

Use of On-Board Imaging to Evaluate Residual Errors for Target Localization in SBRT: A Feedback Analysis

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Background:

Accurate target localization for stereotactic body radiotherapy requires identification of 3D anatomical information. On-board imaging provides both 2D radiographs and cone beam CT (CBCT) to perform target localization and is being introduced for clinical applications. However, the effective use of this system is still under development. This study is aimed to develop a new scheme of using on-board imaging to evaluate residual errors for target localization. It is especially important for SBRT due to inter-fraction variation between simulation and treatment and intra-fraction patient movement associated longer treatment time.

Methods:

The process for on-board target localization for SBRT includes: 1) align patient within immobilization device; 2) obtain orthogonal on-board kV/MV radiographs to compare to reference DRRs from the planning CT and document shifts accordingly; 3) obtain 3D on-board CBCT for comparison to the planning CT; 4) shift patient to align target between CBCT and planning CT; 5) obtain orthogonal 2D kV/MV images to document shift; 6) treatment; 7) obtain orthogonal on-board kV/MV images to assess intra-fraction motion. The shifts as identified by steps 2 and 3 will indicate how target localization accuracy could be improved due to inter-fraction deviation by incorporating 3D anatomical information. Steps 5 and 7 reflect the degree of intra-fraction variation which provides feedback information about the treatment accuracy to improve patient setup.

Results:

We analyzed localization data for 17 treatments from 10 patients treated with SBRT during last 6 months. The localization accuracy as identified in step 3 is illustrated in Fig 1, where CBCT target is overlaid by the planning target contour. Its accuracy is visually judged within 1 mm. Figure 1 also shows the residual errors based on 2D radiographs prior to CBCT acquisition as compared to 3D localization for each treatment. The intra-fraction motion assessed via 2D radiographs prior to and after treatment ranged from 0 to 4 mm with an average of 1 mm, indicating further improvement of patient immobilization may be needed. On the other hand, 3D imaging takes at least 3 times more working efforts compared to 2D imaging.

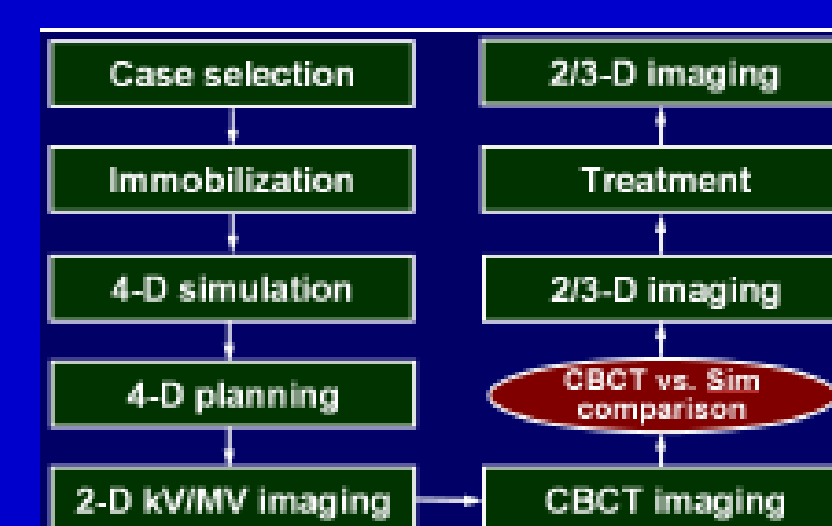


Figure 1. Protocol for CBCT-guided SBRT.

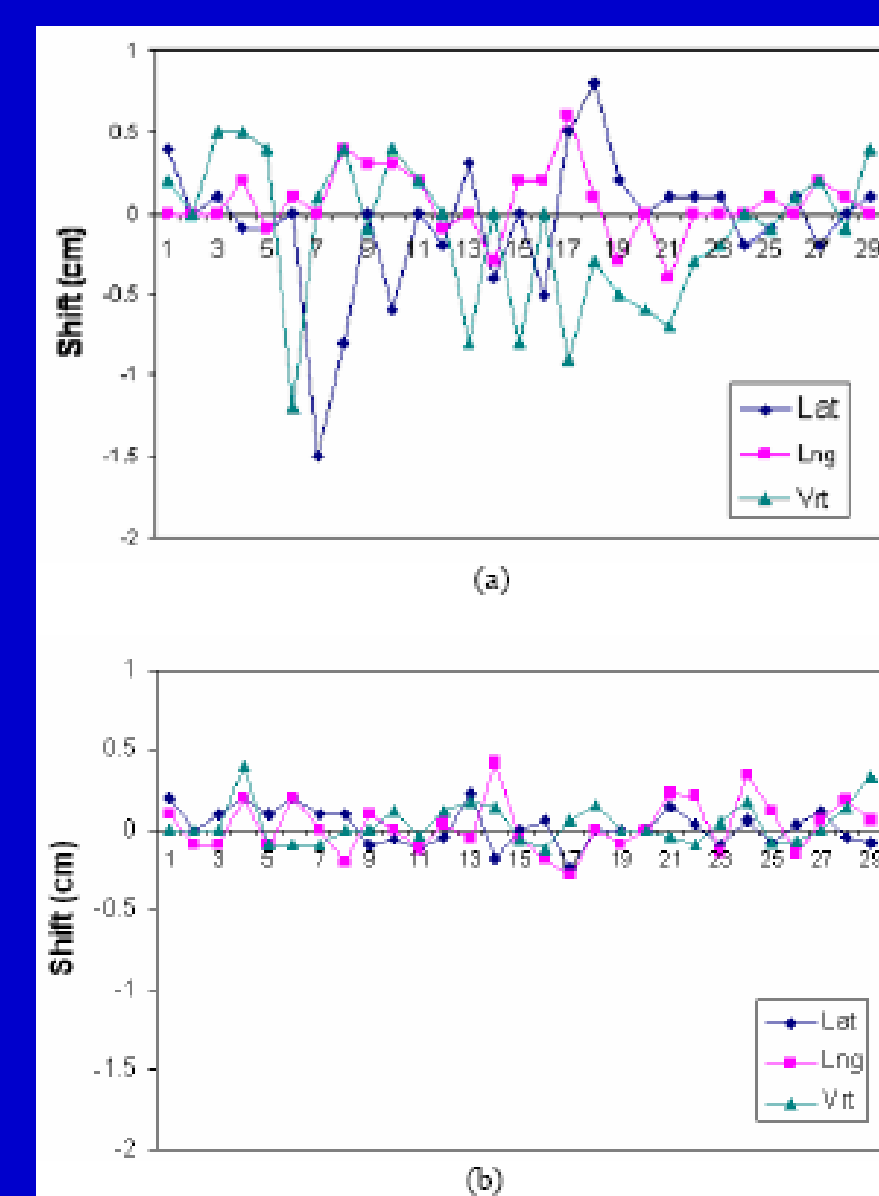


Figure 2. Pre- and post-treatment shifts (a), and shifts between 2D imaging and CBCT (b).

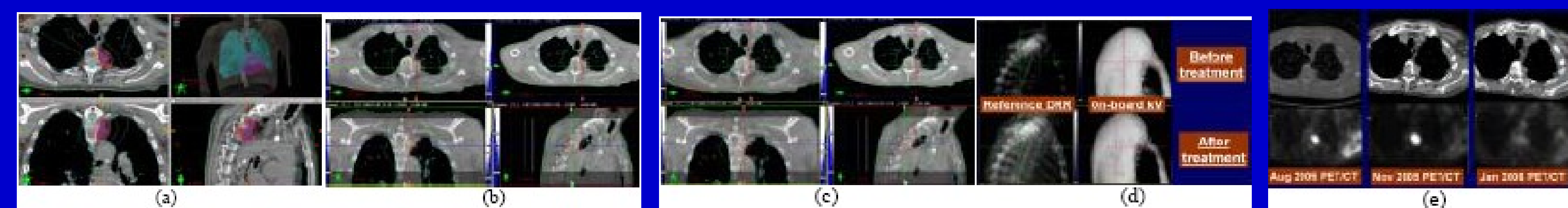


Figure 3. Spine case - 3-D planning (a), 3-D CBCT matching with planning CT [(b)-before matching, and (c)-after matching], 2-D radiograph before and after treatment (d), and treatment outcome of PET images (e).

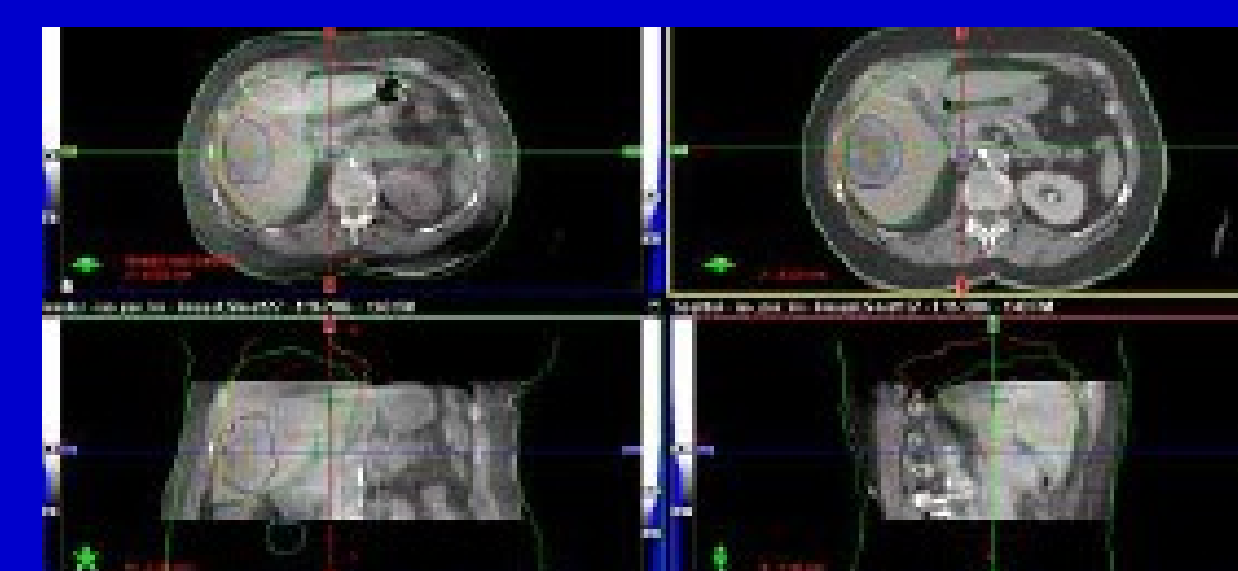


Figure 4. CBCT for the liver case after matching with planning CT (shown with contours).

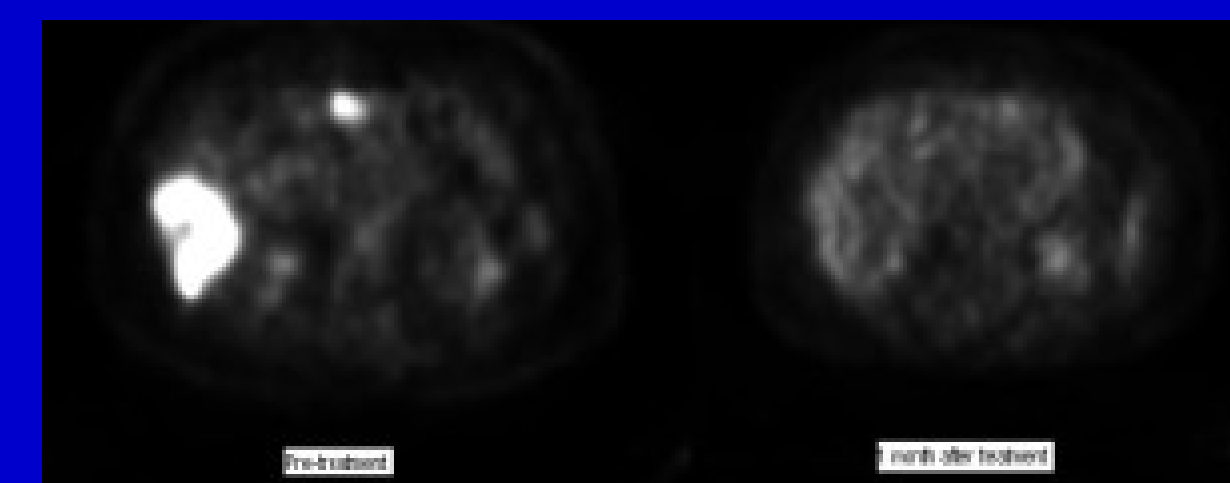


Figure 6. Treatment outcome as shown in PET images: pre-treatment PET (left) and 1 month after the treatment (right).

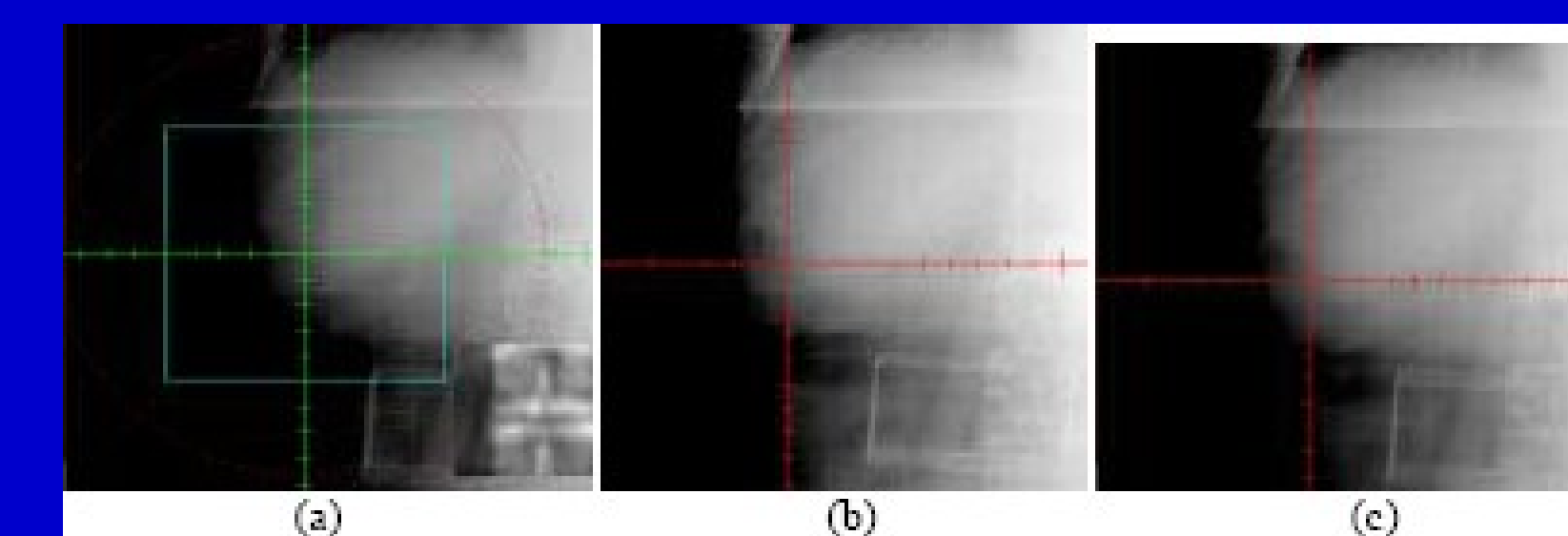


Figure 5. kV radiographs for the liver case taken before correction (a), after correction but before treatment (b), and after treatment. Implanted markers are used to document the deviations (c).

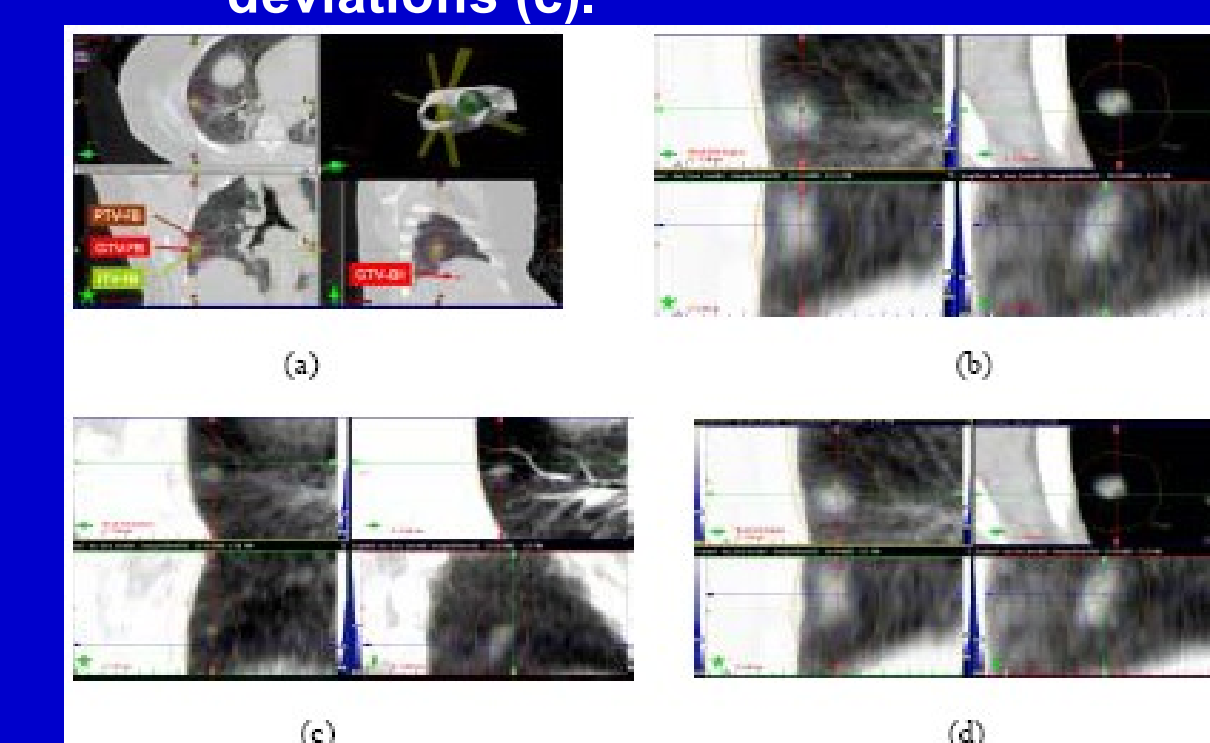


Figure 7. Lung case – treatment plan (a), CBCT pre-shift (b), CBCT after shift before treatment (c), and CBCT after treatment (d).

Conclusion:

The on-board imaging system provides an efficient tool to assess the overall accuracy of treatment. While CBCT is favorable to be used for the identification of inter-fraction deviation, the intra-fraction errors could be effectively identified using 2D imaging method. The residual positioning errors identified by on-board imaging provide useful information for improving patient treatment accuracy.

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