Application of Monitoring Internal Tumor Motion with Surface Guided System for Lung Stereotactic Body Radiotherapy in Deep Inspiration Breath-Hold

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INTRODUCTION

The deep inspiration breath-hold (DIBH) technology used in lung cancer stereotactic body radiotherapy (SBRT) significantly controls the motion of target which brings dosimetric benefits to the organ at risk (OAR). The surface guided radiotherapy (SGRT) system is widely used for providing DIBH reproducibility, but as for the lung target, if the surface motion monitored by SGRT could represent the actual internal target motion still needs to be studied.

AIM

- To study the consistency between surface motion monitored by SGRT and the internal target motion observed by CBCT.
- To study the setup errors and the intrafractional motion of tumor in DIBH under the guidance of SGRT.
- To study the patients' compliance in such new workflow of lung SBRT in DIBH with SGRT.

METHOD

This study included five patients with either primary lung cancer or oligometastatic disease treated with SBRT in DIBH, only patients held breath over 30s were deemed eligible.

- A DIBH-CT scan and a free breathing four dimensions (FB-4D-CT) scan were acquired, the reference surface in DIBH was also acquired by SGRT, named as Ref1. Ref1 was used for patient's setup in DIBH, tolerance was set as ±3 mm translation and ±3◦ rotation.
- A fast cone-beam computed tomography (CBCT) was acquired in DIBH before each intrafraction, named as CBCT1. At the same time, SGRT recorded the surface differences compared to Ref1, named as ∇Ref1. CBCT1 was registered to DIBH-CT, couch shifts (∇shift1) were applied when the patient stayed in DIBH status, then a new surface (Ref2) was acquired which used for monitoring the surface motion in this intrafraction.

METHOD

- Two radiotherapists monitored the surface motions compared with Ref2, beam would be interrupted manually if the difference exceeded the tolerances.
- CBCT2 was acquired in the middle of treatment to verify if the tumor stayed in PTV. In the meanwhile, SGRT recorded the surface differences compared to Ref2, named as ∇Ref2. CBCT2 was registered to the DIBH-CT, couch shifts (∇shift2) were applied, then Ref3 was acquired for monitoring the surface motion in remaining delivery.

  It should be noted that if no couch shifts were adopted, there was no need to acquire a new Ref. For example, couch shifts (∇shift2) were optional if the tumor inside the plan target volume (PTV) region, so the Ref2 would still use for monitoring the surface motion in the remaining delivery. The CBCTs and Refs in the CT acquisition and each treatment delivery were shown in Fig 1.

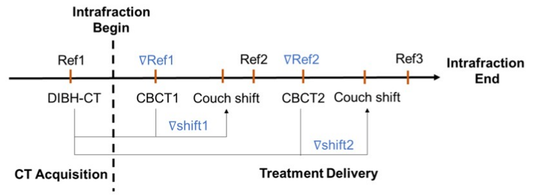

Fig 1. CBCTs and Refs in the CT acquisition and each treatment delivery

- The relationships between ∇Ref1 and ∇shift1, ∇Ref2 and ∇shift2; the relationships between setup errors (according to CBCT1 and DIBH-CT registrations) and intrafractional differences (according to CBCT2 and DIBH-CT registrations) were analyzed with SPSS26.0, results were considered significant when two-tailed p-value less than 0.05.
- Treatment plannings were performed for both DIBH-CT and FB-4D-CT, dose to OARs in DIBH were compared to FB-4D. Both treatment plannings should meet the dose limit, and the latter was seemed as alternate treatment plan if the patient couldn't repeat his/her DIBH status during treatment delivery.

RESULTS

➢ The relationship between ∇Ref1 and ∇shift1, ∇Ref2 and ∇shift2 showed significant correlation with p=0.02, 0.03, separately.

Table 1. Mean and standard deviation of setup errors and intrafractional differences in vertical, longitudinal, lateral and 3D vector

		Vertical (cm)	Longitudinal (cm)	Lateral (cm)	3D Vector (cm)
Setup errors	Mean	0.21	-0.08	-0.10	0.58
	Deviation	0.33	0.48	0.14	0.28
Intrafractional differences	Mean	0.02	-0.08	0.00	0.27
	Deviation	0.15	0.25	0.10	0.16

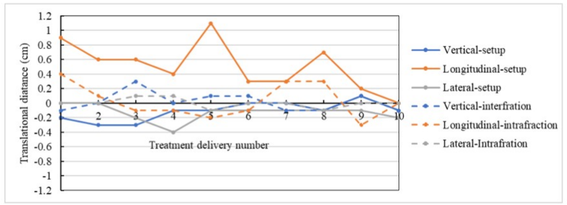

Fig 2. Setup errors and intrafractional differences of patient1

➢ As for the setup errors:

- The setup errors ranged from -0.3 to 0.9cm, -1 to 1.1cm, -0.4 to 0.3cm in vertical, longitudinal and lateral direction, respectively. Highest ranges were observed in longitudinal direction.
- The setup errors at least 0.3cm were 35.14%, 45.95%, 8.11% in vertical, longitudinal and lateral direction, respectively.
- The mean 3D vector was 0.58cm (0 to 1.1 cm) .

➢ As for the intrafractional differences:

- The intrafractional differences ranged from -0.4 to 0.3cm, -0.6 to 0.4cm, -0.2 to 0.2cm in vertical, longitudinal and lateral direction, respectively. Highest ranges were also observed in longitudinal direction.
- The intrafractional differences at least 0.3cm accounted for 4.17%, 12.50%, 0% in vertical, longitudinal and lateral direction, respectively, which were much less than the setup errors.
- The mean intrafractional differences were close to zero for all three translational directions.

➢ The Pearson correlation coefficient of the setup error and the intrafractional difference in lateral direction was 0.583 with a significant relationship p=0.003, while no significant relationship in the other two translational directions and 3D vector direction were observed.

➢ The intrafractional differences were significantly smaller than the setup errors in the longitudinal, lateral and 3D vector, p=0.028, p=0.002, p<0.001, paired t-test respectively, while no significant difference was observed in the vertical direction, p=0.056.

CONCLUSIONS

- The intrafractional differences were significantly smaller than the setup errors (except the vertical) and the mean values were close to zero, which verified the reproducibility and stability of internal tumor in DIBH with SGRT monitoring.
- The good consistency between CBCT and SGRT meant that SGRT could be used for monitoring the intrafractional movement of lung tumor in DIBH. However, the setup error still existed although under the guidance of SGRT, and the highest ranges of setup error were observed in longitudinal direction. It prompted that the interfractional CBCT was necessary, but whether the intrafractional CBCT was needed should be further discussed.

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ACKNOWLEDGEMENTS

This study was supported by National Key R&D Program of China, Ministry of Science and Technology of the People's Republic of China 2022YFC2404606 and National High Level Hospital Clinical Research Funding 2022-PUMCH-B-116

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