Correlating Pre- and Post-Operative Imaging with Hounsfield Units to Assess the Flexibility of the Lumbar Spine and Surgical Correction Outcomes in Idiopathic Scoliosis

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Poster 11

Objectives

This study evaluates the predictive value of Hounsfield Units (HU) in assessing lumbar spine flexibility and surgical outcomes in adolescent idiopathic scoliosis (AIS) patients.

Introduction

Figure 1: A patient with adolescent idiopathic scoliosis (AIS).

- Scoliosis is defined as the deviation of the spine within the coronal plane, to greater than or equal to 10 degrees, with adolescent idiopathic scoliosis being the most prevalent spinal deformity in children (1).
- Predicting the lumbar spine's flexibility is vital for pre-operative planning in AIS patients undergoing corrective surgery (2). Spinal flexibility plays a key role in deciding the degree of correction that can be achieved surgically, influencing both surgical planning and outcomes.
- HU are a measurement of density (3) obtained from computed tomography (CT) scans and are commonly used to evaluate bone density (4).
- Spinal radiographs, including spinal CT scans play an important role in surgical decision-making processes, particularly in the surgical management of AIS (5).

Despite their established role in bone density assessment, HU's potential for evaluating intervertebral disc (IVD) density and predicting spinal flexibility remains unexplored (4). This study aims to address this gap by:

1. Investigating the correlation between HU and lumbar spine flexibility.
2. Evaluating HU as a predictor of surgical correction outcomes.
3. Exploring HU as a potential alternative to the conventional use of multiple X-rays to assess flexibility, reducing radiation exposure (6).

Methods

- Retrospective study of 20 AIS patients, aged 10–19 years, who underwent posterior scoliosis correction surgery between January 1, 2023, and December 31, 2024.
- Data was extracted from pre-operative images (supine CT scans, erect X-rays, and bending X-rays) and erect post-operative X-rays. Lumbar spine flexibility was calculated by comparing pre-operative erect and bending disc angles and correction percentage was calculated by comparing pre-operative erect and post-operative erect X-rays.
- Patient data included:
  a. Lenke classification
  b. Cobb angles
  c. Truncal shift
  d. Intervertebral disc (IVD) angles from T12 to L5
  e. Number and placement of pedicle screws

The relationship between HU and lumbar spine flexibility was assessed by plotting each intervertebral level's flexibility and HU on scatter plots, followed by a statistical analysis using Pearson's and Spearman's correlation coefficients. Similarly, the relationship between HU and the surgical correction of the lumbar spine was analysed using scatter plots and the same statistical methods. Additionally, trends within the patient population were evaluated using mean data analysis tables.

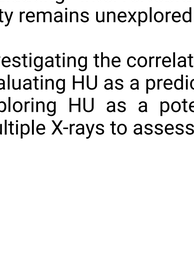

Figure 2: Disc Angle Measurements

Disc angles were measured on Synapse (NHS wales software), from the superior to the inferior end-plate of each intervertebral disc.

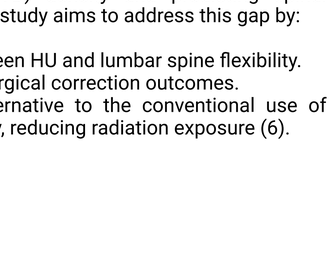

Figure 3: HU measurements

Hounsfield units (HU) were measured on a pre-operative CT scan, using Synapse, by a free-hand outline of the IVD and the mean (M) value was recorded for this study.

Results

Scatter Plot and Statistical Analysis Findings

- **L2/L3:** a moderate, statistically significant positive correlation was observed between correction percentage and Hounsfield units in table 2 ($p = 0.020$).
- **L2/L3**: A moderate positive correlation was observed between HU and correction percentages in figure 5 ($R^2 = 0.265$).
- **L1/L2**: A weak correlation can be observed between bending flexibility and Hounsfield units in table 1 ($p = 0.404$).
- **L3/L4:** A weak correlation can be observed between bending flexibility and Hounsfield units in table 3 ($p = 0.245$).

These findings suggest that HU have some predictive value for the surgical correction of idiopathic scoliosis. However, the data demonstrated limited predictive value for lumbar spine flexibility.

Mean Data Analysis

The mean pre-operative Cobb angle 70.3 (± 16.55) which reduced to a mean post-operative Cobb angle 25.1 (± 12.33) yielding a mean correction percentage of 69.1%.

Mean HU values of IVD levels:
- **L1/L2:** 86.25
- **L2/L3:** 82.1
- **L3/L4:** 78.1

Mean correction percentages (%):
- **L1/L2:** 21.35%
- **L2/L3:** 29.6%
- **L3/L4:** 25.65%

Mean bending flexibility (%):
- **L1/L2:** 2.65%
- **L2/L3:** 20.05%
- **L3/L4:** 11.3%

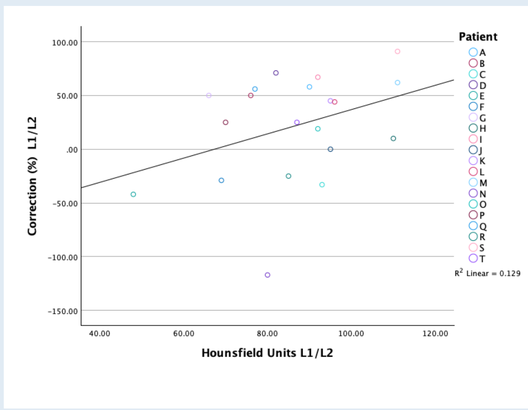

Figure 4: Correlating HU with disc angle L1/L2 correction percentage (erect pre-/post- operative X-ray).

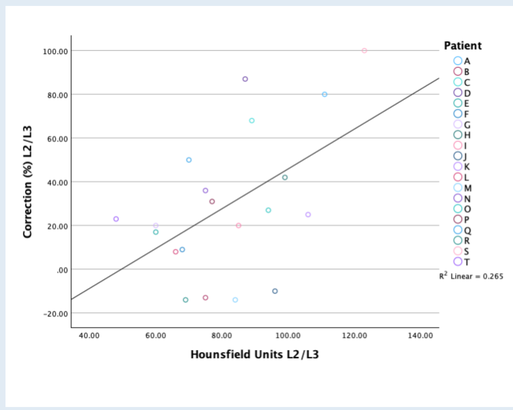

Figure 5: Correlating HU with disc angle L2/L3 correction percentage (erect pre-/post- operative X-ray).

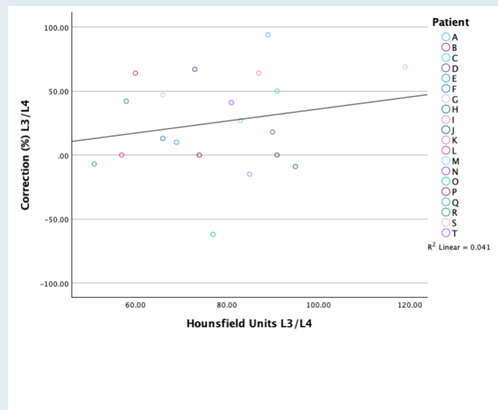

Figure 6: Correlating HU with disc angle L3/L4 correction percentage (erect pre-/post- operative X-ray).

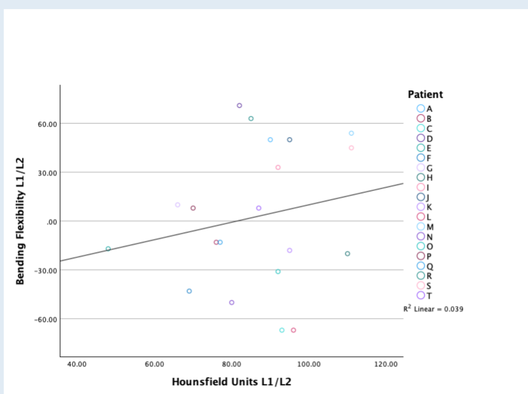

Figure 7: Correlating HU with disc angle L1/L2 flexibility (pre-operative erect/ bending X-ray)

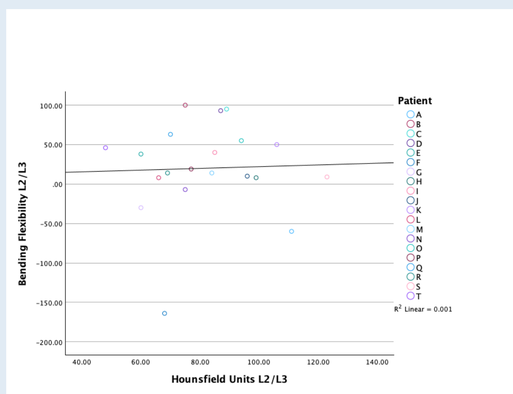

Figure 8: Correlating HU with disc angle L2/L3 flexibility (pre-operative erect/ bending X-ray)

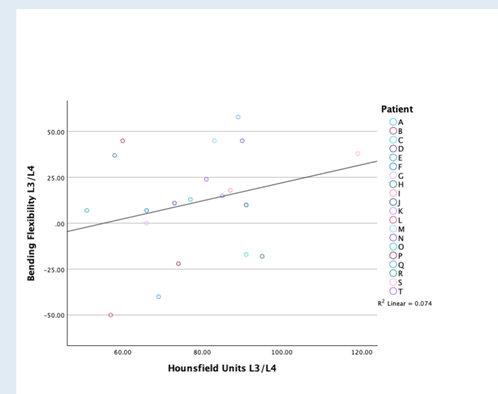

Figure 9: Correlating HU with disc angle L3/L4 flexibility (pre-operative erect/bending X-ray)

		Bending Flexibility L1/L2	Correction (%) L1/L2	Hounsfield Units L1/L2
Bending Flexibility L1/L2	Pearson Correlation	1	.481*	.197
	Sig. (2-tailed)		.032	.404
	N	20	20	20
Correction (%) L1/L2	Pearson Correlation	.481*	1	.360
	Sig. (2-tailed)	.032		.119
	N	20	20	20
Hounsfield Units L1/L2	Pearson Correlation	.197	.360	1
	Sig. (2-tailed)	.404	.119	
	N	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

Table 1: Pearson's correlation of L1/L2 flexibility, correction percentage and HU.

		Bending Flexibility L2/L3	Correction (%) L2/L3	Hounsfield Units L2/L3
Bending Flexibility L2/L3	Pearson Correlation	1	.257	.183
	Sig. (2-tailed)		.274	.439
	N	20	20	20
Correction (%) L2/L3	Pearson Correlation	.257	1	.515*
	Sig. (2-tailed)	.274		.020
	N	20	20	20
Hounsfield Units L2/L3	Pearson Correlation	.183	.515*	1
	Sig. (2-tailed)	.439	.020	
	N	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2: Pearson's correlation of L2/L3 flexibility, correction percentage and HU.

		Bending Flexibility L3/L4	Correction (%) L3/L4	HU L3/L4
Bending Flexibility L3/L4	Pearson Correlation	1	.453*	.273
	Sig. (2-tailed)		.045	.245
	N	20	20	20
Correction (%) L3/L4	Pearson Correlation	.453*	1	.204
	Sig. (2-tailed)	.045		.389
	N	20	20	20
Hounsfield Units L3/L4	Pearson Correlation	.273	.204	1
	Sig. (2-tailed)	.245	.389	
	N	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3: Pearson's correlation of L3/L4 flexibility, correction percentage and HU.

Conclusion

This study explored the potential of HU in predicting spinal flexibility and surgical correction in AIS patients. We found a strong positive correlation between HU and the surgical correction of the lumbar spine, suggesting that HU may predict surgical outcomes. In contrast, we observed a weak correlation between HU and lumbar spine flexibility, suggesting that HU may be more useful for predicting surgical outcomes rather than assessing spinal flexibility. Additionally, HU could serve as an alternative to the conventional use of multiple X-rays to assess spinal flexibility, reducing radiation exposure for patients (5).

Acknowledgments

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