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Quantification of Intra- and Interfractional Target Motion and Deformation in Gastric Cancer Radiotherapy

INTRODUCTION

Accurate radiotherapy for gastric cancer is extremely challenging due to respiratory-induced motion and deformation as well as deformations between different treatment days.

AIM

To assess **respiratory-induced stomach motion and deformation** as well as **interfractional deformations**, and if/how these should be incorporated in radiation treatment planning.

METHODS

Data

- **5 patients** with **4-6 fiducial markers** distributed over the stomach for pre-operative gastric image-guided RT (Figure 1)
- 3-4 **4DCTs** per patient (17 in total)
- 20-25 daily **4DCBCTs** per patient (118 in total)

The markers were localized and their center of mass (COM) per scan was determined for every end-inhalation (EI) scan and end-exhalation (EE) scan (Figure 2). Per scan, the maximum rigid body error (**RBEmax; maximum observed difference in distance**) between markers and COM was determined.

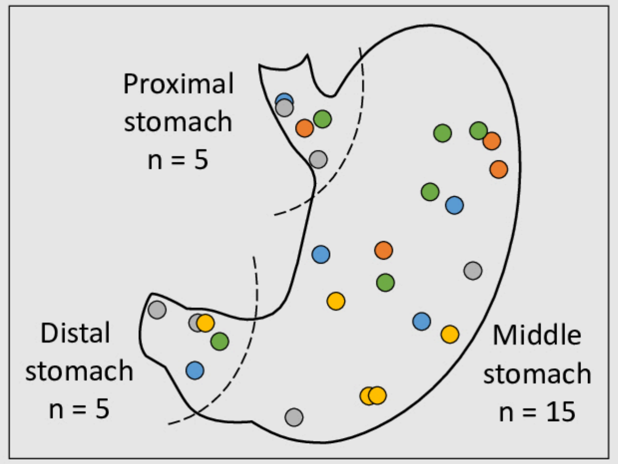

Figure 1: Approximate locations of all 25 visible markers in the five patients. Each dot represents a marker, different colors represent the patients.

Analysis

1) **COM respiratory amplitude**
Determined in superoinferior (SI), anteroposterior (AP) and left-right (LR) directions.
2) **Motion vs deformations**
Comparison between respiratory motion, intrafractional deformation and interfractional deformation.
   - Vector respiratory motion of COM
   - Intrafractional deformation = RBEmax between EI and EE scan
   - Interfractional deformation = RBEmax between first EI scan and the respective scans
3) **Relative motion of proximal stomach vs distal stomach during respiration**
Difference in respiratory motion between markers at most proximal and distal part of stomach upon inhalation (Figure 1). Marker pairs were present in 74 scans (3 patients).

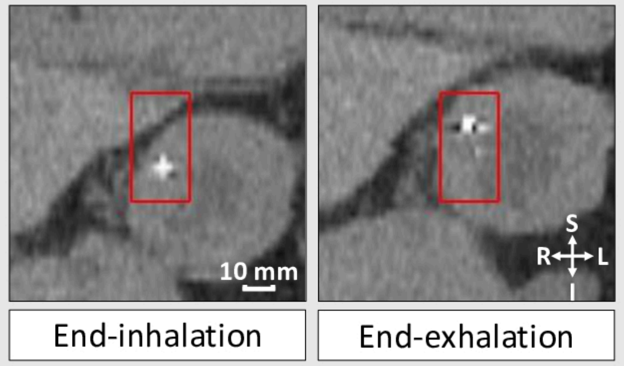

Figure 2: Marker displacement between end-inhalation and end-exhalation phase in 4DCT scan in the coronal view. The red box is the same location in both phases.

RESULTS

1) **COM respiratory amplitude**
Respiratory amplitude of COM was larger in SI than AP, and larger in AP than LR direction (Figure 3). The significant difference in amplitude between the directions suggests a potential need for anisotropic margins.

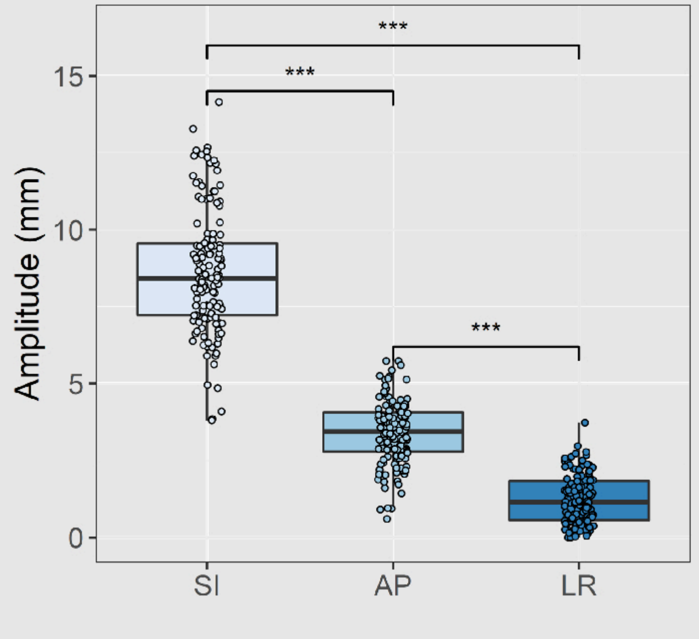

Figure 3: Respiratory amplitude of COM was larger in SI than AP direction, and larger in AP than LR direction (paired Wilcoxon signed-rank test). N_{CT}=17 and N_{CBCT}=118. *** p<0.001

Tukey boxplots
Box = IQR, bar = median,
Whiskers = minimum/maximum point within 1.5×IQR

2) **Motion vs deformations**
Respiratory amplitude and interfractional deformation were significantly larger than respiratory-induced intrafractional deformations (Figure 4). The magnitude of interfractional deformation is large (median=8.6 mm) and should be managed during radiation therapy.

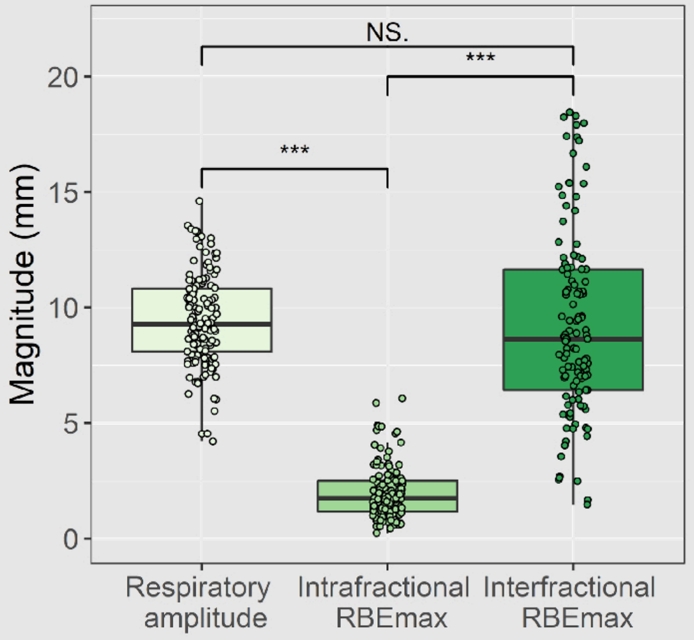

Figure 4: Comparison between vector respiratory motion (=respiratory amplitude), intrafractional deformation (= intrafractional RBEmax) and interfractional deformation (= interfractional RBEmax). Interfractional deformation was larger than intrafractional deformation (Wilcoxon rank-sum test). Vector respiratory motion was larger than intrafractional deformations. N_{CT}=17 and N_{CBCT}=118. *** p<0.001

3) **Relative motion of proximal stomach vs distal stomach during respiration**
Upon inhalation, significant relative motion of distal marker with respect to proximal marker was observed for individual patients; the direction appears to be patient-dependent (Figure 5). For the group, a relative motion was only observed in LR direction (1.8 mm to the right upon inhalation).

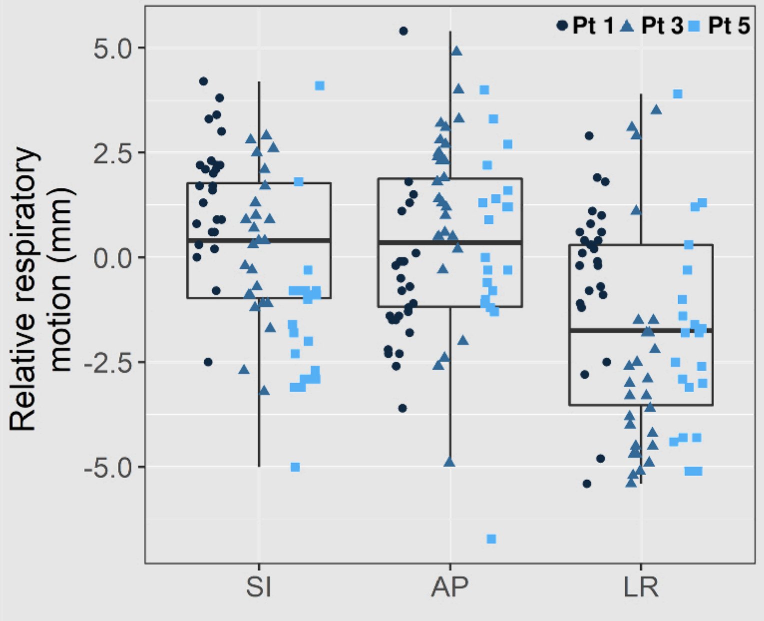

Figure 5: Relative motion of distal marker with respect to proximal marker. Wilcoxon signed-rank tests were performed for the group and the individual patients. For the group, significant relative motion was observed in right direction. For patient 1, significant relative motion was observed in superior and posterior direction. For patient 3, significant relative motion was observed in anterior and right direction. For patient 5, significant relative motion was observed in inferior and right direction. N=74 (N_{CT}=10 and N_{CBCT}=64).

CONCLUSION

Respiratory-induced stomach motion is substantial and can differ between proximal and distal stomach. The result suggest that **respiratory-induced motion/deformation** should be incorporated in **treatment margins** or dealt with by **tracking/gating.** Conversely, magnitude and character of the **interfractional deformations** imply these should be managed by **adaptive radiotherapy.** However, more data is needed for (anisotropic) margin calculations and determination of a suitable adaptive radiotherapy strategy.

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