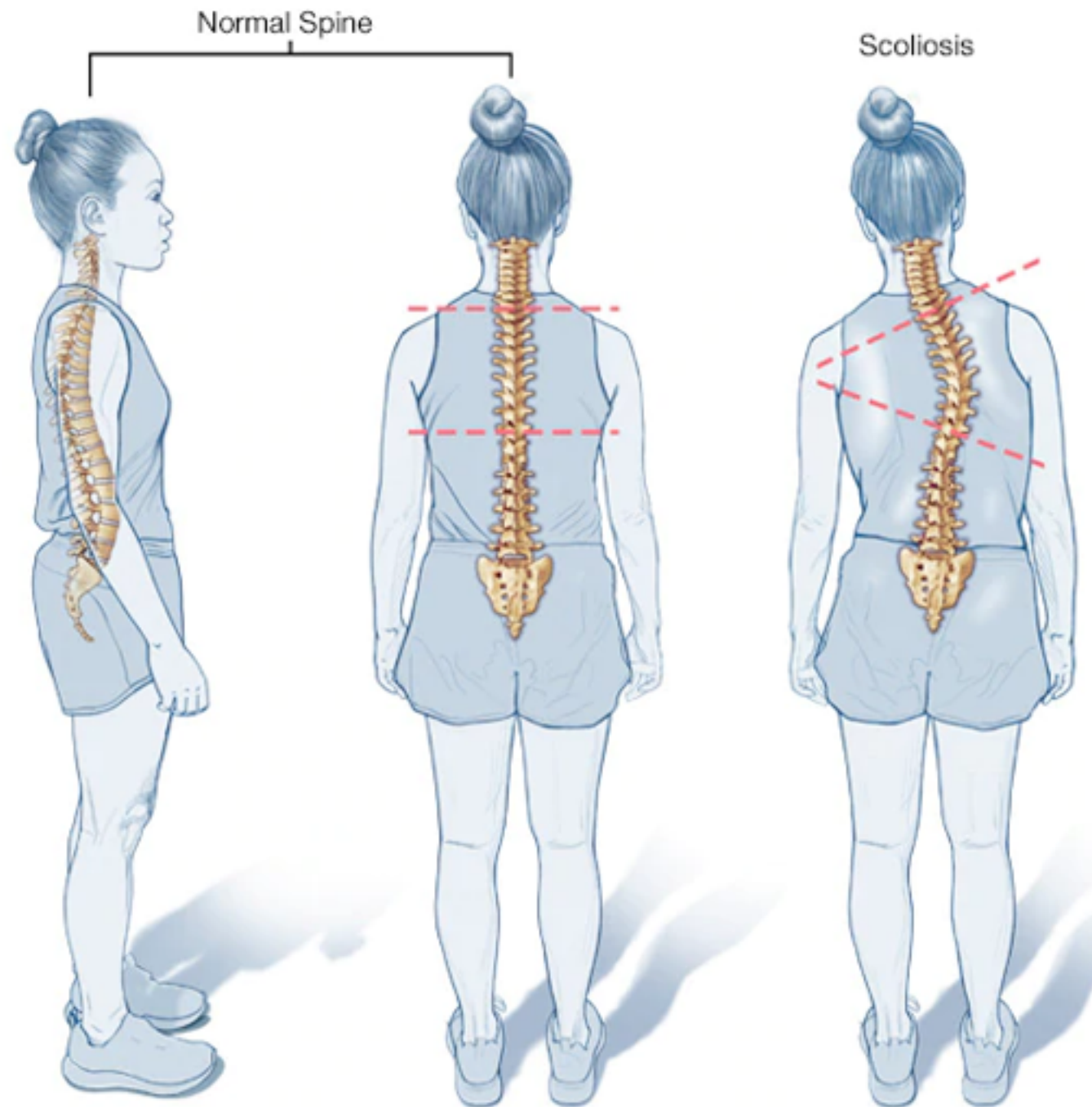
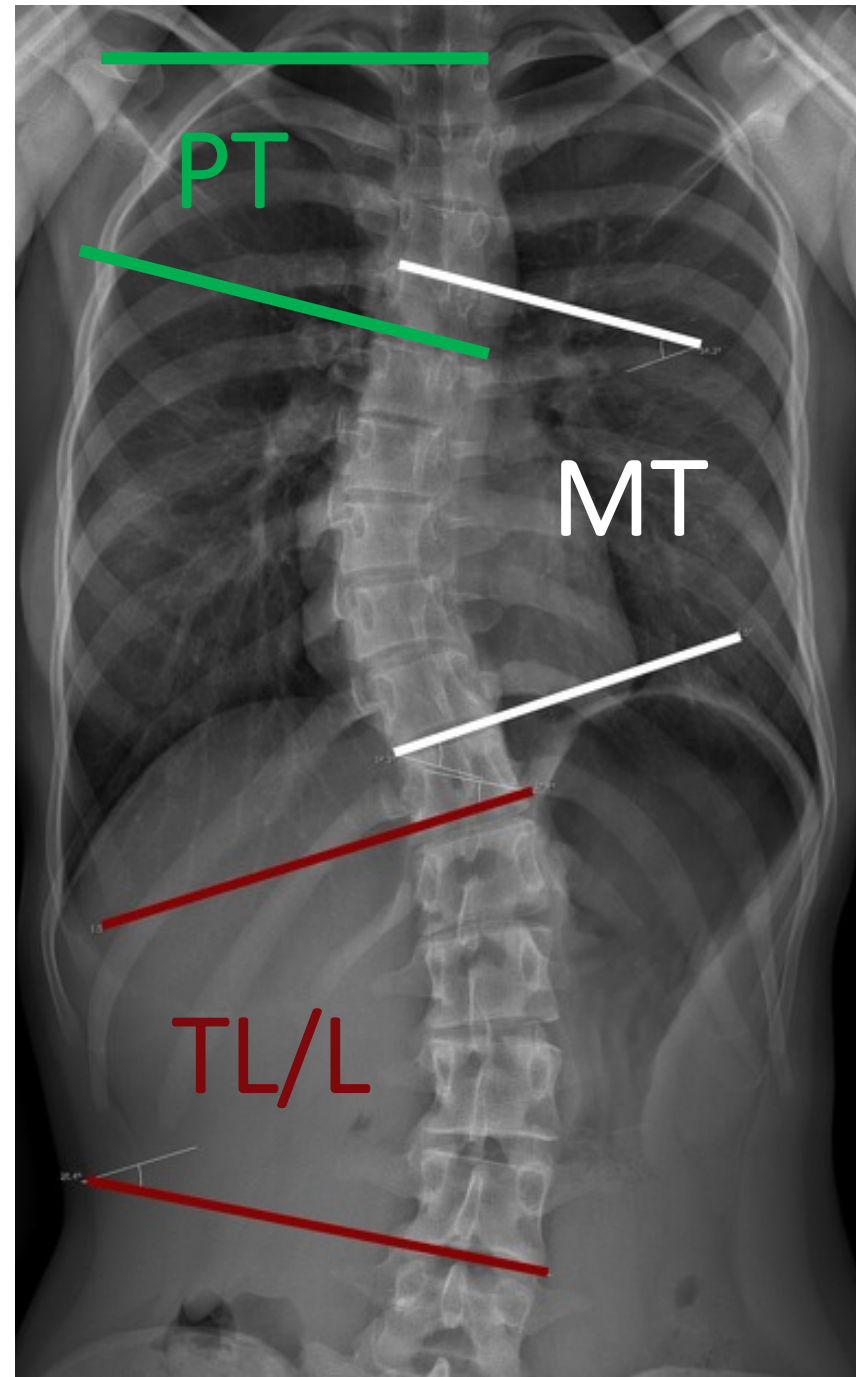


AUTOMATIC SCOLIOSIS ASSESSMENT



















SCOLIOSIS: OVERVIEW



COBB ANGLE MEASUREMENT



LENKE CLASSIFICATION

| <u>Lumbar Spine Modifier</u> | <u>Curve Type (1 - 6)</u> | | | | | |
|---|---|---|---|--|---|---|
| | <u>Type 1</u> (Main Thoracic) | <u>Type 2</u> (Double Thoracic) | <u>Type 3</u> (Double Major) | <u>Type 4</u> (Triple Major) | <u>Type 5</u> (TL/L) | <u>Type 6</u> (TL/L - MT) |
| A (No to Minimal Curve) |  1A* |  2A* |  3A* |  4A* | | |
| B (Moderate Curve) |  1B* |  2B* |  3B* |  4B* | | |
| C (Large Curve) |  1C* |  2C* |  3C* |  4C* |  5C* |  6C* |
| Possible Sagittal structural criteria (To determine specific curve type) |  Normal |  PT Kyphosis |  TL Kyphosis |  PT + TL Kyphosis | | |

* T5-12 sagittal alignment modifier: -, **N**, or +
 - : <10°
 N : 10-40°
 + : >40°

PITFALLS

Accuracy affected by:

- Selection of vertebrae
- Observer bias
- Image quality



High inter and intra-observer variability
(3-5° MAD for Cobb Angles [2]-[4])



Time consuming



TEAM



Academic

Darragh Maguire – Biomedical Engineering

Dr John Healy – Electronic Engineering

Dr Kathleen Curran – Medicine



Clinical

Mr Michael Dodds, Consultant Orthopaedic Surgeon

Mr Connor Green, Consultant Orthopaedic Surgeon

Prof Eoin Kavanagh, Consultant Radiologist

Dr Rosanne-Sara Lynham, Orthopaedic Registrar

Dr Ivan Welaratne, Specialist Registrar in Radiology



```
graph LR; A[Vertebral Segmentation] --> B[Fitting of Endplates]; B --> C[Cobb Angle Calculation]; C --> D[Lenke Curve Type Probability Analysis];
```

Vertebral
Segmentation

Fitting of
Endplates

Cobb Angle
Calculation

Lenke Curve
Type Probability
Analysis

PROPOSED SYSTEM



```
graph LR; A[Vertebral Segmentation] --> B[Fitting of Endplates]; B --> C[Cobb Angle Calculation]; C --> D[Lenke Curve Type Probability Analysis];
```

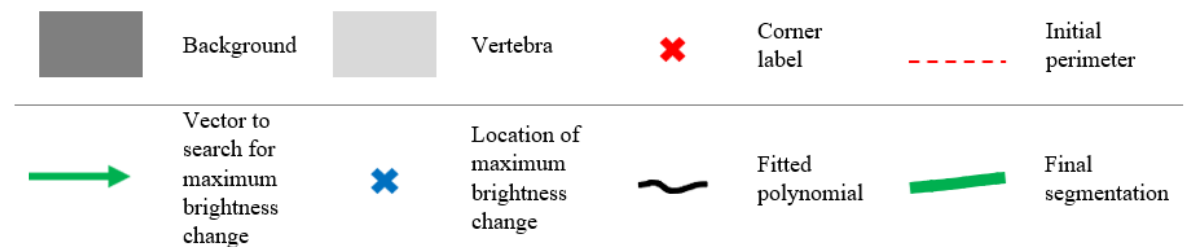
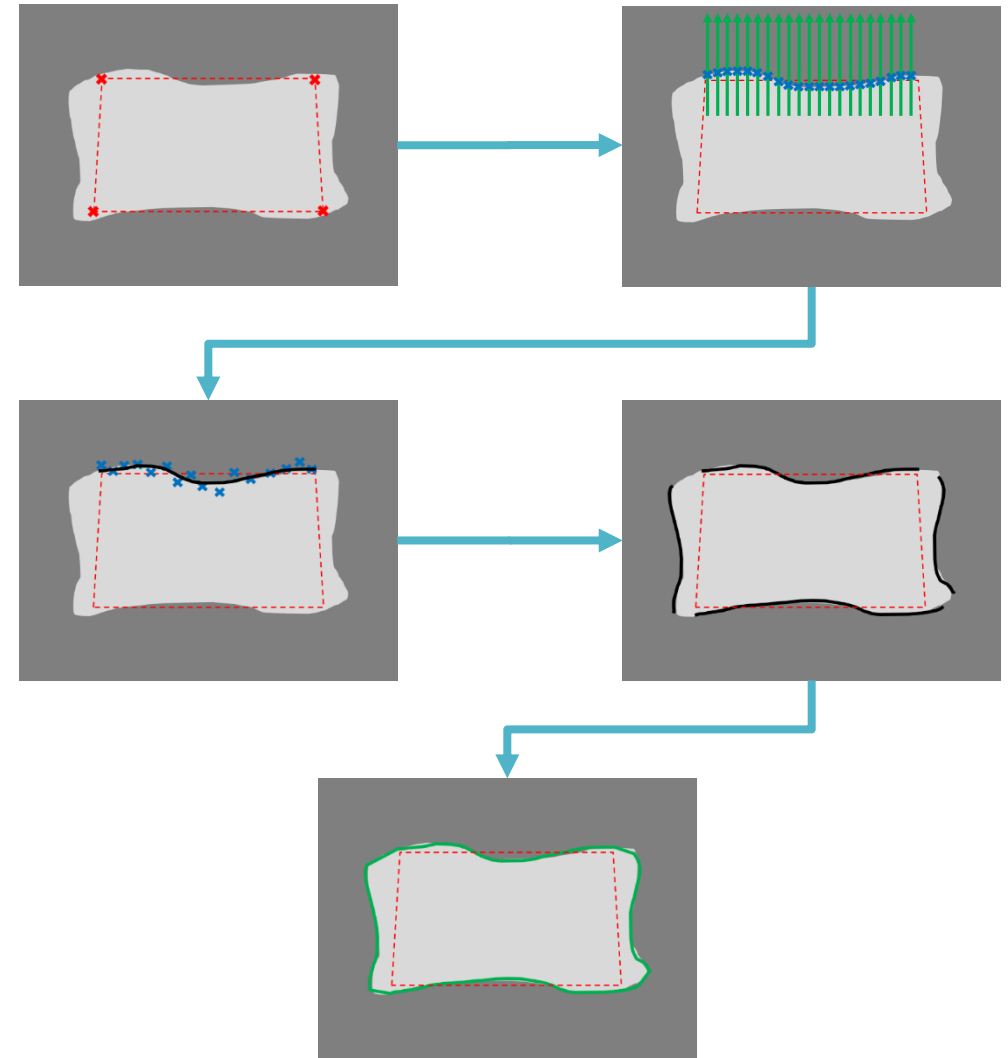
Vertebral
Segmentation

Fitting of
Endplates

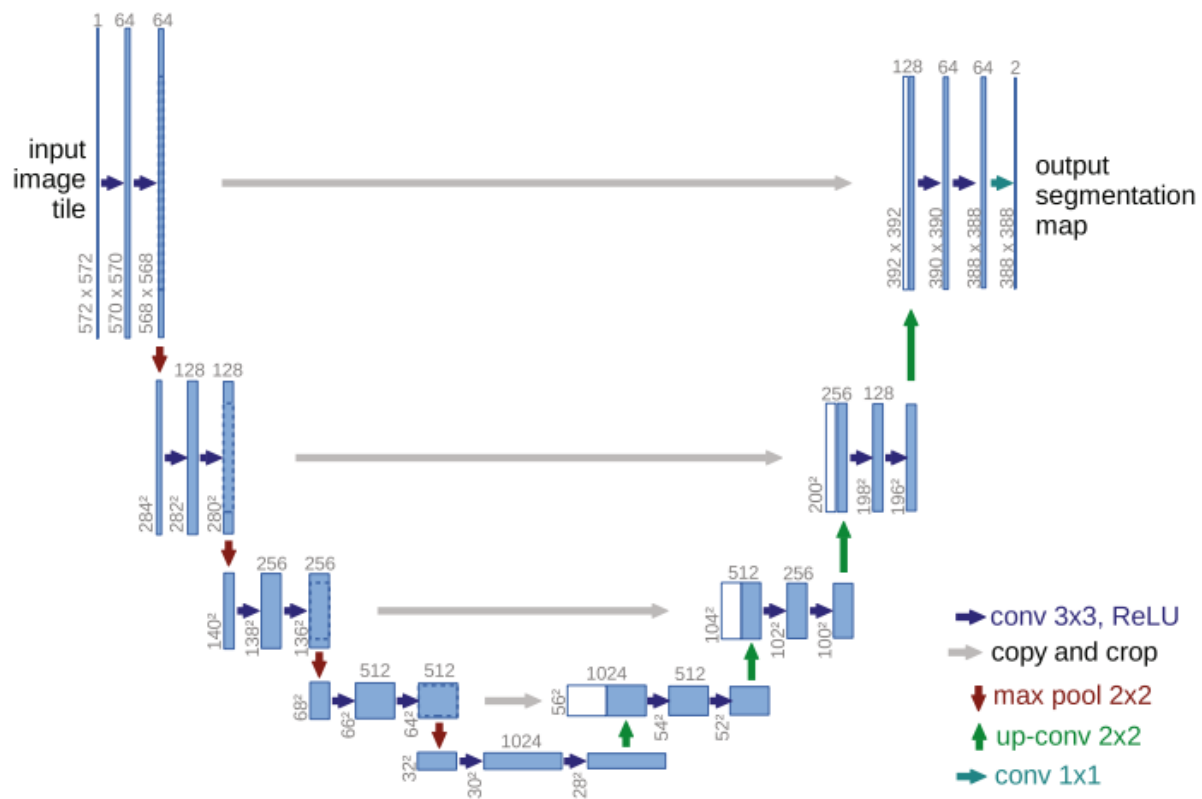
Cobb Angle
Calculation

Lenke Curve
Type Probability
Analysis

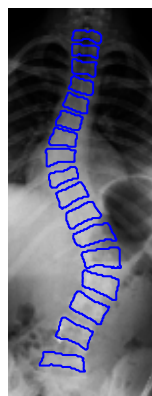
NOVEL GROUND- TRUTH VERTEBRAL SEGMENTATIONS



Vertebral Segmentation Network



Random Sample of Images & Corresponding Vertebral Segmentations



Vertebral Segmentation



```
graph LR; A[Vertebral Segmentation] --> B[Fitting of Endplates]; B --> C[Cobb Angle Calculation]; C --> D[Lenke Curve Type Probability Analysis]
```

Vertebral
Segmentation

Fitting of
Endplates

Cobb Angle
Calculation

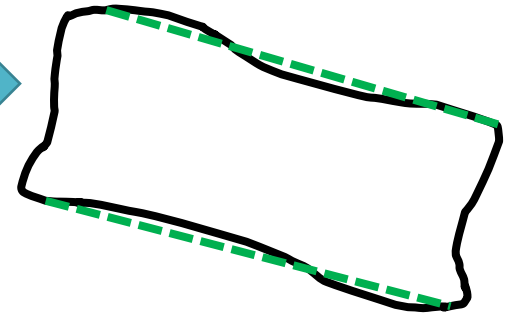
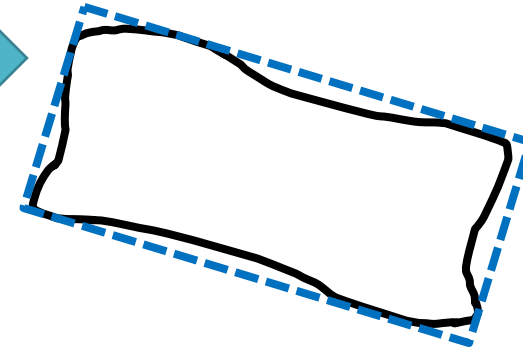
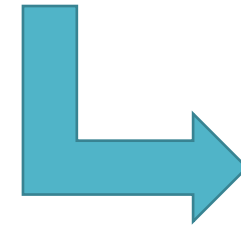
Lenke Curve
Type Probability
Analysis

Fitting of Endplates

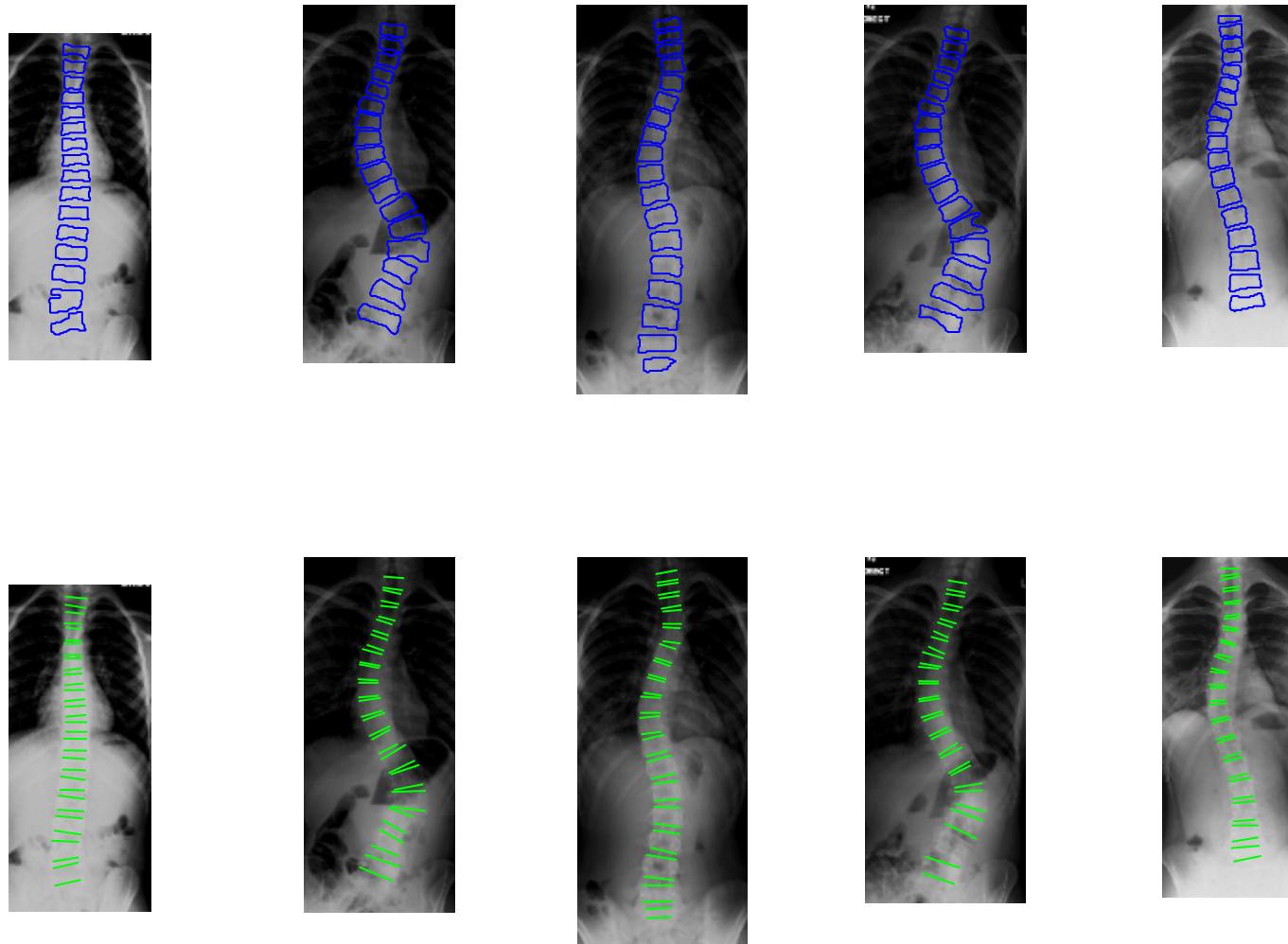
Minimum
Bounding
Rectangle



Linear Least
Squares Fit



Random Sample of Vertebral Segmentations & Corresponding Fitted Endplates



Vertebral Segmentation



Fitted Endplate

```
graph LR; A[Vertebral Segmentation] --> B[Fitting of Endplates]; B --> C[Cobb Angle Calculation]; C --> D[Lenke Curve Type Probability Analysis];
```

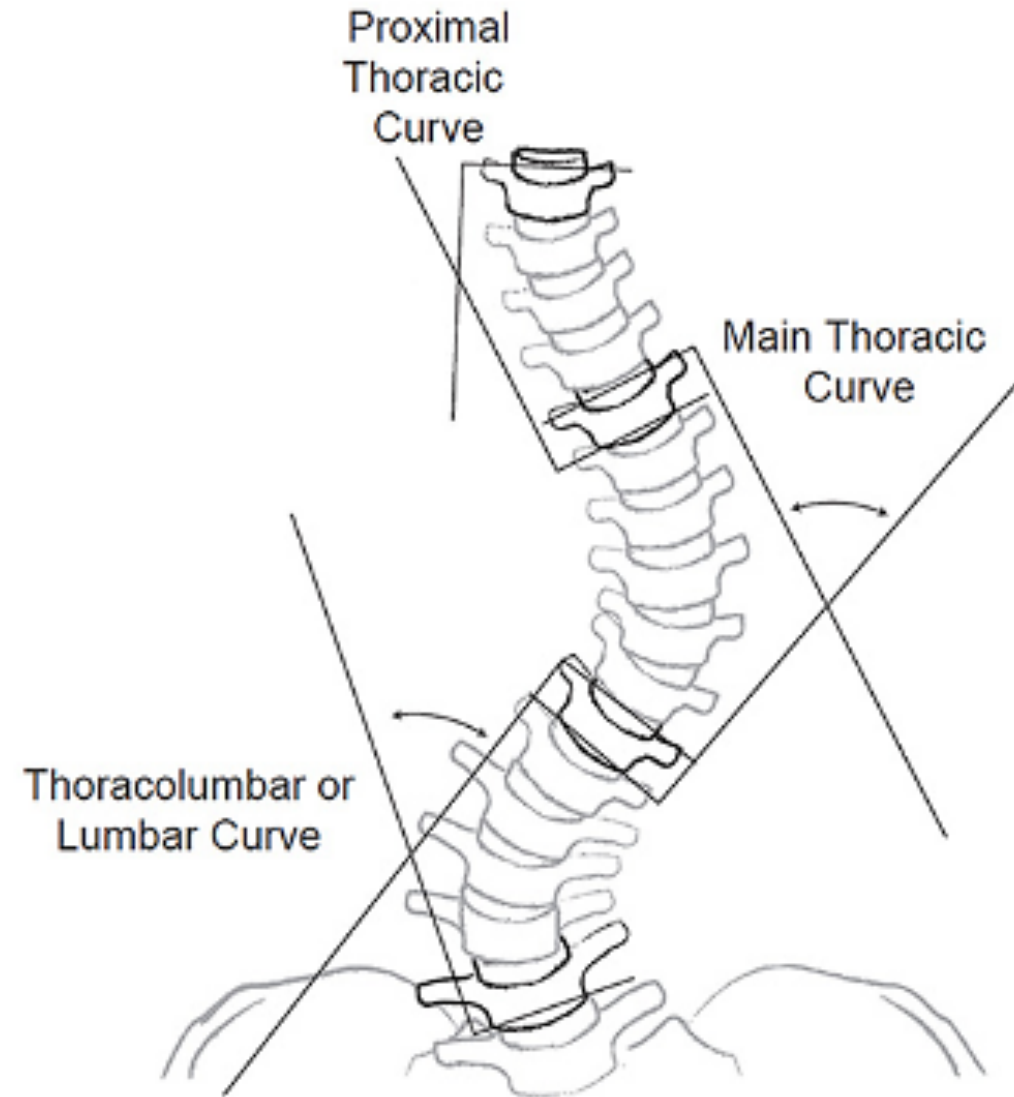
Vertebral
Segmentation

Fitting of
Endplates

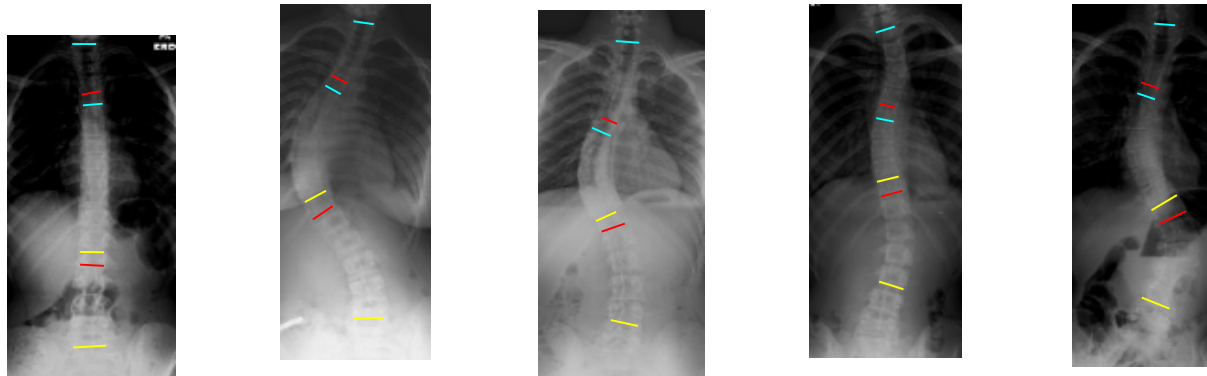
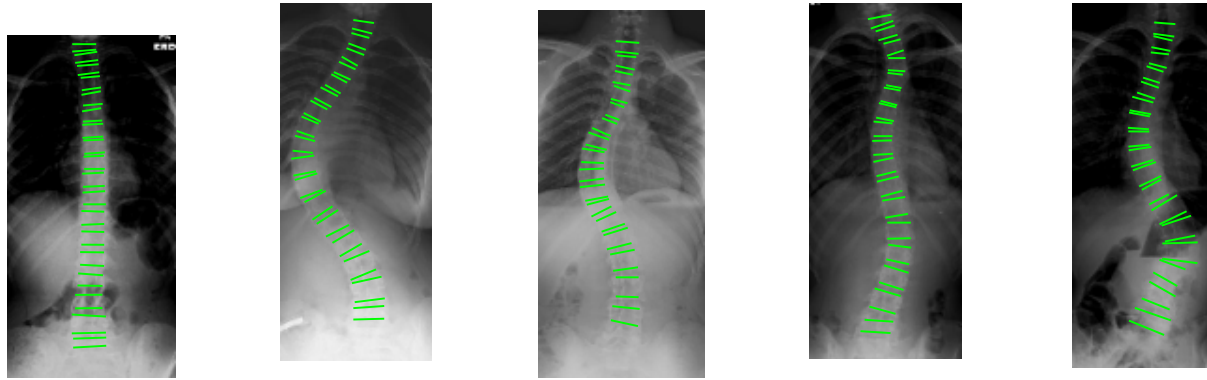
Cobb Angle
Calculation

Lenke Curve
Type Probability
Analysis

Cobb Angle Calculation



Random Sample of Fitted Endplates & Corresponding Cobb Angles



— PT Cobb Angle — Fitted Endplate — MT Cobb Angle — TL/L Cobb Angle

```
graph LR; A[Vertebral Segmentation] --> B[Fitting of Endplates]; B --> C[Cobb Angle Calculation]; C --> D[Lenke Curve Type Probability Analysis];
```

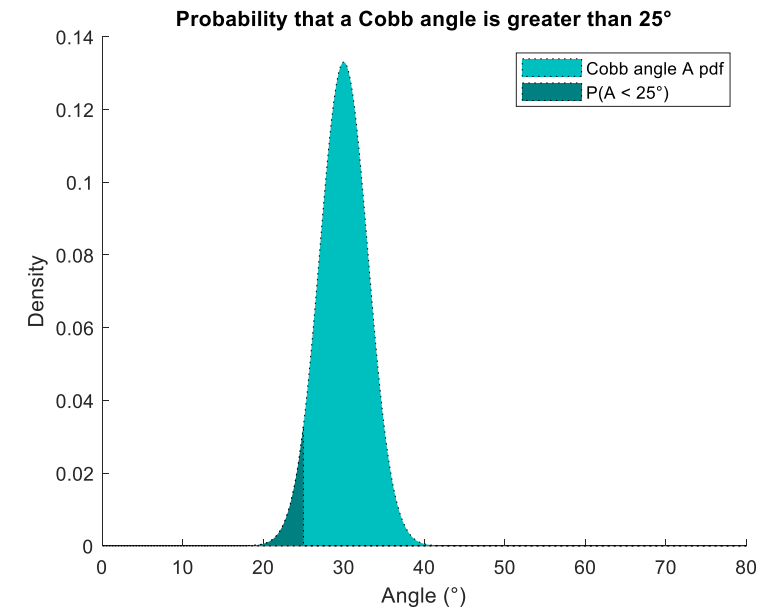
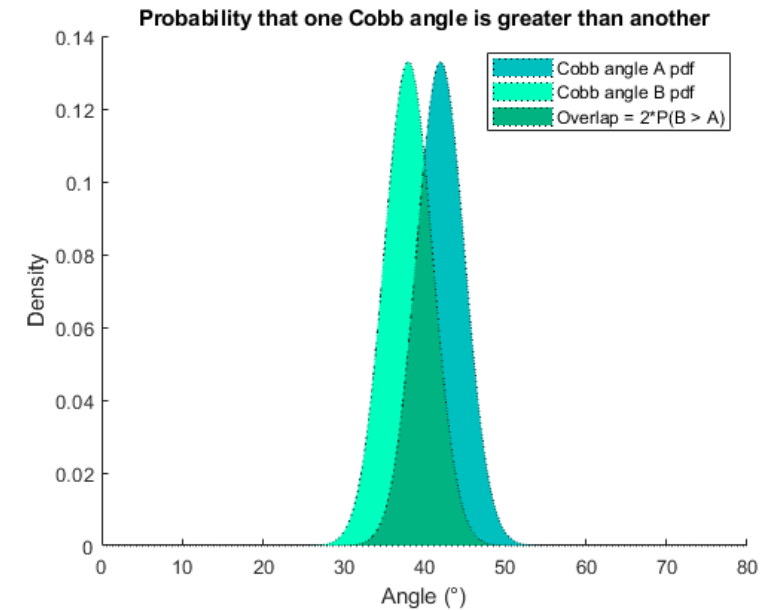
Vertebral
Segmentation

Fitting of
Endplates

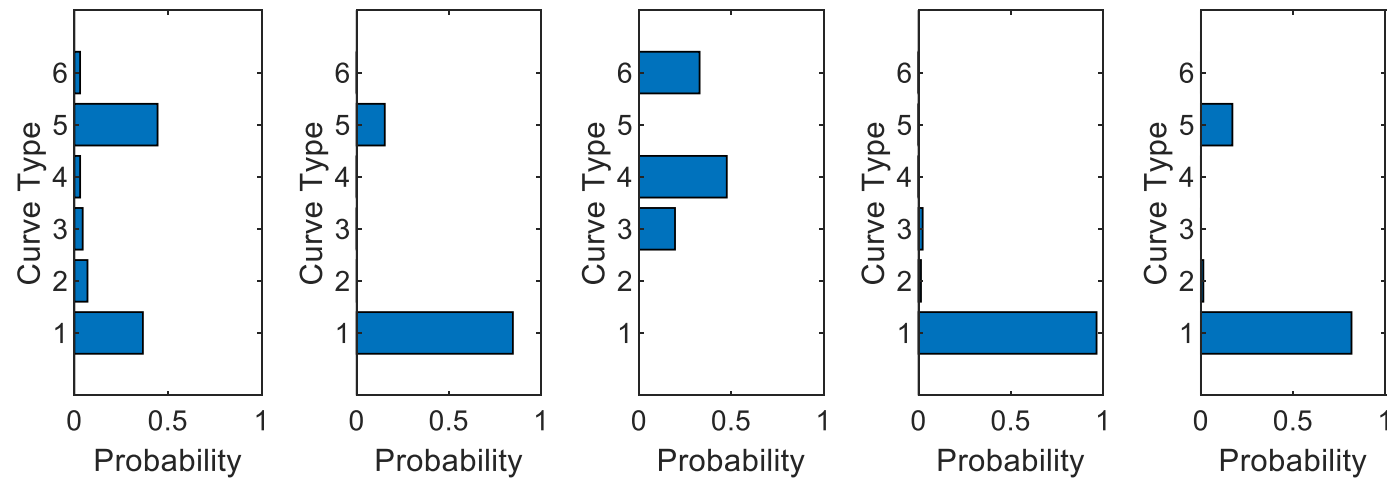
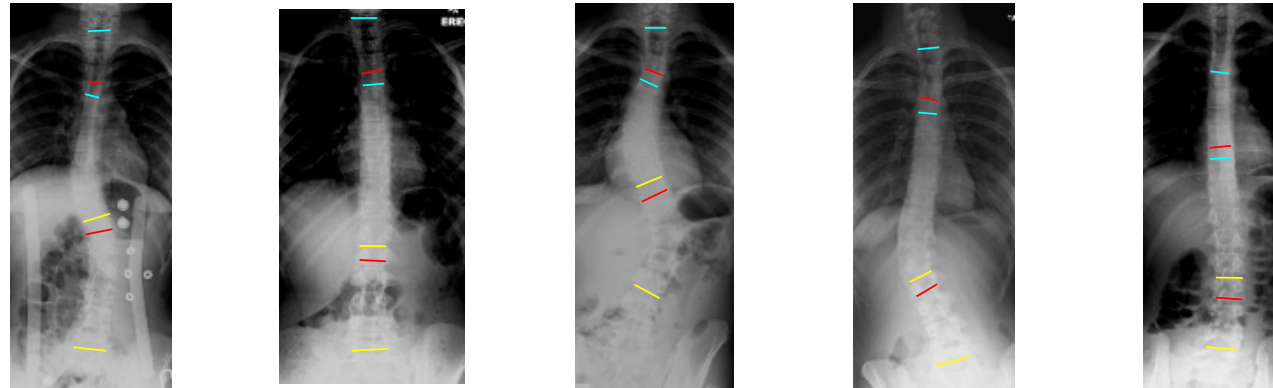
Cobb Angle
Calculation

Lenke Curve
Type Probability
Analysis

Novel Lenke Curve Type Probability Analysis

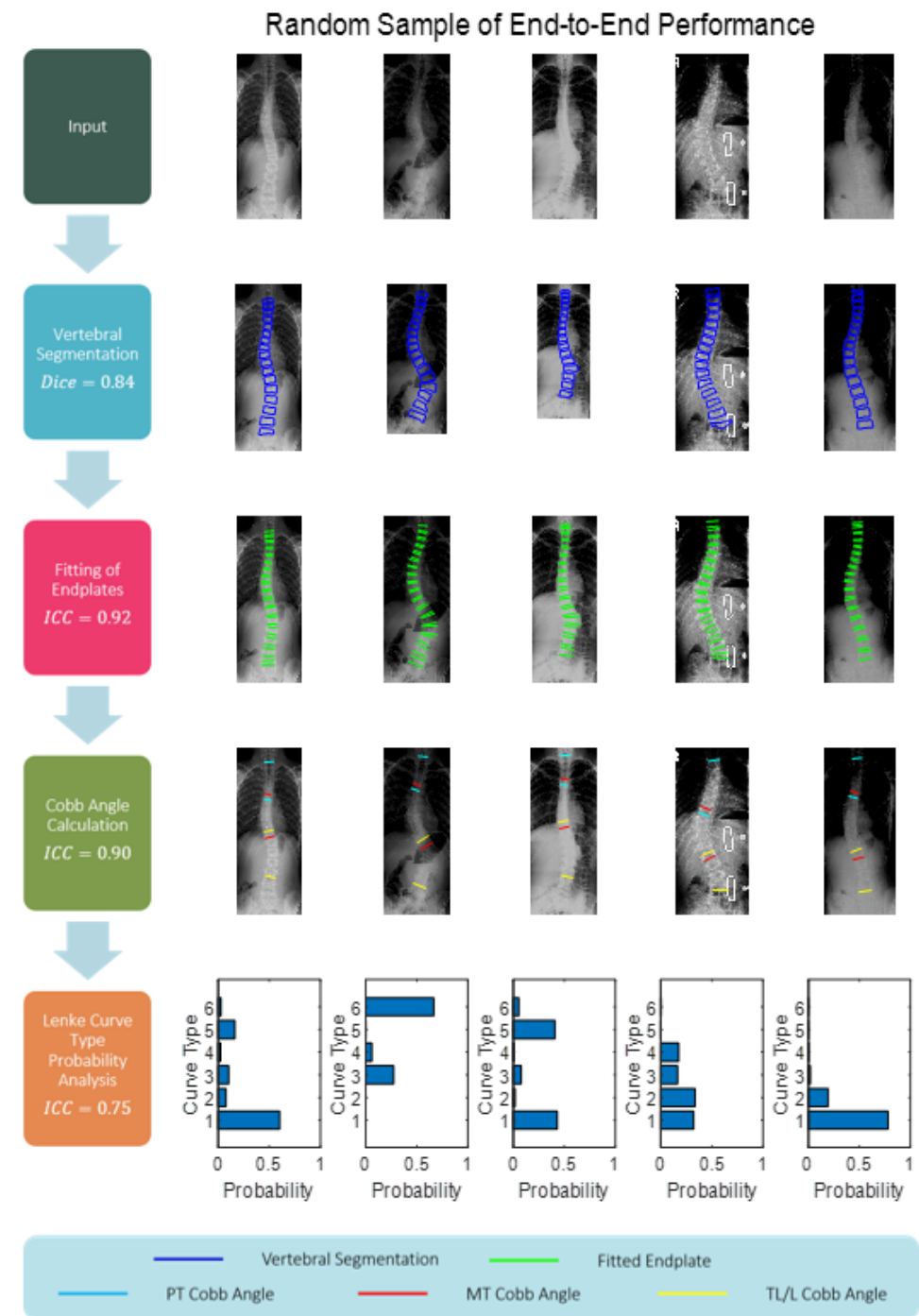


Random Sample of Cobb Angles & Corresponding Lenke Curve Type Probabilities



— PT Cobb Angle — MT Cobb Angle — TL/L Cobb Angle

Overview of Performance



Future Work: Automatic Assessment

Vertebral Segmentation

- Cobb Angle Measurement
- Lenke Curve Type Classification

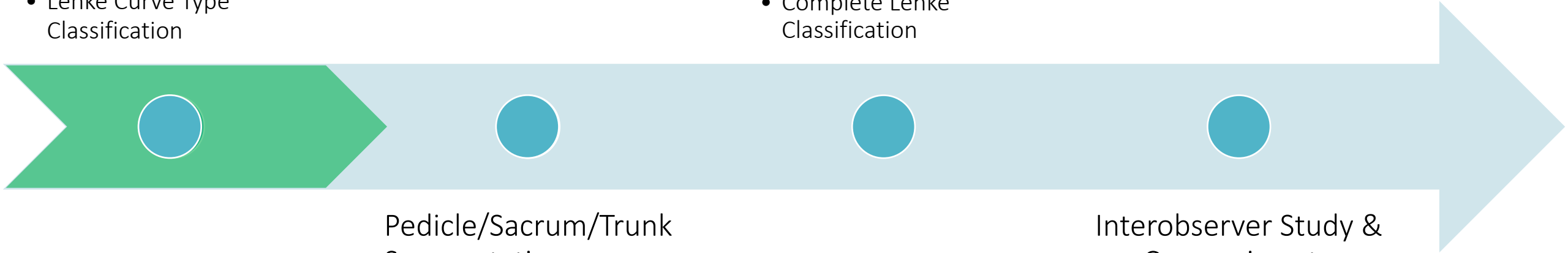
Bending & Sagittal View X-ray Analysis

- Complete Lenke Classification

Pedicle/Sacrum/Trunk Segmentation

- Trunk Shift Measurement
- Lenke Lumbar Modifier Assignment

Interobserver Study & Comparison to Automatic Methods



Lenke Probability Analysis as an Aid to Current Clinical Practice

Calculator

After all fields are entered, please click on the link to
the calculated Lenke Classification.

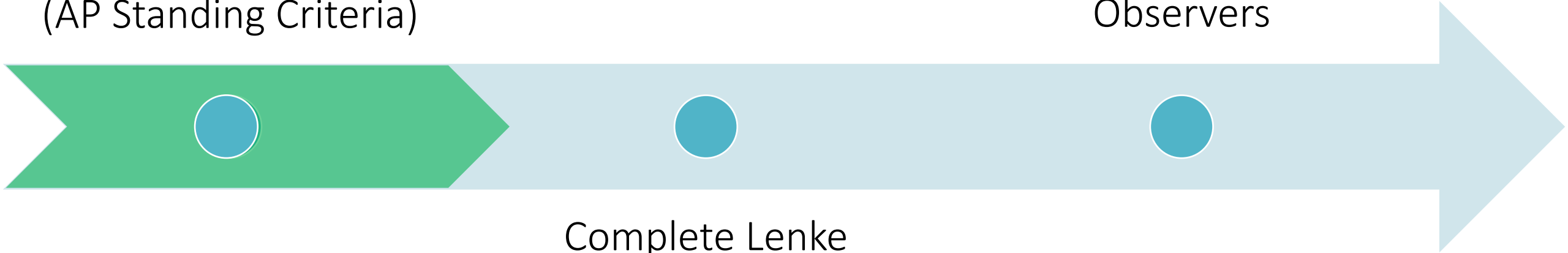
| Coronal Measurements | Sagittal Measurements |
|--|--|
| Proximal Thoracic Cobb: <input type="text"/> | T2-T5 Kyphosis: <input type="text"/> |
| Proximal Thoracic Bend: <input type="text"/> | T5-T12 Kyphosis: <input type="text"/> |
| Thoracic Cobb: <input type="text"/> | T10-L2 Kyphosis: <input type="text"/> |
| Thoracic Bend: <input type="text"/> | |
| Thoracolumbar Cobb: <input type="text"/> | |
| Thoracolumbar Bend: <input type="text"/> | |
| | Lumbar Modifier |
| | <input type="radio"/> Between Lumbar Apex Pedicles |
| | <input type="radio"/> Touches Lumbar Apex Pedicle |
| | <input type="radio"/> Outside Lumbar Apex Pedicles |

Future Work: Lenke Probability Analysis

Lenke Curve Type
Probability Analysis
(AP Standing Criteria)

Application of Analysis
on Cobb Angles
Measured by Multiple
Observers

Complete Lenke
Classification
Probability Analysis



Clinical Impact



Automatic Scoliosis Assessment

- Improved clinical workflows

Lenke Probability Analysis

- Prevention of misclassification

Contribution to Future Research

- Journal articles & open-source software

References

- [1] L. G. Lenke, R. R. Betz, J. Harms, K. H. Bridwell, and et al, 'Adolescent idiopathic scoliosis: A new classification to determine extent of spinal arthrodesis', *J. Bone Jt. Surg. Am. Vol. Needham*, vol. 83, no. 8, pp. 1169–81, Aug. 2001.
- [2] S. Langensiepen *et al.*, 'Measuring procedures to determine the Cobb angle in idiopathic scoliosis: a systematic review', *Eur. Spine J.*, vol. 22, no. 11, pp. 2360–2371, Nov. 2013, doi: 10.1007/s00586-013-2693-9.
- [3] M. C. Tanure, A. P. Pinheiro, and A. S. Oliveira, 'Reliability assessment of Cobb angle measurements using manual and digital methods', *Spine J.*, vol. 10, no. 9, pp. 769–774, Sep. 2010, doi: 10.1016/j.spinee.2010.02.020.
- [4] R. Lechner, D. Putzer, D. Dammerer, M. Liebensteiner, C. Bach, and M. Thaler, 'Comparison of two- and three-dimensional measurement of the Cobb angle in scoliosis', *Int. Orthop.*, vol. 41, no. 5, pp. 957–962, May 2017, doi: 10.1007/s00264-016-3359-0.

Questions?