Diaphragm motion as a function of the scoliotic spinal curve in thoracic insufficiency syndrome (TIS)

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INTRODUCTION

Thoracic Insufficiency Syndrome (TIS) represents a complex and challenging clinical condition characterized by severe chest and spine deformities, leading to compromised lung development and function. Understanding how scoliosis influences respiratory function is crucial.

Background: Scoliosis significantly impacts breathing by restricting chest development and muscle activity.

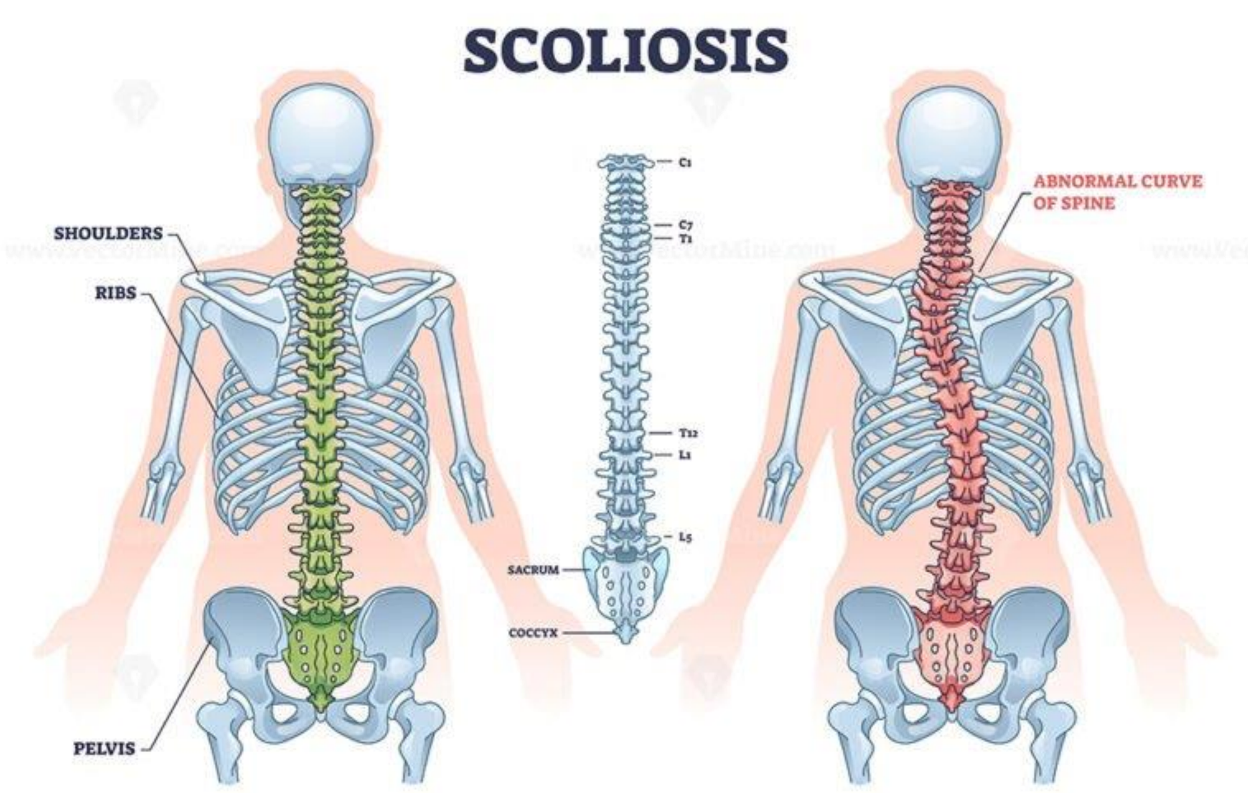

Fig. 1(a) Health case. Fig. 1(b) Scoliosis case.

Purpose: To uncover the impact of scoliosis on respiratory function by analyzing diaphragm motion.

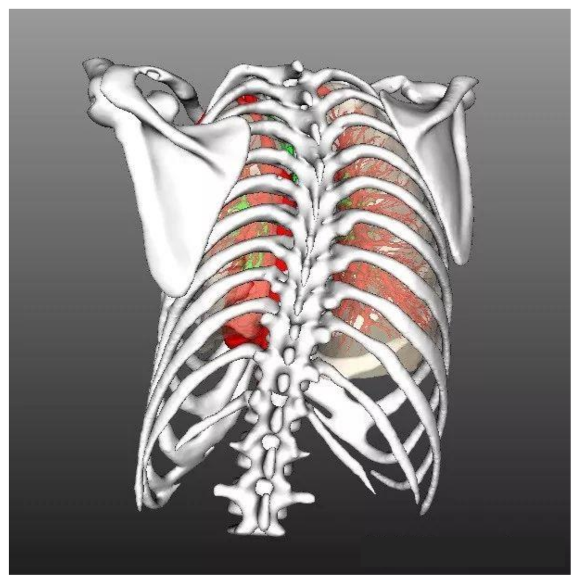

Fig. 2 Thoracic cavity

Fig. 3 Diaphragm

The diaphragm is a crucial component of the respiratory system, facilitating the inhalation and exhalation of gases by changing its shape via contraction and relaxation. Analysis of the relationship between diaphragm motion and the spinal curve could uncover the impact of scoliosis on respiratory.

METHODS

Diaphragm Segmentation: For each case, we performed 4D reconstruction of slices from dMRI scans and manually segmented the diaphragm for each slice.

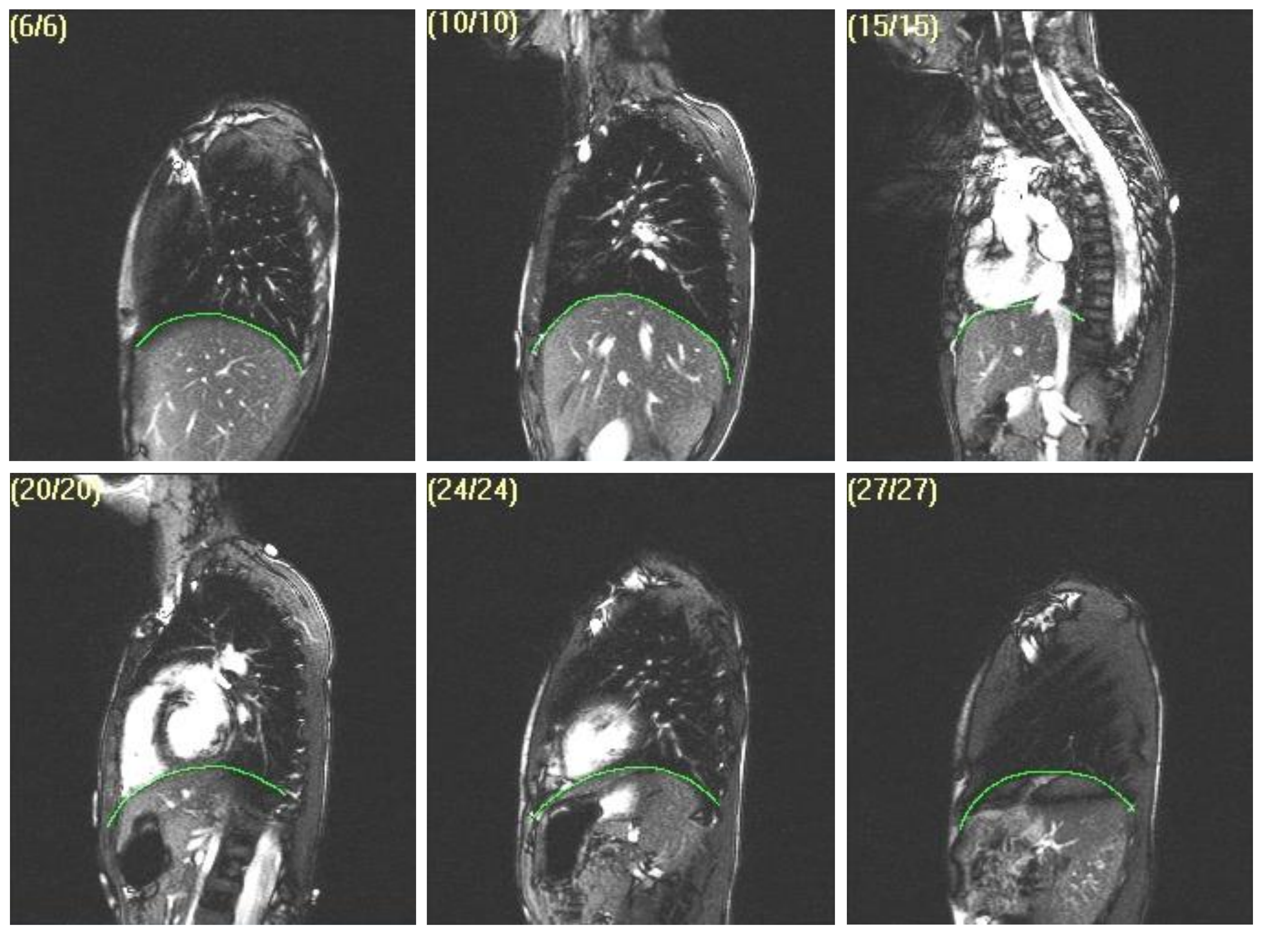

Fig. 4 Diaphragm segmentation on sagittal plane.

Diaphragm Motion: The diaphragm is divided into 2 hemidiaphragms, with 25 points selected on each hemidiaphragm. We divide the 25 points into 13 regions, and calculated the mean of velocity for each region.

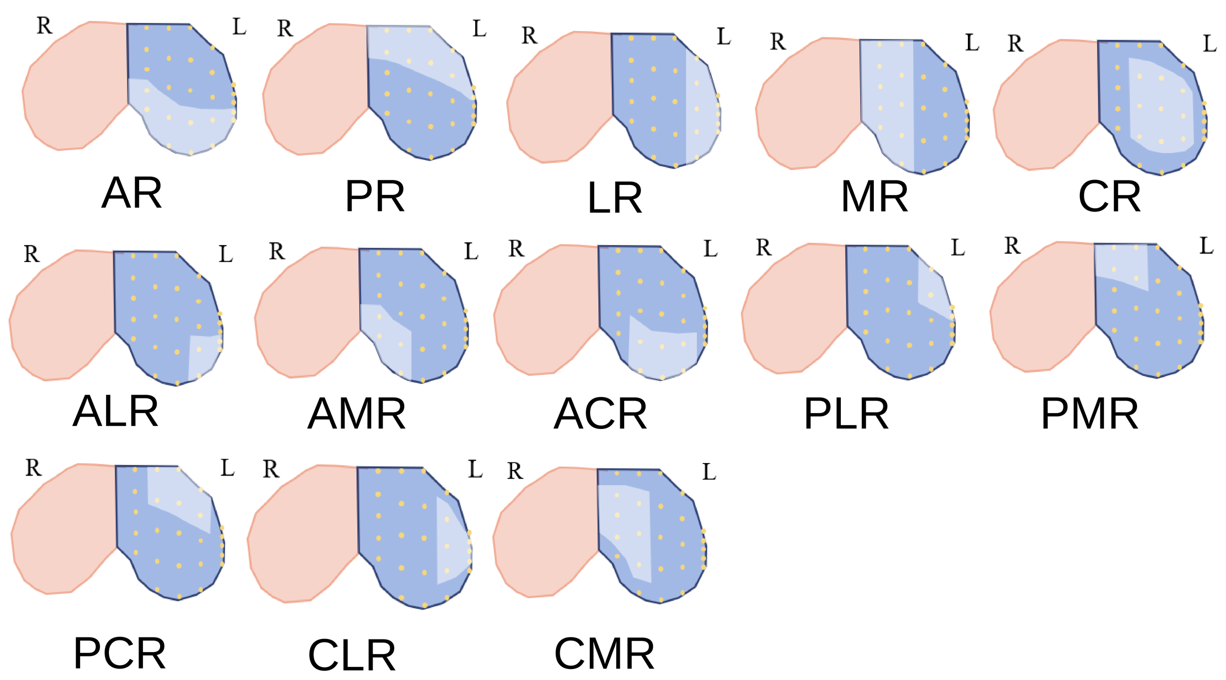

Fig. 5 Illustration of 13 regions.

Statistical Analysis

We performed the following statistical analysis:

- T-test comparison between MTC-R and MTC-L group.
- Pearson correlation analysis between diaphragm velocities and major curve angles (TCA and LCA).

RESULTS

MTC-R vs MTC-L: The leftward curve of the spine can greatly restrict the expected motion of the left hemidiaphragm.

Table 1. Comparison of hemi-diaphragm velocities in 13 regions between MTC-R and MTC-L major spinal curves. Bold numbers indicate a confidence level greater than 95%.

Region	AR	PR	LR	MR	CR	ALR	AMR	ACR	PLR	PMR	PCR	CLR	CMR
LHD	+1.185 (0.248)	+1.633 (0.115)	**+2.808 (0.010)**	+0.180 (0.859)	**+2.454 (0.022)**	+1.359 (0.187)	+0.299 (0.767)	**+2.206 (0.037)**	**+2.378 (0.026)**	+0.099 (0.922)	+1.740 (0.095)	**+3.449 (0.002)**	-0.033 (0.974)
RHD	+1.261 (0.220)	+0.498 (0.623)	+1.094 (0.285)	+0.749 (0.461)	+1.081 (0.290)	+0.535 (0.597)	+1.048 (0.305)	+1.451 (0.160)	+1.462 (0.157)	+0.085 (0.933)	-0.534 (0.598)	+1.323 (0.198)	+0.926 (0.364)

The first value in each cell is the effect size and the second value in parentheses is the P-value.
"+" sign for the effect size indicates that the mean diaphragm velocities for the first entity in the pair under comparison is greater than that for the second entity. "−" sign indicates that the mean diaphragm velocities for the first entity in the pair is less than that for the second entity.
MTC-R indicates main thoracic curve with apex to the right; MTC-L indicates main thoracic curve with apex to the left; LHD indicates left hemi-diaphragm; RHD indicates right hemi-diaphragm; AR, PR, MR, etc. are representative regions of each hemi-diaphragm defined in the methods section.

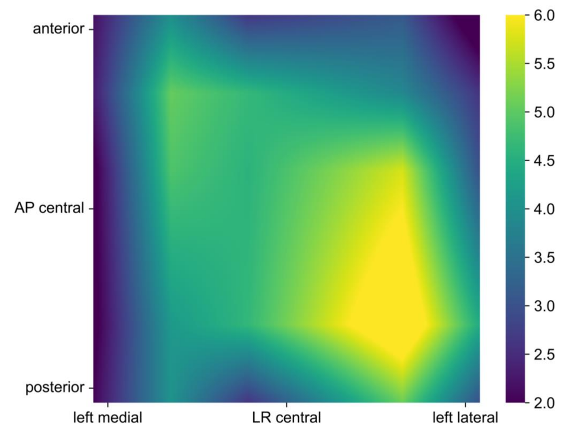

Fig. 6(a) MTC-R.

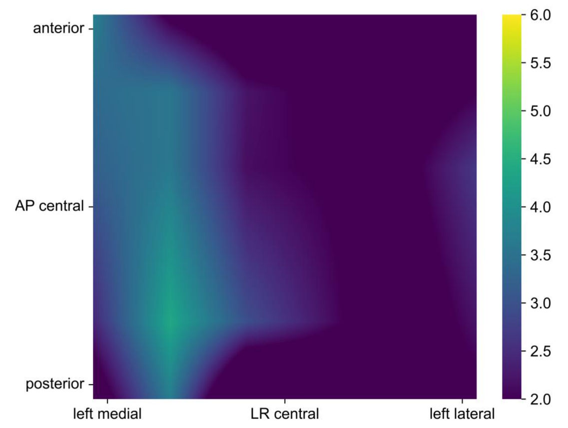

Fig. 6(b) MTC-L.

Velocity map of the left hemi-diaphragm.

Correlation analysis: Moderate positive correlations between diaphragm velocities in the central and anterior-central regions with LCA (0.405 and 0.471 respectively), implying that as LCA bends more to the left, the velocities of the diaphragm in these two specific regions on the LHD decrease.

CONCLUSIONS

1. **A new study of the relationships between scoliotic spinal curve and diaphragm motion, to investigate the impact of scoliosis on respiratory function.**
2. **T-testing between the MTC-R group and the MTC-L group revealed the influence of spinal curvature sidedness on the motion of the left hemi-diaphragm.**
3. **The high-confidence correlation analysis conducted on 13 regions of each hemi-diaphragm revealed a significant influence of spinal major curve angles on hemi-diaphragm velocities in specific regions.**

REFERENCES

1. Udupa JK, Tong Y, et al. Understanding respiratory restrictions as a function of the scoliotic spinal curve in thoracic insufficiency syndrome: A 4D dynamic MR imaging study.
2. Hao Y, Udupa JK, Tong Y, et al. Regional diaphragm motion analysis via dynamic MRI.