# Quantify the Difference in Target Margin Sharpness Demonstrated on 4DCT and 4DCBCT Images

[1]Yulun Tseng, [2]Miao Zhang, [2]Margie Hunt, and [2]Yulin Song
[1]Graduate Program in Medical Physics, Columbia University, NY, USA
[2]Department of Medical Physics, Memorial Sloan Kettering Cancer Center, NY, USA

## Purpose:

Prior to the delivery of a respiratory-gated lung cancer treatment, a 4DCBCT image is often acquired and matched to the planning 4DCT image for patient setup verification. However, the difference in target margin sharpness between 4DCT and 4DCBCT can degrade the accuracy of the target localization. This study quantifies the difference in target margin sharpness between the two imaging modalities, and the findings can be used to improve the accuracy of current procedure.

## Methods:

A lung phantom (Fig.1) was programmed to simulate different patient breathing motions with the combinations of 5, 10, and 20 mm amplitudes and 15, 20, and 30 breath cycles per minute. Then 4D images were acquired with a CT simulator and a TrueBeam CBCT to generate the maximum intensity projection (MIP) images. By defining the average intensities of a 7 x 7 mm ROI within the normal lung structure and the target center as 0% and 100%, respectively, the Edge-Response Widths (ERWs) in lateral, AP, and SI directions were calculated. ERW is the spatial distance between the locations of 25% and 75% intensity levels on the profile (as shown in Fig.2) and is a practical parameter to quantify target margin sharpness.

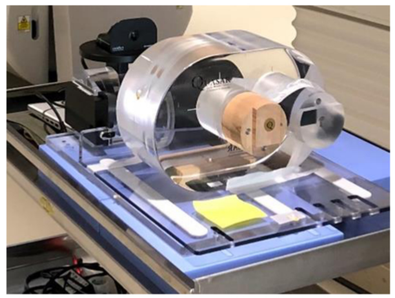

Fig.1: The lung phantom.

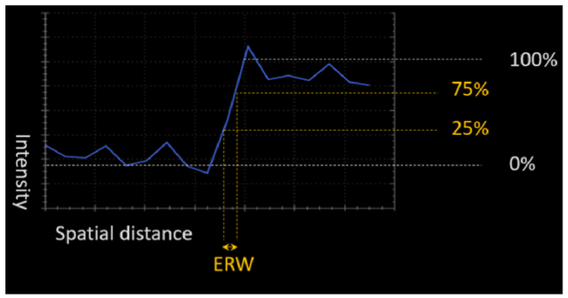


Fig.2: Edge-Response Width (ERW) represents the spatial distance between the locations of 25% and 75% intensity levels on the profile.

## Results:

ERW was predominantly affected by motion amplitude and less by motion frequency and speed. In lateral direction, the mean differences in ERW* were 0.19, 0.15, and 0.16 cm for 5, 10, and 20 mm amplitudes. In AP direction, the mean differences* were 0.12, 0.13, and 0.44 cm for the three amplitudes. In SI direction, the differences* were -0.06, -0.02, and -0.01 cm.

## Conclusions:

Proper individualized margin sharpness should be determined based on the patient's breathing amplitude and frequency prior to performing 4DCBCT-to-4DCT registration for patient setup verification. The additional margin on the 4DCT-defined target is to compensate for the incompatibility in margin sharpness between the two imaging modalities.

* The following table summarizes the calculated Edge-Response Widths (ERWs) demonstrated on the 4DCT and 4DCBCT MIP images for the phantom motion combinations of 5, 10, and 20 mm amplitudes and 15, 20, and 30 breath cycles per minute (BPM).

| Edge-Response Width (ERW) | | 5 mm amplitude | | | 10 mm amplitude | | | 20 mm amplitude | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 15 BPM | 20 BPM | 30 BPM | 15 BPM | 20 BPM | 30 BPM | 15 BPM | 20 BPM | 30 BPM |
| Lateral direction (cm) | 4D-CT | 0.10 | 0.12 | 0.10 | 0.11 | 0.10 | 0.10 | 0.12 | 0.13 | 0.16 |
| | 4D-CBCT | 0.28 | 0.30 | 0.32 | 0.26 | 0.24 | 0.26 | 0.30 | 0.28 | 0.31 |
| | Difference | 0.16 | 0.18 | 0.22 | 0.15 | 0.14 | 0.16 | 0.18 | 0.15 | 0.15 |
| | Averaged difference | ≈ 0.19 | | | ≈ 0.15 | | | ≈ 0.16 | | |
| AP direction (cm) | 4D-CT | 0.11 | 0.11 | 0.11 | 0.10 | 0.12 | 0.10 | 0.11 | 0.10 | 0.25 |
| | 4D-CBCT | 0.24 | 0.21 | 0.23 | 0.24 | 0.22 | 0.26 | 0.55 | 0.60 | 0.63 |
| | Difference | 0.13 | 0.10 | 0.12 | 0.14 | 0.10 | 0.16 | 0.44 | 0.50 | 0.38 |
| | Averaged difference | ≈ 0.12 | | | ≈ 0.13 | | | ≈ 0.44 | | |
| SI direction (cm) | 4D-CT | 0.28 | 0.23 | 0.26 | 0.24 | 0.18 | 0.21 | 0.16 | 0.18 | 0.22 |
| | 4D-CBCT | 0.20 | 0.23 | 0.17 | 0.23 | 0.19 | 0.16 | 0.19 | 0.18 | 0.17 |
| | Difference | -0.08 | 0.00 | -0.09 | -0.01 | 0.01 | -0.05 | 0.03 | 0.00 | -0.05 |
| | Averaged difference | ≈ -0.06 | | | ≈ -0.02 | | | ≈ -0.01 | | |