

Development of A Novel Image Guidance Alternative for Patient Localization using Topographic Images for TomoTherapy

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Abstract: To develop a faster and lower dose topogram based image registration for TomoTherapy as an alternative image guidance tool to volumetric megavoltage computed tomography (MVCT). Topogram procedures were performed for an anthropomorphic thorax phantom on a TomoTherapy HD unit (Accuray Inc., Sunnyvale, CA) using couch speeds from 1-4 cm/s and gantry angles of 0 and 90 degrees, other scanning parameters are: 1 mm imaging jaw, compression factor of 1, 30 seconds scanning duration with all multileaf collimators (MLCs) open. The raw exit detector data was exported after each scan. The topogram was reconstructed from a fan beam source for TomoTherapy beam and detector geometry at a SSD of 85 cm. A reference image, so called Digitally Reconstructed Topogram (DRT) was created by integrating the trajectories through the kVCT simulation with the topogram geometry. Image registration was performed by visually aligning the bony structure in topogram to the DRT. Image resolution was determined by the radius of curvature for the detector array, source to axis distance, source to detector distance, detector spacing, and number of detectors. The localization errors were 1.5, 2.5 mm in medio-lateral and anterior-posterior direction, larger errors in cranial-caudal direction was observed for faster couch speeds (i.e., ≥ 3 cm/s). The topographic imaging time was 30 sec (versus 3-5 minutes for MVCT thorax scan) with imaging dose less than 1% of MVCT scan. Topograms with appropriate couch speed provide reliable patient localization images while significantly reducing pre-treatment imaging time. Topogram can be used as an alternative and/or additional patient alignment tool to MVCT on TomoTherapy.

1. Introduction

The unique geometric design and integrated on-board imaging system [1-5] allow for acquisition of megavoltage CT (MVCT) image but also topographic images on Tomotherapy Hi-ART system. The linear accelerator mounted on CT-like gantry, treatments are delivered with continuous and simultaneous gantry and couch rotation [1-3].

In this work, a fast and low-dose alternative (Topogram) to current 3D megavoltage CT (MVCT) localization tool for patient alignment on Tomo was presented. The Topogram could be employed as a precursor or post-treatment alignment verification tool for patient localization. In addition, Topogram offers large longitudinal field of view, which is desirable for cranial-spinal irradiation (CSI), total marrow irradiation (TMI), etc.



The purposes of this work are 1) to investigate patient localization using topographic images on a TomoTherapy unit using various phantoms; and 2) to study the impact of different couch moving speeds on MV topogram localization.

2. Methods and Materials

Topogram procedures were created on TomoTherapy treatment console and for three anthropomorphic phantoms, including head (20 cm length), thorax (45 cm length) and spine (17 cm length) phantoms. The topogram procedures consisted of four couch speeds, 1 cm/s, 2 cm/s, 3 cm/s, and 4 cm/s (maximum couch speed) with a scanning duration of 30 seconds. All MLC leaves were opened to provide the largest field of view. A data compression factor of 1 was used for the topographic scans. An air scan was acquired to normalize the raw detector output. For patient localization, two topograms were acquired for each phantom and four different couch speeds at gantry angles of 0° and 90°.

To obtain the correct reference image from the simulation CT, a digitally reconstructed topogram (DRT) was generated in the TomoTherapy beam and detector geometry [4-6]. To assess daily setup errors, known shifts were applied to the phantom for the topographic images. Image registration was performed by rigidly aligning the visible anatomy of the phantom in the topogram with the anatomy of the created DRT. MVCT scans were performed for the same phantoms using the normal imaging jaw width (4 mm). For MVCT imaging registration, we used bony and soft tissue to align the MVCT to the kVCT. The MVCT was set up with known shifts from the kVCT position. The shifts derived from topogram were compared to the MVCT image.

3. Results

3.1 The reference image and the MV Topograms on Tomo

A digitally reconstructed topogram (DRT), the reference image, was generated based on the CT simulation (KVCT) in the TomoTherapy beam and detector geometry. Figure 1 shows the reconstructed DRT for a thorax phantom. Figure 2 illustrates the reconstructed MV topogram at couch speeds of 1 cm/s and 4 cm/s (the fastest couch moving speed on Tomo).

Figure 1 The digitally reconstructed topogram for a thorax phantom.

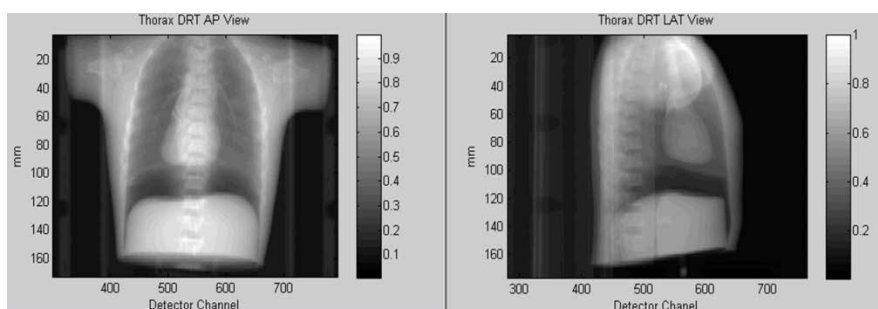
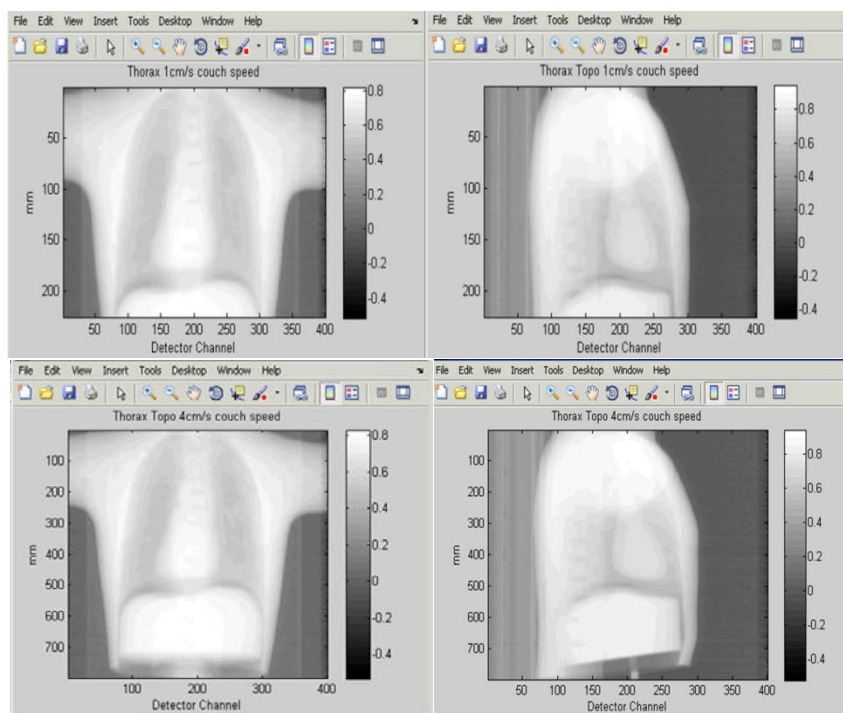


Figure 2 Reconstructed MV Topograms on Tomotherapy at couch speeds of 1 cm/s versus 4.0 cm/s.



3.2 MV based Topogram registration

Topogram registration was performed by rigid aligning the visible anatomy of the phantom with the anatomy of the created DRT. Figure 3 illustrated MV based Topogram.

Figure 3 MV based Topogram registration for the thorax phantom.

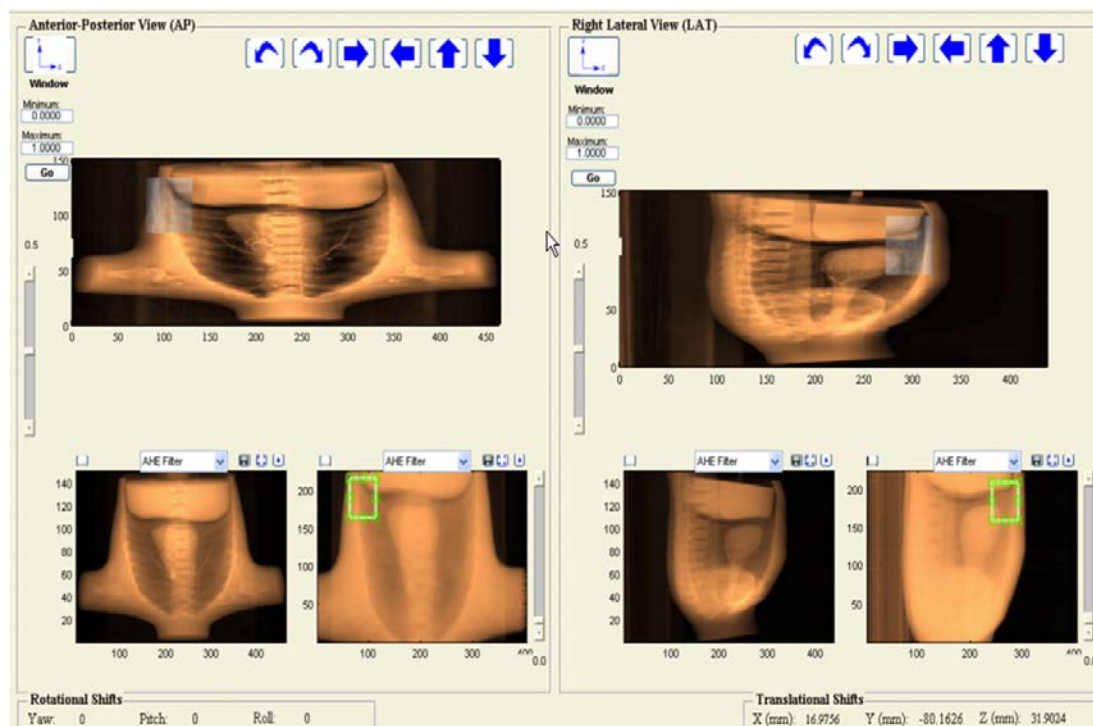


Table 1 shows relative positional errors using MVCT versus Topogram scans at different couch speeds. At maximum couch speed (4 cm/s), the topogram was markedly blurred in the cranial-caudal (CC) direction, and the blurred voxels gave a high positional error of 8.1 mm in the CC direction. The errors in the remaining directions, such as medio-lateral (ML), cranial-caudal (CC), were on the order of the slice thickness of the MVCT so are at an acceptable level. Based on these our preliminary measurements, a couch speed of 3 cm/s or slower might be the couch speed achievable with reasonable positional errors due to voxel deformation in the topogram. At couch speeds of 1 cm/s, 2 cm/s and 3 cm/s, the relative shifts were within 5 mm in all ML, CC and AP directions; while for faster couch speed of 4 cm/s, the relative shifts between different couch speeds might be larger in AP direction.

Table 1 Relative positional errors using Topogram versus MVCT Tomotherapy.

Direction	MVCT (mm)	Topo (mm)
ML	2	1.5
CC	2	8.1
AP	2	2.5

3.3 Scanning image time

Compared with the imaging acquisition time of 2-5 min for MVCT scans, the time required to acquire clinically acceptable topograms for the selected phantom were significantly shorter using topograms. Based on these results, a couch speed of 3 cm/s is the fastest couch speed achievable with reasonable positional errors due to voxel deformation in the topogram as shown in Table 1.

4. Conclusion

Topograms can be a fast alternative and/or additional patient alignment tool to megavoltage CT guidance on Tomotherapy. The implement of topogram on Tomotherapy may significantly reduce pre-treatment MVCT imaging time while provides reliable patient localization information compared to current MVCT guidance.

References

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