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Evaluation of the feasibility of performing markerless tracking for lung SBRT patients

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Purpose

Tumor tracking based on fiducial markers using the VERO SBRT system uses a correlation model to estimate internal tumor position based on external motion surrogate. Previous studies in our department showed the feasibility and accuracy of performing a marker-based tracking. The drawback of this technique is the implantation of a marker as a surrogate for the tumor motion, as majority of patients are not eligible for marker implantation due to risk of pneumothorax in COPD patients and anatomical challenges. For this reason, our goal was to implement a less invasive technique suitable for a larger cohort of patients using state-of-the-art imaging. In this study, we report on the first simulation of a markerless real-time tumor tracking solution based on the Vero SBRT gimbaled Linac system for the treatment of lung tumors.

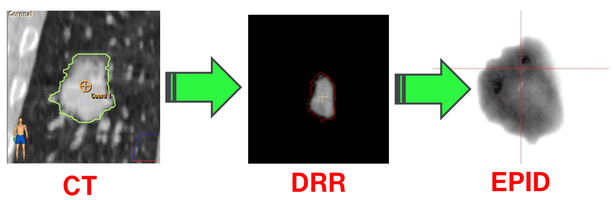

Fig 1. Workflow of the markerless tumor tracking using CT, DRR and EPID (left to right).

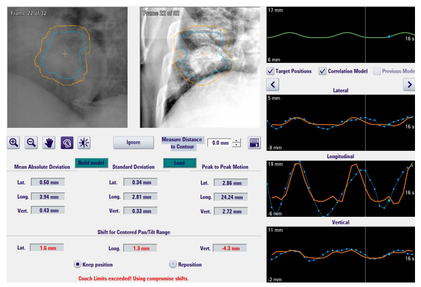

Fig 2. Screenshot of the model check interface.

Materials and Methods

Eight previously treated patients with a marker-based tracking were used to analyze the feasibility of markerless tracking. The marker was erased from the fluoroscopic images in order to analyze the markerless environment of the ExacTrac v3.5 system (Brainlab, München, Germany). The density of the lesion was used as a surrogate for tracking. The accuracy of the target identification for a reference image pair, which is provided to the markerless tracking algorithm, was compared against the marker-based implants detection (Fig 1). The result gives an estimation of the manual target identification error (Fig 2). Additionally, the user-variability and the patient-variability of the manual target identification error were analyzed. Furthermore, 15 patients treated with internal target volume (ITV) were simulated for markerless tracking.

Results

Analysis of the 3D deviations and average deviations of all 8 patients showed relatively good agreement, with an average deviation across all analyzed cases of 2 mm (Table 1). We found that markerless trackability requires tumor to be clearly bounded on CT and exhibit sufficient contrast. Moreover, the results were analyzed by different users and no user-dependency was observed. While the use of implants as a reference might be a limitation as they don't represent ground truth, ongoing studies have shown the feasibility of this approach without implants.

Table 1. Deviations in x, y, z and averaged over all coordinates between the markerless detected target and marker-based implant for all patients.

Patient	dx (mm)	dy (mm)	dz (mm)	Average deviation (mm)
1	2,70	0,56	0,78	1,35
2	1,13	2,37	5,36	2,95
3	1,38	1,62	0,49	1,16
4	2,17	1,37	1,69	1,74
5	1,95	1,18	0,24	1,12
6	2,16	2,23	0,52	1,63
7	1,12	0,48	0,47	0,69
8	5,30	8,06	4,70	6,02
Average	**2,24**	**2,23**	**1,78**	**2,08**

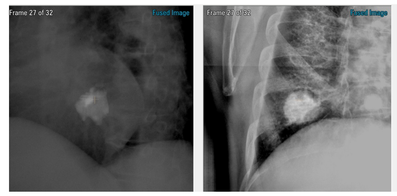

Fig 3. Fusion of the CT and DRR shown for one frame out of all the analyzed fluoro-sequences.

Conclusion

This study is a proof of principle that stereoscopic x-ray images are feasible to perform markerless detection of moving lung lesions. This approach would allow a large number of patients to benefit from non-invasive tracking technique with the possibility to reduce margins without compromising the precision of dose delivery and without increasing treatment duration. Further research and development in the real-time markerless tumor tracking are warranted to refine algorithms and validate efficacy across diverse patient populations and treatment scenarios.