hecquet
C. Marty

Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves

- PI 52 range 34–84 fixed after skeletal maturity
- CL 40 +/- 10
- PT 12 range 5–30
- TK 20–50
- SS 40 range 20–65
- LL 30–80

SS sacral slope
PT pelvis tilt
I incidence

$$PI = PT + SS$$



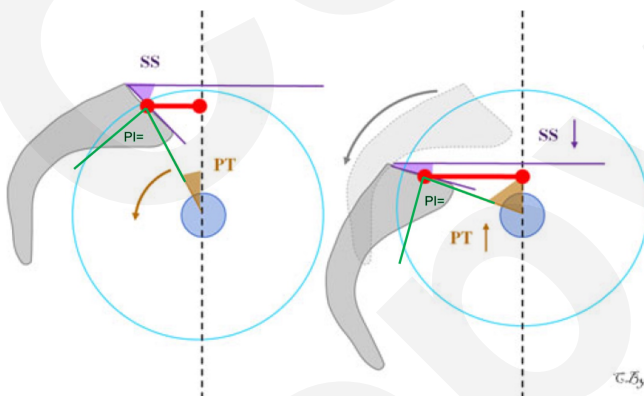
Fig. 10 Pelvic parameters: pelvis tilt, sacral slope, incidence angle. SS sacral slop, PT pelvis tilt and I incidence

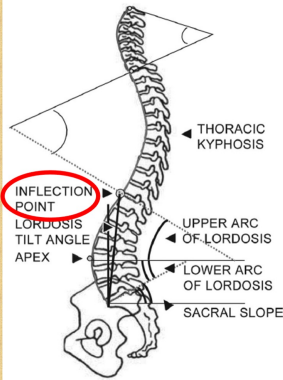
Classification of the Normal Variation in the Sagittal Alignment of the Human Lumbar Spine and Pelvis in the Standing Position

Pierre Roussouly, MD,* Sohrab Gollogly, MD,* Eric Berthonnaud, PhD,† and Johannes Dimnet, PhD†

- Stagnara et al. 1982 “the span of possible values of maximum kyphosis and lordosis in subjects with no spinal disease is considerable ...It is therefore unreasonable to speak of normal kyphotic or lordotic curves.”

SPINE Volume 30, Number 3, pp 346–353
©2005, Lippincott Williams & Wilkins, Inc.





Upper arc = inf arc TK

Lower arc = SS

Roussouly Classification of Spine Types

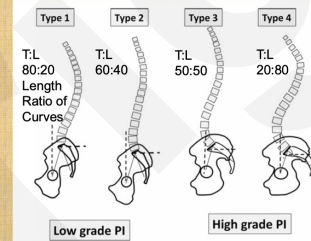


Fig. 4 The shape of lumbar lordosis depends on SS orientation. Type 1 and 2 have SS < 35°; Type 3 has 35° < SS < 45°; Type 4 has SS > 45°. Generally Type 1 and 2 have a low PI and Type 3 and 4 have a high PI

• Sacrum:

• Horizontal = High PI

• Vertical = Low PI

• PI-LL normally within 10°

Shape of Spine

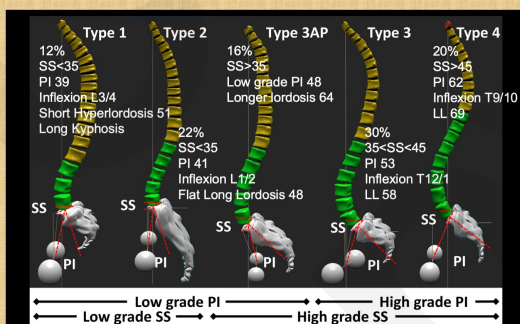
- Type 1 – discopathy TL junction, OA facets distal arc, retrolisthesis at junction, nutcracker spondylolysis L5 in hyperlordotic area
- Type 2 – increased risk disc herniation (central) at younger age, multilevel discopathy
- Type 3 – average / normal spine
- Type 4 – L5 isthmic lysis, later age posterior OA and L4/5 SPL

Eur Spine J
DOI 10.1007/s00586-017-5111-x

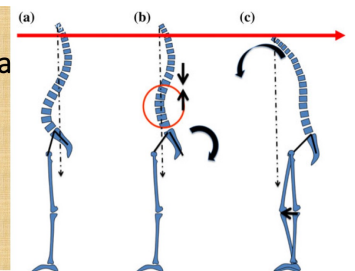
ORIGINAL ARTICLE

Classification of normal sagittal spine alignment: redefining the Roussouly classification

Féthi Laouissat^{1,2} · Amer Sebaaly⁴ · Martin Gehrchen³ · Pierre Roussouly²

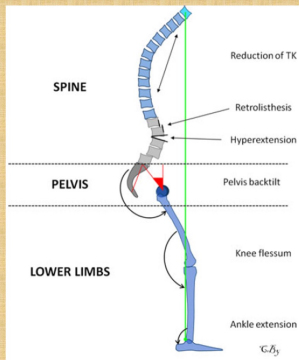


Compensatory Mecha



	Definition
Sagittally balanced	The spine is able to align the gravity line and keep horizontal gaze with little muscle effort
Hidden sagittal imbalance	The spine is able to align the gravity line and keep horizontal gaze with increased muscle effort
Uncompensated sagittal imbalance	The spine is unable to align the gravity line or keep the horizontal gaze

Reduced PI = poor ability to compensate



Importance of Sagittal Balance

Eur Spine J (2015) 24:1251–1258
DOI 10.1007/s00586-014-3454-0

ORIGINAL ARTICLE

Pelvic incidence-lumbar lordosis mismatch predisposes to adjacent segment disease after lumbar spinal fusion

Dominique A. Rothenfluh · Daniel A. Mueller ·
Esin Rothenfluh · Kan Min

- PI-LL <10 = 25% revision rate for ASD 4yrs vs
- PI-LL >10 = 78%
- AdjSegDis group had higher preop PI with non matched LL

Eur Spine J
DOI 10.1007/s00586-016-4807-7

ORIGINAL ARTICLE

Normative data for parameters of sagittal spinal alignment in healthy subjects: an analysis of gender specific differences and changes with aging in 626 asymptomatic individuals

Yasutsugu Yankawa^{1,2} · Fumihiko Kato³ · Kota Suda³ · Masatsune Yamagata⁴ ·
Takayoshi Ueta⁵ · Munehito Yoshida¹

Table 8 Sagittal vertical axis (SVA)

Decade	Male	Female	P value
20–29	−2.1 ± 8.2	−4.6 ± 13.5	NS
30–39	3.0 ± 9.2	−4.1 ± 13.0	<0.01
40–49	5.0 ± 13.7	0.9 ± 9.0	0.070
50–59	4.5 ± 11.8	3.4 ± 11.1	NS
60–69	5.5 ± 14.0	4.6 ± 10.4	NS
70–79	10.3 ± 14.4	10.7 ± 15.2	NS
All	4.5 ± 11.9	1.8 ± 13.1	<0.01
Total	3.1 ± 12.6		

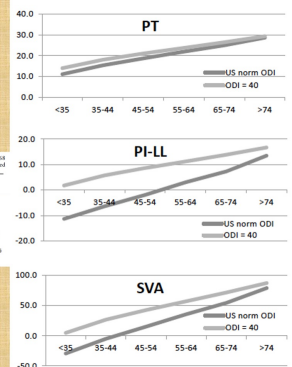


Age Specific Norms

Spine
DEFORMITY

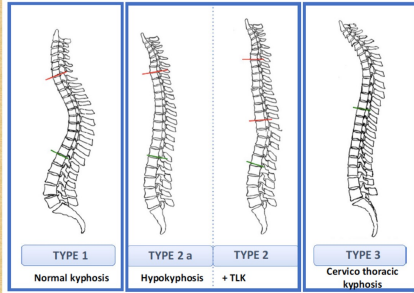
Defining Spino-Pelvic Alignment Thresholds

Should Operative Goals in Adult Spinal Deformity Surgery Account for Age?
Renaud Lafage, MS,* Frank Schwab, MD,* Vincent Chaillet, MD,† James K. Henry, BA,* Jeffrey Gum, MD,‡
Justin Smith, MD, PhD,‡ Richard Haidich, MD,‡ Christopher Shaffrey, MD,‡ Han J. Kim, MD,‡
Christopher Ames, MD,‡ Justin Scheer, BS,† Eric Klingenberg, MD,‡ Shay Bess, MD,‡ Douglas Burton, MD,‡
and Virginie Lafage, PhD,† International Spine Study Group

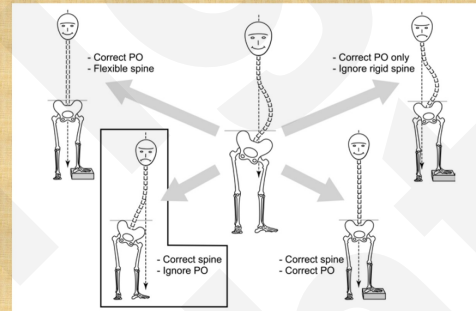


Sagittal classification in adolescent idiopathic scoliosis: original description and therapeutic implications

K. Abelin-Genevois¹ • D. Sassi¹ • S. Verdun² • P. Roussouly¹
European Spine Journal (2018) 27:2192–2202
<https://doi.org/10.1007/s00586-018-5613-1>



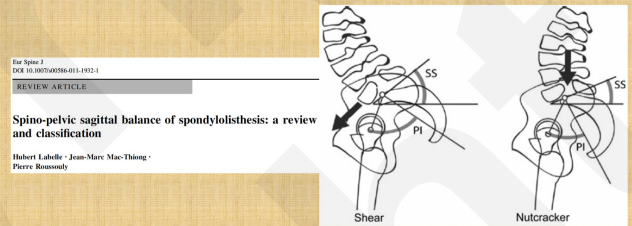
Don't Forget Pelvic Obliquity / LLD



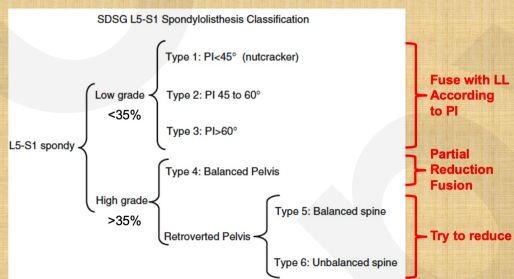
Goals of Deformity Correction

- “to achieve a balanced spinal alignment through rigid fusion, prevent further deformity and alleviate neurological symptoms”
- **Sagittal Correction:**
 - Segmental Lordosis
 - SVA<4-5cm
 - Match PI and LL +/- 10deg
 - PT<20 degrees
 - GAP Score / Surgaline / KEOPS ...

And just to confuse issues...

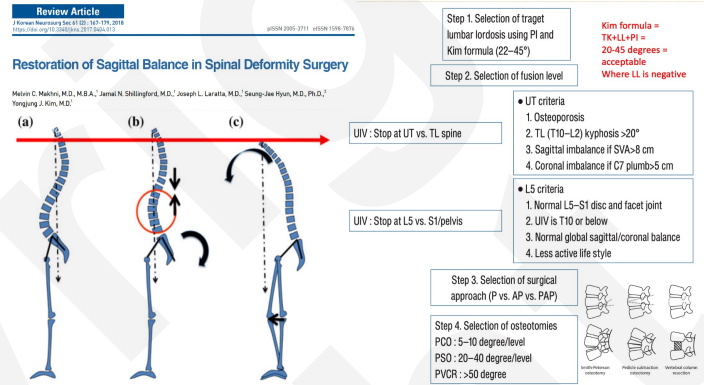


Algorithms for 5/1 Slips



Adult Spinal Deformity - Have an Algorithm...

- What does the patient want?
- What is most appropriate for your patient?
- Surgical factors to consider - ABC Approach:
 - **A**ge **A**lignment **A**natomy **A**ccess
 - **B**one Quality / **B**alance
 - **C**ompression – central / lateral / foraminal
 - **D**isc Height / **D**egeneration / **D**eformity / **D**ura
 - **E**valuate Stability – supine / erect / dynamic
 - **F**acet Orientation / **G**ap
 - **H**ow many operations?...



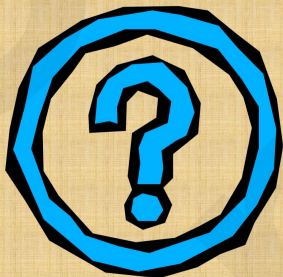
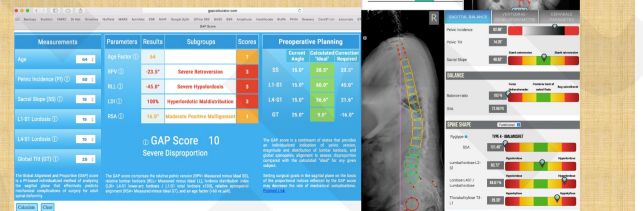
Indirect vs Direct Decompression

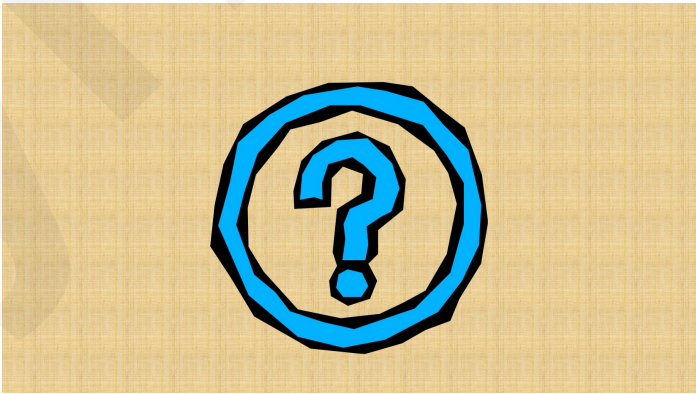
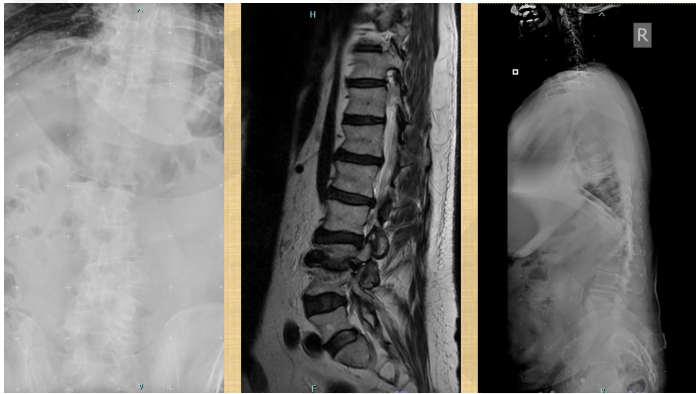
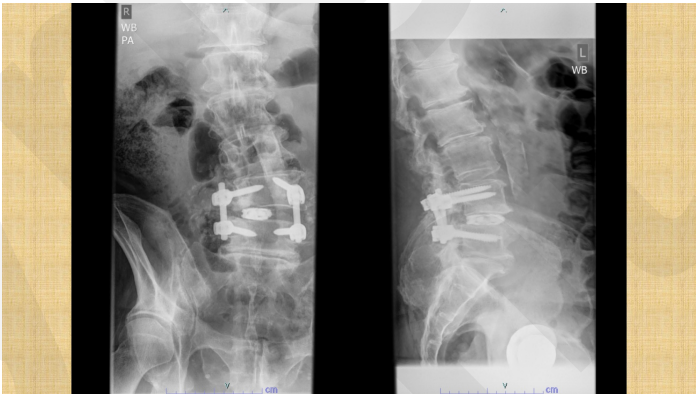
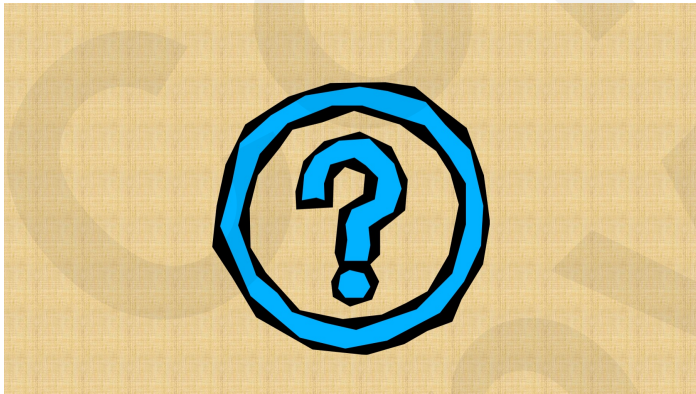
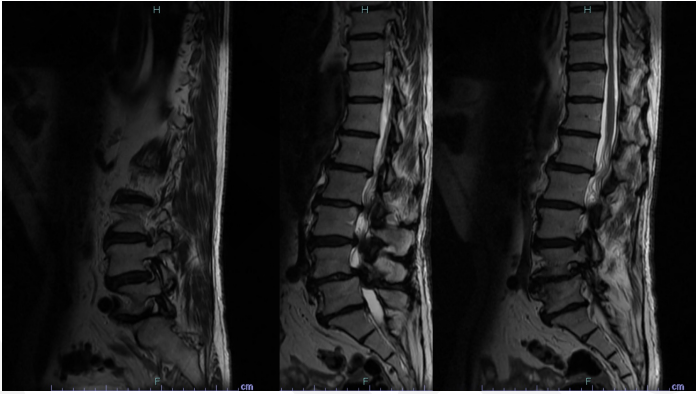
- Indirect decompression
 - Minimum risk to the nerves
 - ALIF / LLIF – allow good fusion footprint
 - Harmonious spine / segmental lordosis – hyperlordotic cages
 - LLIF 4.1% failure rate to decompress
- Direct decompression
 - Allows inspection of the nerves
 - TLIF and PSO
 - (Can reduce fusion)

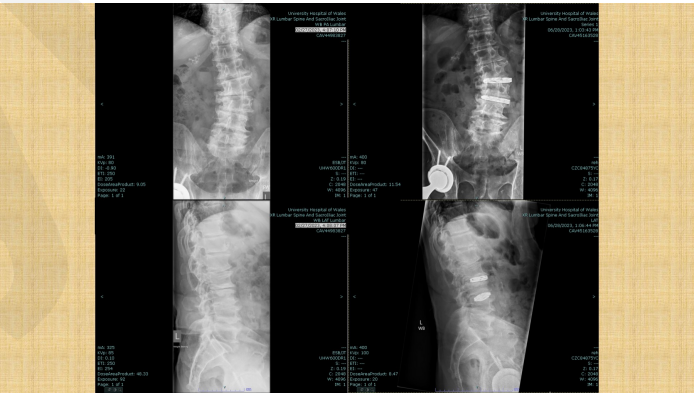
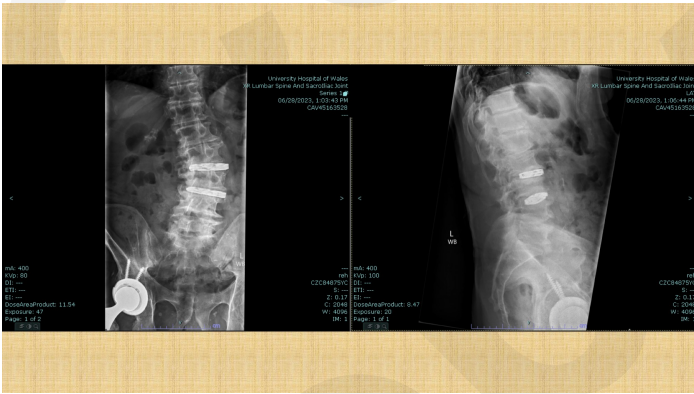
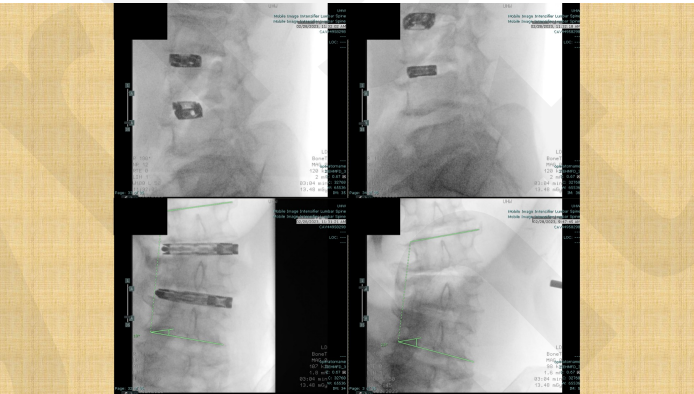
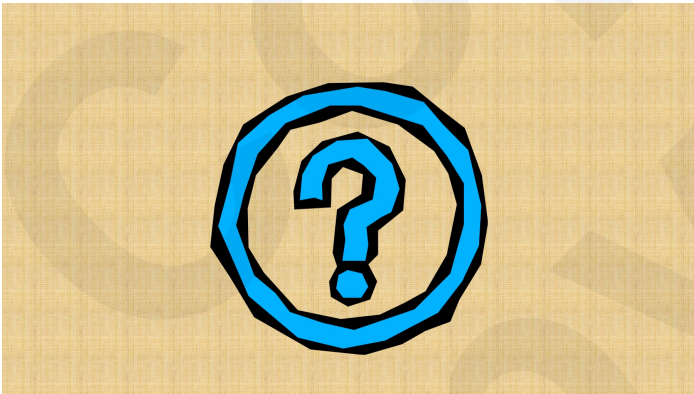
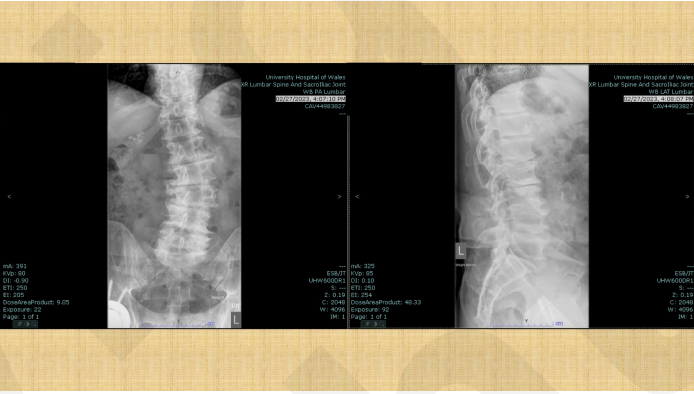
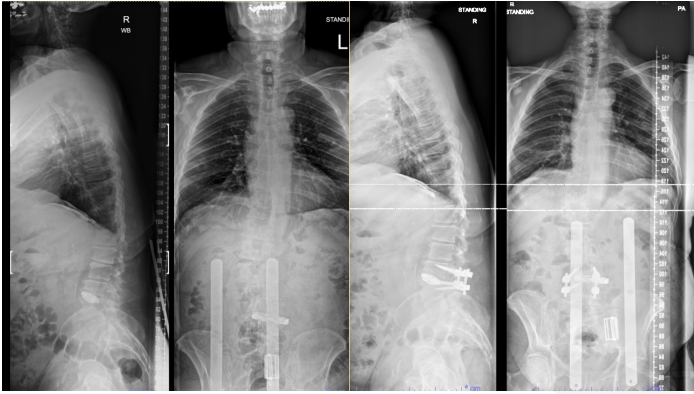


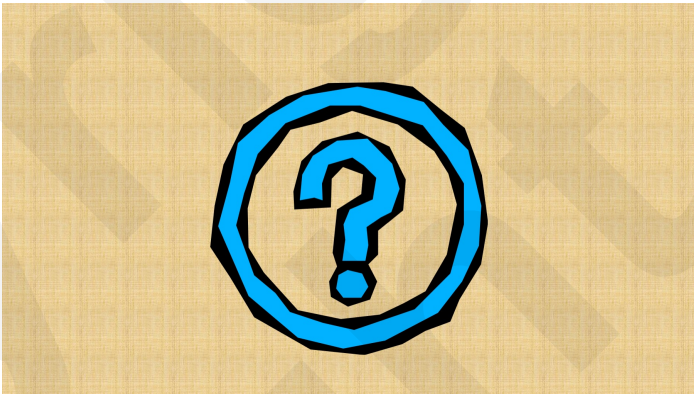
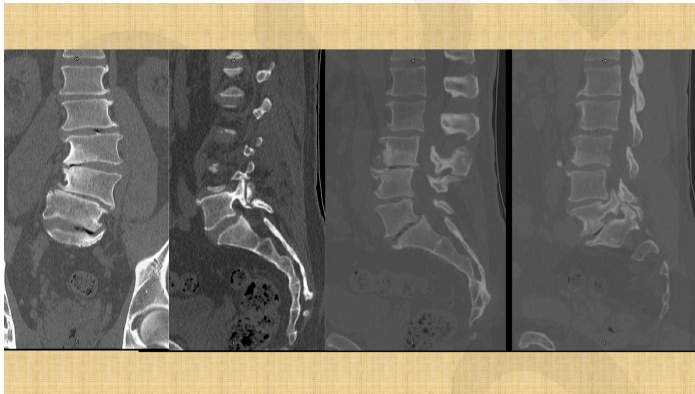
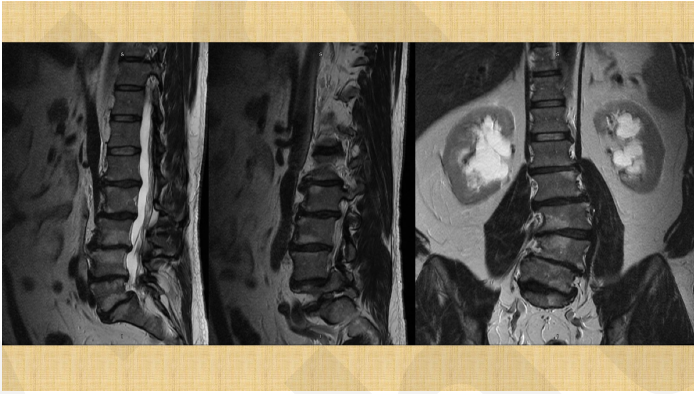
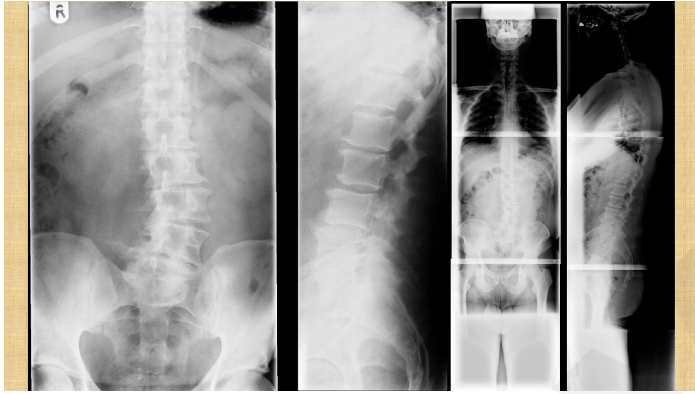
Surgical Planning

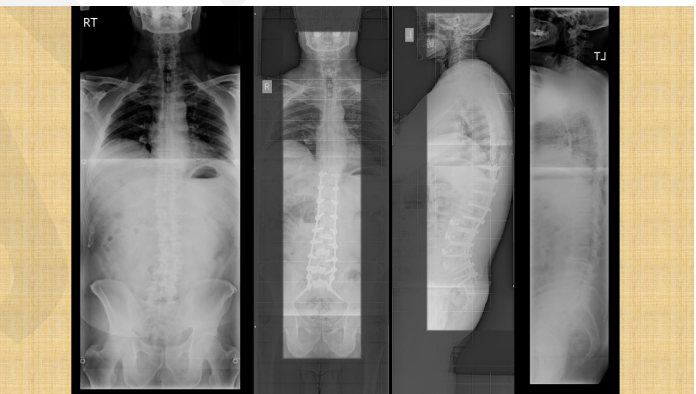
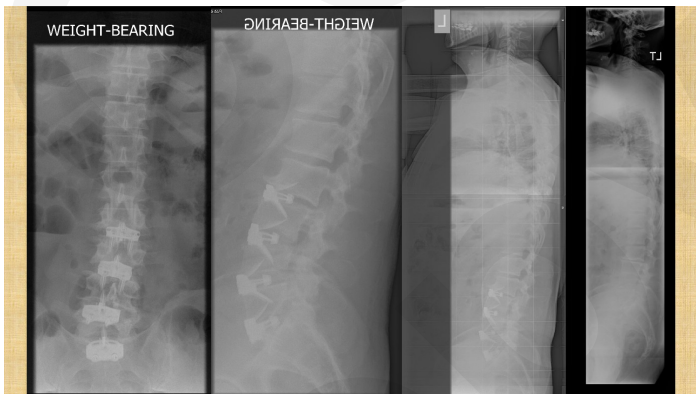
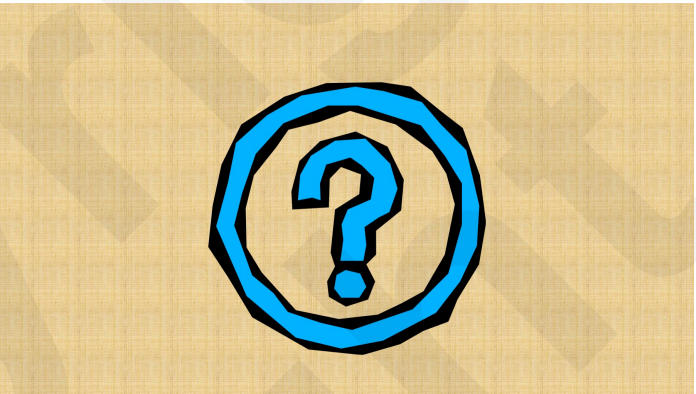
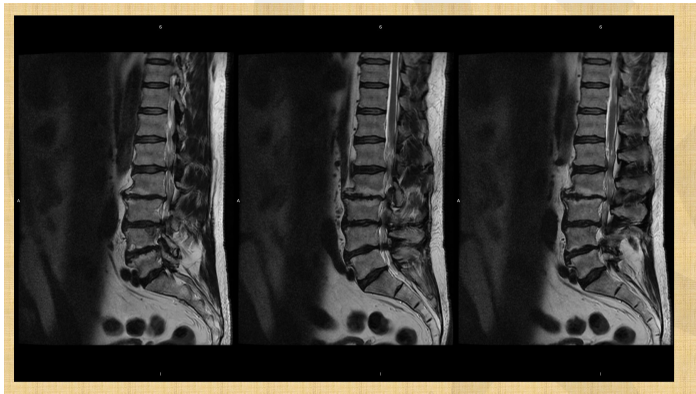
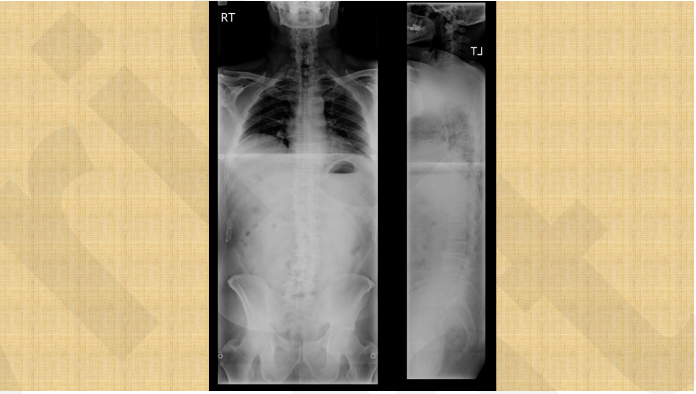
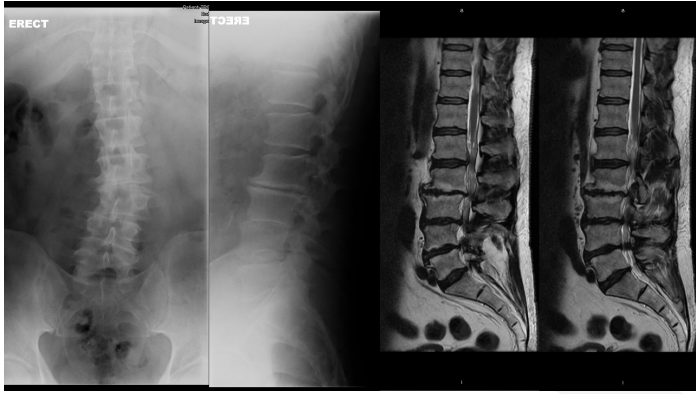
- Depends on understanding all the above!!!
- There are some tools to help:

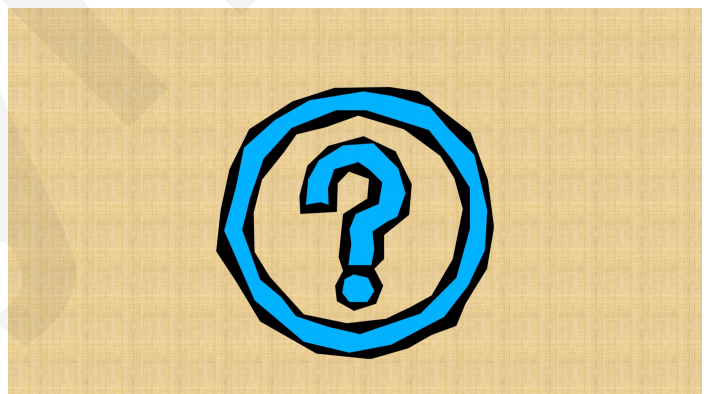
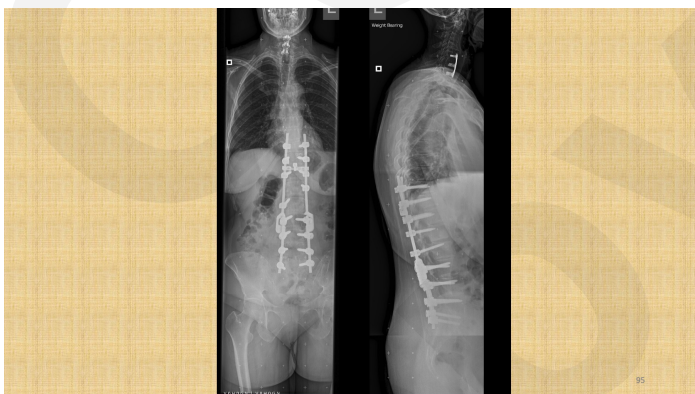
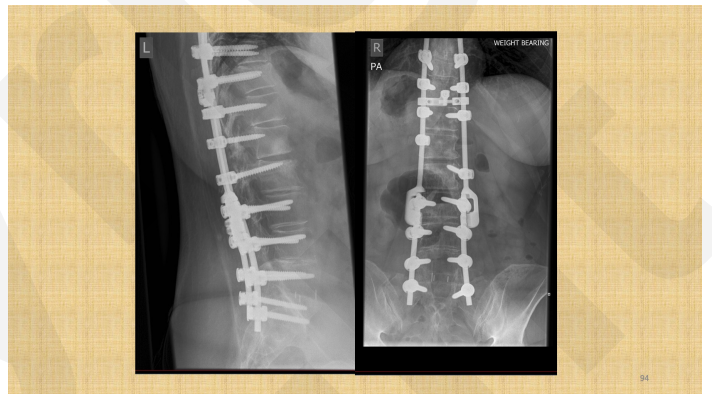
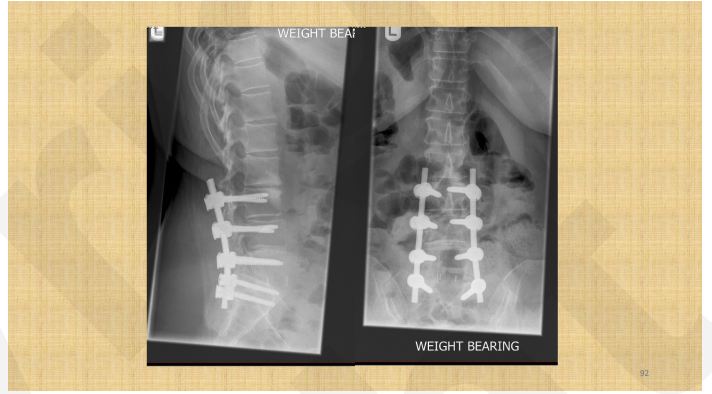
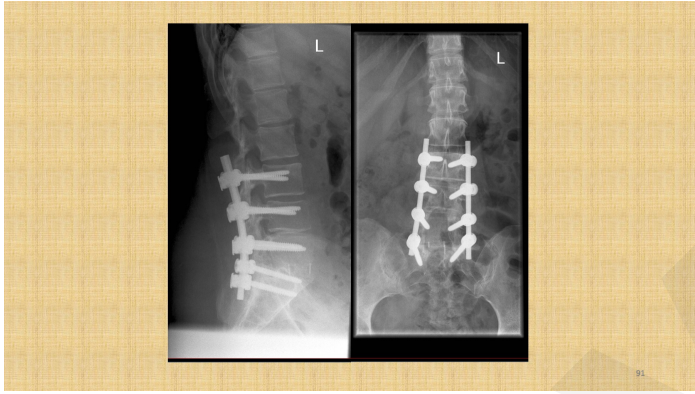


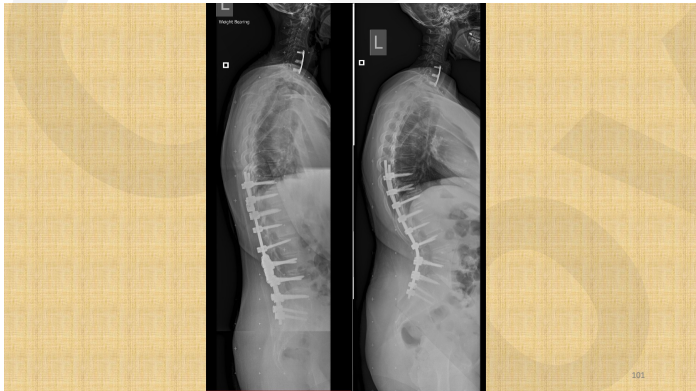
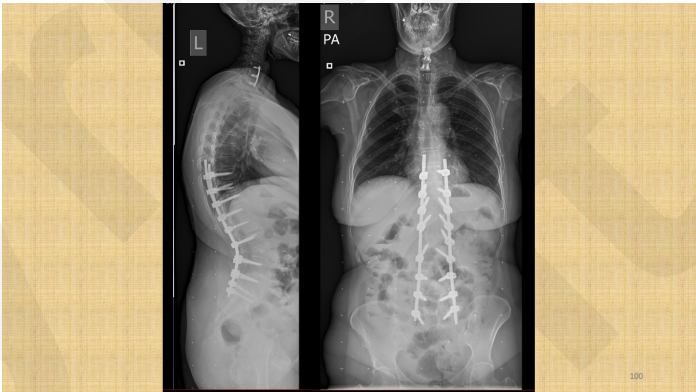
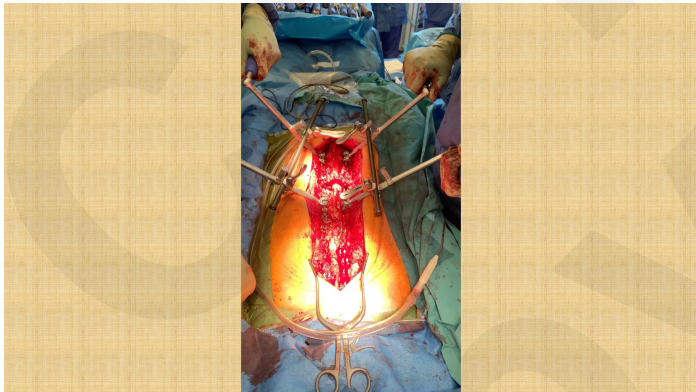
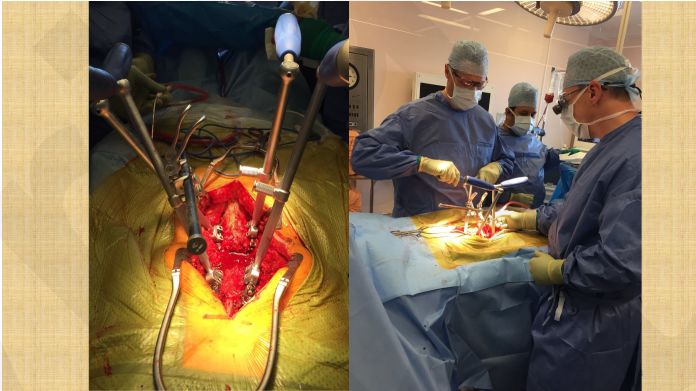
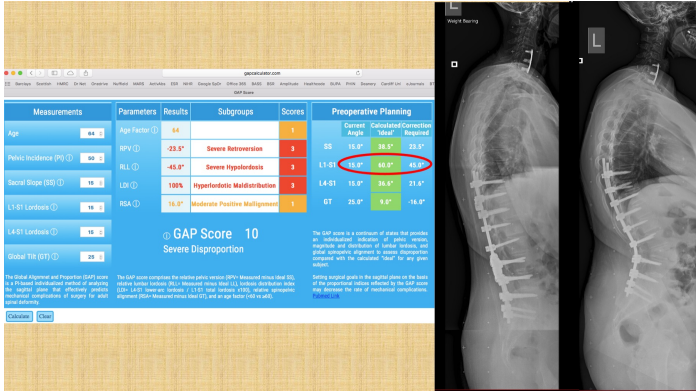


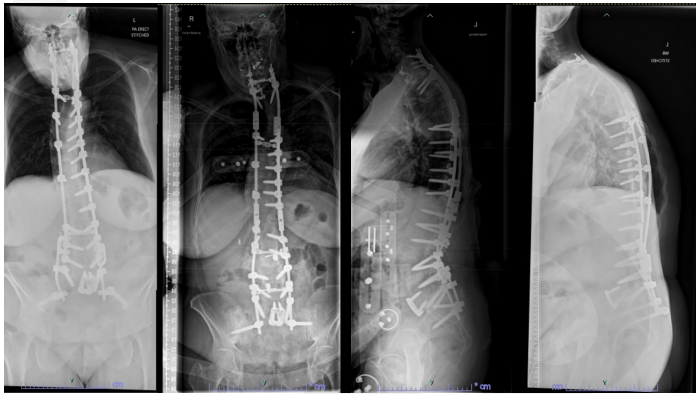
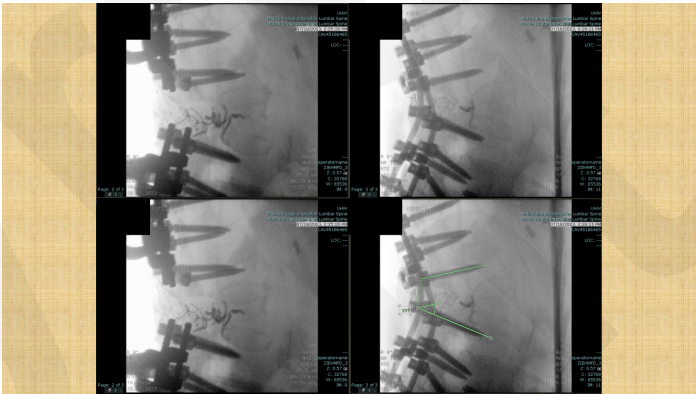
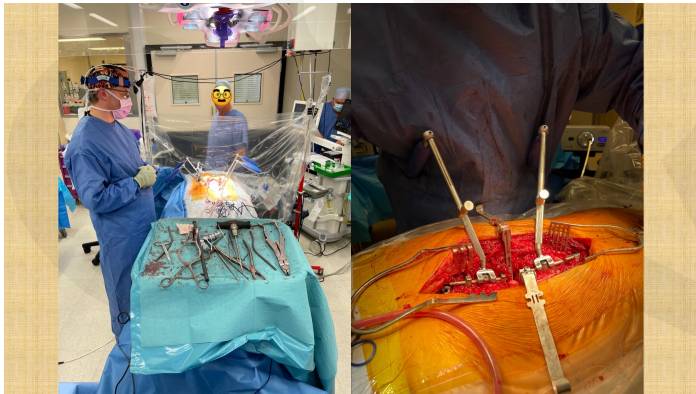
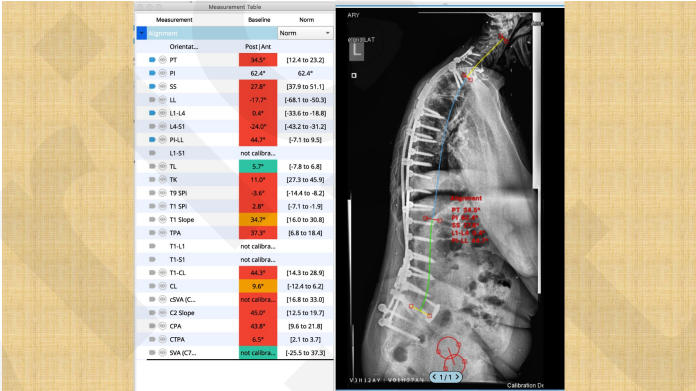
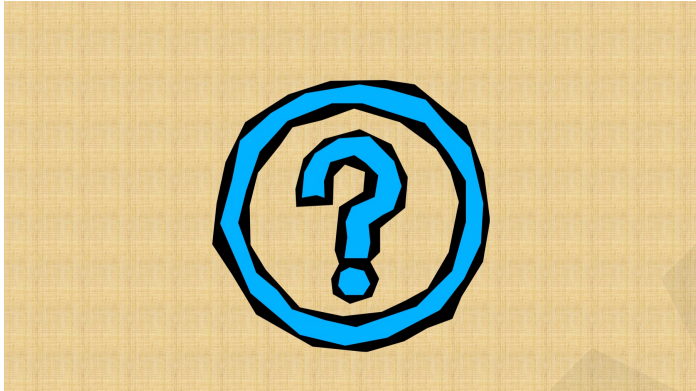




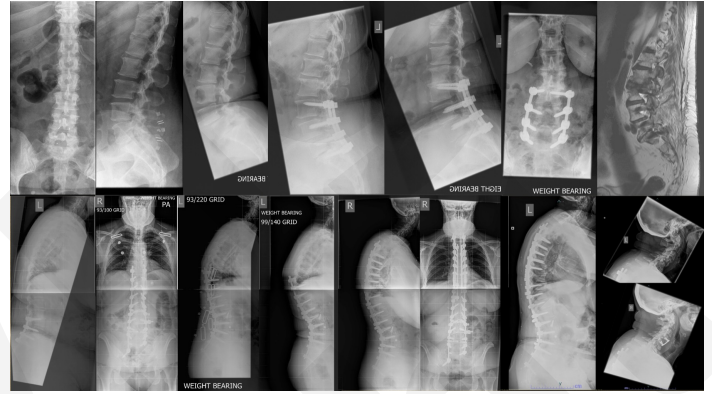
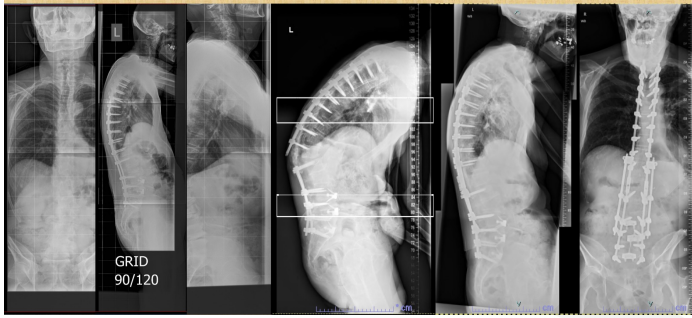








When it goes wrong...



Spine Deformity

Perioperative Outcomes and Complications of Pedicle Subtraction Osteotomy in Cases With Single Versus Two Attending Surgeons
Christopher P. Ames, MD^{1,2}, Jeffrey J. Barry, MD³, Sassan Keikavari, MD⁴, Ozgur Dolek, MD⁵, Michael H. Weber, MD⁶, Vadai Deviren, MD⁷

TOP SECRET

Review

Dual surgeon operating to improve patient safety

R. Ellis^{a,b,*}, J.A. Hardie^c, D.J. Summerton^d, P.A. Brennan^{a,c}



Or Just Decompress Alone...



The Spine Journal 17 (2017) 175–182



Clinical Study
Sagittal imbalance in patients with lumbar spinal stenosis and outcomes after simple decompression surgery

E. Kyung Shin, BS^a, Chi Heon Kim, MD, PhD^{a,c,d,g}, Chun Kee Chung, MD, PhD^{a,c,d,e}, Yunhee Choi, PhD^f, Dahae Yim, MS^f, Whei Jung, BS^f, Sung Bae Park, MD^{a,c,d,g}, Jung Hyeon Moon, MD^{a,c}, Won Heo, MD^{a,c}, Sung-Mi Kim, RN^a

- 83 patients with lumbar stenosis
- 54% had sagittal imbalance
- In 73% it normalized at 1 year with decompression alone

Day to Day Lumbar Degen Patients

- Keep it simple
 - Patient factors
 - Age / Fitness / Morbidities
 - Examination
 - Stand upright - legs straight
 - Walking
 - Erect Lumbar XRs
 - Compare to lying MRI (Slips / Scoliosis)
 - Look at L4 / look at Sacrum / look at Hips
 - Measure the PILL and observe the lordosis L4-S1
 - If in doubt – get whole spine films
 - IS A FUSION REALLY REQUIRED???

Know When To Quit



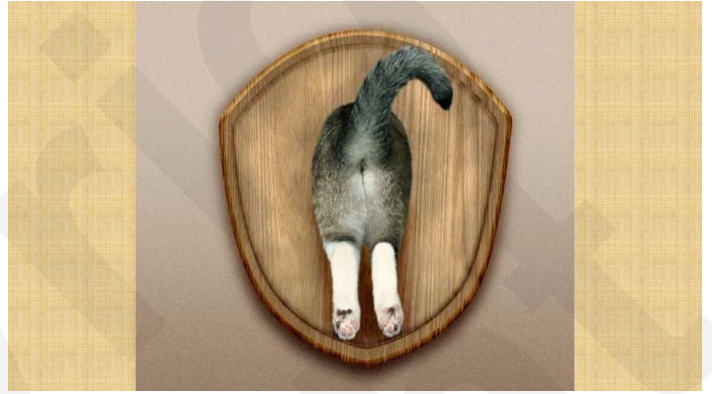
A man's got to know his limitations





Adult Spinal Deformity:

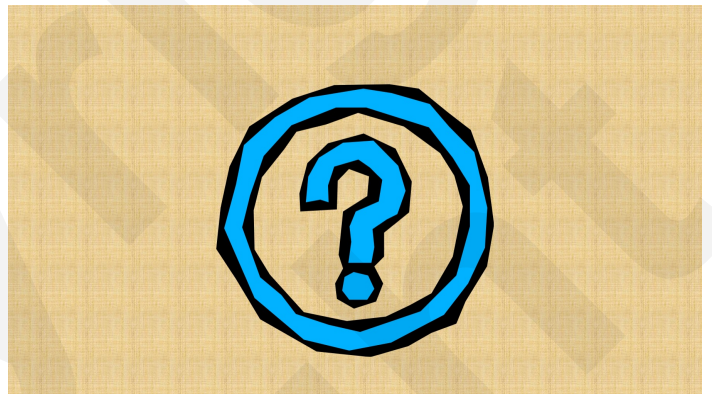
**Pay attention to the detail
Never let your guard down
Otherwise it'll be a...**



And Finally...

**Patient-specific Rods for Surgical Correction
of Sagittal Imbalance in Adults**
Technical Aspects and Preliminary Results

Federico Solla, MD,* Cédric Y. Barrey, MD, PhD,†‡ Evalina Burger, MD,§
Christopher J. Kleck, MD,§ and Vincent Fièvre, MD||



Thank you