Respiratory Tumor Motion Reduction using an Abdominal Arc Compression Device

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ASTRO 50th ANNUAL MEETING
Boston, MA 2008
Abstract # 2223

Purpose:

To investigate how the use of an abdominal arc compression device impacts on respiration-induced liver motion as assessed by volumetric 4DCT imaging.

Methods:

Fifteen patients with with 21 different tumor locations have undergone simulation for a course of Stereotactic Body Radiation Therapy (SBRT) treatment using a novel abdominal arc compression device adapted to a clinically established double-vacuum whole body immobilization device (BodyFix, Medical Intelligence). The compression device consists of a carbon fiber arc, and a choice of abdomen compression plates that are placed caudal to the xyphoid on the anterior abdomen with the intent to restrict liver respiration motion. All patients underwent 4DCT imaging with and without the compression device in place; when no abdominal compression was used, the double vacuum was still utilized. Target volumes were delineated in free breathing (FB) scans, 10 respiratory phases, and maximum-intensity projection (MIP) reconstructions. We assessed the range of tumor motion with and without abdominal compression in place, and compared planning target volumes typically used for SBRT planning (PTV_{FB}: GTV_{FB} + 5 mm axial, 10 mm cranio-caudal; PTV_{MIP}: internal target volume, ITV_{MIP} + 5 mm). We also assessed patient tolerance.

Results:

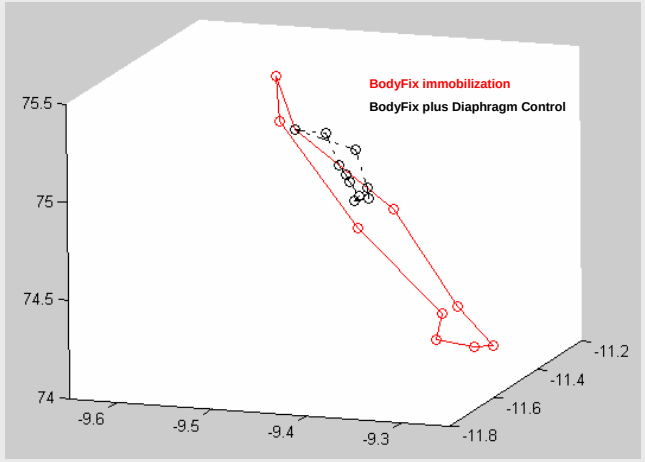
Among the patients studied, only 1 patient rejected the use of the arc compression for SBRT delivery. While the pattern of motion remained unchanged in 19/21 cases studied, the range of motion differed significantly with a smaller range of target motion observed in 4DCT studies acquired with arc compression (p=0.002, and p=0.02 for cranio-caudal, and anterio-posterior motion, respectively). PTVs derived from both GTV_{FB} and ITV_{MIP} target volumes were smaller in arc compression studies by up to 35.4% (mean PTV_{FB} reduction 6.6%, with 18/21 studies having a smaller PTV_{FB}; mean PTV_{MIP} reduction 10.6%, with 18/21 studies showing a smaller PTV_{MIP}; maximum PTV_{MIP} increase observed was 4.3%).

Conclusion:

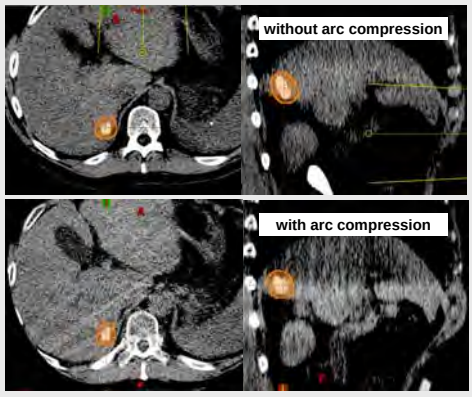
The studied addition of an arc abdominal compression device resulted in reduced liver tumor respiration-induced motion in the majority of patients. PTVs for planning were consequently smaller in volume by up to 35.4%. Based on pre-treatment comparative assessment, 17 tumors in 12 patients were treated using the abdominal arc compression device (1 patient refused despite assessed PTV_{MIP} reduction of 24%). The observed discrepancies between FB studies derived PTV, and PTV derived from ITV_{MIP} that fully incorporate the respiration motion envelope of a tumor, indicate the necessity to incorporate more advanced volumetric imaging tools when assessing the clinical impact of novel immobilization devices.

Abdominal arc compression device used in the present study (BodyFix and Diaphragm Control, Medical Intelligence, Schwabmuenchen, Germany). Patient immobilization is afforded by the BodyFix whole body immobilization system (right figure). The abdominal pressure device consists of an carbon fiber arc that is locked to the BodyFix carbon fiber base board or the linear accelerator table couch top. Variable sized abdominal pressure plates and indexed pressure screws allow for individualized application of pressure onto the upper abdomen.

Axial and sagittal CT reconstruction of a HCC case treated by SBRT using BodyFix immobilization with the abdominal pressure device attached.



Centroid motion trajectories of a HCC during 4DCT SBRT simulation. Target motion following patient immobilization in the BodyFix whole body immobilization device without (red line), and with an abdominal arc compression device (black line)). Use of abdominal compression reduced SBRT liver target motion significantly, with the majority of motion reduction in the cranio-caudal direction.



Left figures:

Changes in PTV volumes resulting from MIP based ITV extension by 5 mm without (upper figures) and with abdominal compression.

In this particular case, a PTV volume reduction of 27.2% was afforded by use of abdominal compression.