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Original paper

Localization accuracy of robotic radiosurgery in 1-view tracking

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ABSTRACT

Purpose: When a lung lesion is detected by only one couple of X-ray tube and image detector integrated with CyberKnife®, the fiducial-less tracking is limited to 1-view (34% of lung treatments at Centro Diagnostico Italiano). The aim of the study was mainly to determine the margin needed to take into account the localization uncertainty along the blind view (*out-of-plane* direction).

Methods: 36 patients treated in 2-view tracking modality (127 fractions in total) were included in the study. The actual tumor positions were determined retrospectively through logfile analysis and were projected onto 2D image planes. In the same plots the planned target positions based on biphasic breath-hold CT scans were represented preserving the metric with respect to the imaging center. The internal margin necessary to cover in out-of-plane direction the 95% of the target position distribution in the 95% of cases was calculated by home-made software in Matlab®. A validation test was preliminarily performed using XLT Phantom (CIRS) both in 2-view and 1-view scenarios.

Results: The validation test proved the reliability of the method, in spite of some intrinsic limitations. Margins were estimated equal to 5 and 6 mm for targets in upper and lower lobe respectively. Biphasic breath-hold CT led to underestimate the target movement in the hypothetical out-of-plane direction. The inter-fractional variability of spine-target distance was an important source of uncertainty for 1-view treatments.

Conclusion: This graphic comparison method preserving metric could be employed in the clinical workflow of 1-view treatments to get patient-related information for customized margin definition.

1. Introduction

The CyberKnife® robotic radiosurgery system [1] (Accuray Inc., Sunnyvale, CA, USA) stands out as a treatment delivery in lung Stereotactic Body Radiation Therapy (SBRT) because of the real time tumor tracking option to account respiratory motion [2,3]. The Synchrony® module [4] matches information about tumor location and patient's respiratory cycle from the stereoscopic imaging and breath monitoring subsystems respectively, in order to build a correlation model and hence a prediction model to enable the robotic arm to correct dynamically the beam direction. From the point of view of treatment accuracy, the gold standard is the fiducial-based target tracking system (FTTS) [5], but it exposes patients to the risk of adverse events related to fiducial insertion [6,7]. Therefore the preferred treatment option for inoperable patients with lung tumors is often the fiducial-free approach [8,9], called Xsight® Lung Tracking System (XLTS), which detects and tracks directly the image intensity of the lung tumor in the orthogonal X-ray projections at 45° from vertical [10]. The accuracy of this non-invasive modality depends mainly on the number of X-ray projections (*2-view*, *1-view* or *0-view*) that detect successfully the lesion during the treatment and it must be taken into account in the target margin definition [11]. For this reason, prior to the planning step in the lung treatment workflow, a simulation session is performed to establish the best possible strategy.

The management of 1-view scenario is particularly challenging and it is implemented by Lung Optimized Treatment® (LOT) package [12] in MultiPlan® Treatment Planning System (TPS). LOT assumes the CT study as a reliable model to estimate automatically the Internal Target Volume (ITV) along the unusual perspective of the untracked (*out-of-plane*) direction and hence to include the localization uncertainty in the Planning Target Volume (PTV) definition. The general recommendation is to use 4D-CT imaging for planning, while the use of the biphasic

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breath-hold CT study should be evaluated carefully [3].

The retrospective analysis of *logfiles* generated by CyberKnife during fiducial-based treatments is the consolidated method to determine the dynamic tracking accuracy. Many authors [13–17] have studied the main components of set-up uncertainty (targeting, correlation and prediction errors) assuming the hypothesis of rigid body, while others [18,19] have examined the deformation error. The localization error for organ motion in 0-view treatments was deeply investigated by Descovich *et al.* [20] using log data from 2-view treatments. Jung *et al.* [21] verified that segmentation ability of X-ray images in XLTS is comparable with that of FTTS. In this context there is very little literature on CyberKnife treatments in 1-view modality. A *White Paper* published by Accuray in 2013 [12] about LOT system gave some reference indications from the analysis of 29 fiducial-based treatments collected from three different clinical sites which used both biphasic and single CT. In April 2018 1-view tracking was mentioned in two different and extensive works [22,23]. In particular, Nakayama *et al.* [22] asserted that there are no significant differences in correlation and prediction errors between XLTS and 1-view tracking, while Ricotti *et al.* [23] estimated an overall geometric accuracy for each fiducial-free modality using retrospectively 2-view log data and 4D-CT acquisitions.

We conducted a retrospective study addressed to define the ITV-to-PTV margin necessary to compensate the localization uncertainties arising in the management of the case 1-view compared with the reference 2-view. It is our belief that this class of treatments cannot be approximated simply to an intermediate situation between 2-view and 0-view, but rather it has to be considered differently because of its related specific issues. The retrospective analysis proposed by Descovich *et al.* [20] was adapted for 1-view mode with some important changes in order to define a population-based margin, taking into account the target motion. Aim of the work was also to distinguish inter-fractional and intra-fractional components of localization uncertainty when using biphasic breath-hold CT for planning. For this dual purpose, a deep study of the lung treatment database at Centro Diagnostico Italiano was performed for patient selection and a home-made software was realized and validated for data analysis.

2. Methods and materials

2.1. Patient data and data acquisition

Table 1 reports useful information about lung cancers treated at Centro Diagnostico Italiano (Milan, Italy) in 2016 in relation to the tracking method and anatomical tumor location. Almost one-third of lung patients underwent CyberKnife SBRT in 1-view tracking modality. Tumors were mainly located in upper and lower lobes and for 1-view mode there was a slightly predominance of cases in lower lobe with respect to 2-view.

All patients considered in this study were treated on CyberKnife VSI® system (Accuray Inc., Sunnyvale, CA, USA) using dynamic tracking exclusively in 2-view mode. The set of data generated in 2-view treatments is indeed adequate to simulate 1-view scenarios, otherwise unknown, and hence to verify retrospectively the system localization accuracy in the management of the 1-view case. Thirty-six lung cancer treatments over a total of 127 fractions were included and their characteristics are listed in Table 2. We considered only tumors in upper and lower lobes, as defined by physicians, in order to investigate any possible margin dependence on tumor location. Patients gave written informed consent for the use of their anonymized data.

Table 1
Classification of lung cancers treated at Centro Diagnostico Italiano in 2016 in relation to tracking method and anatomical tumor location.

Tracking method		
Fiducial-based		1%
Fiducial-free	2-view	53%
	1-view*	34%
	0-view	12%
Tumor Location	*2-view*	*1-view*
Upper lobe	45%	36%
Middle lobe	22%	18%
Lower lobe	33%	46%

* 18% of treatments were 1-view A and 16% 1-view B.

Table 2
Patient and treatment characteristics of the sample. All selected patients were treated in 2-view modality.

Patient sample	Upper lobe	Lower lobe	Total group
PTV volume [cm^3]§	15 [2–78]	24 [2–371]	18 [2–371]
Prescribed dose [Gy]§	51 [25–54]	50 [25–54]	50 [25–54]
Treatment fraction time [min]§	37 [28–54]	41 [26–50]	38 [26–54]
Total number of fractions	66	61	127
Number of treatments	20	16	36
In: one fraction	2	1	3
three fractions	12	6	18
four fractions	2	3	5
five fractions	4	6	10

§ Expressed in terms of median, minimum and maximum values

As usual practice at our center, patients were trained to hold not forced breath in exhale and inhale phases, then immobilized with a 5-point thermoplastic mask on CT couch. After that, a biphasic CT was acquired by Somatom Definition scanner (Siemens Healthcare GmbH, Erlangen, Germany) using a specific lung protocol and a slice thickness of 1 mm. In the simulation step of planning, physicians contoured in the exhale and inhale CT scans the Target Tracking Volume (TTV), defined as the evident disease on the window width and level of the mediastinum. The MultiPlan® TPS (version 5.2, Accuray Inc., Sunnyvale, CA, USA) calculated automatically and regardless of the tracking method the Internal Target Tracking Volume (ITTV) on the primary CT as the envelope of the TTV in exhale and inhale phases. The TTV motion detected by the monitoring system during the 2-view treatments was stored in logfile by CyberKnife. These data were used to represent the actual target position because in the hypothesis of rigid body the movement extent of the TTV barycenter can be approximated to that of the Gross Tumor Volume (GTV). In this respect, the TTVs and ITTVs were considered to be representative of the GTVs and ITVs respectively.

It is important to note that 1-view treatments differs from 2-view ones for two main aspects. First of all, in the 1-view planning step the ITV is automatically expanded by TPS only across the view unable to track the tumor, called out-of-plane direction. The main consequence is that also the PTV is defined in an original way as expansion of ITV along the untracked (*out-of-plane*) and tracked (*in-plane*) directions, which are illustrated in Fig. 1 as red axes on the x-ray paths. The point of view results substantially different from the standard 3D patient reference frame (blue axes in Fig. 1). Secondly, in the 1-view pre-treatment phase the patient positioning is performed through an image-guided alignment of the spine and then applying rigidly a shift calculated by TPS on the base of the spine-ITV center distance in the planning CT, as in a normal spine-tracking or 0-view treatment. The accuracy of the last shift depends on the reliability of the CT model in relation to the treatment reality and it could affect the target localization in 0-view and 1-view treatments. In particular with regard to 1-view case, this source of uncertainty can entail an unpleasant (but precautionary) interruption of the therapeutic beam when the system detects the ITV center out of tolerance with respect to the planned position in Superior-Inferior (SI) and cannot perform autonomously the correction due to the lack of information in out-of-plane direction. Conversely in the 2-view modality the patient positioning can be achieved by an additional image-guided shift which aligns the real ITV center detected through two pair of radiograph images in exhale and inhale phases. This full-image-guided patient alignment is regardless of the relative spine-ITV

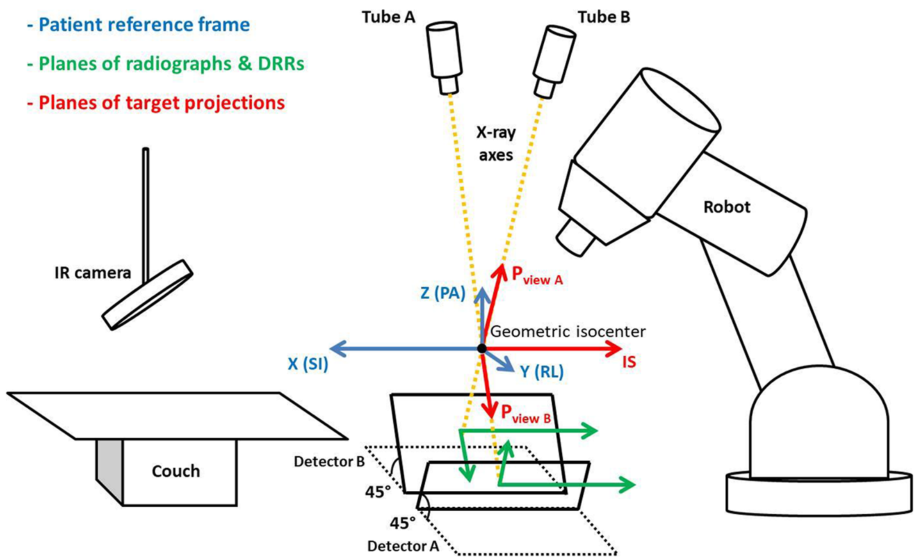

Fig. 1. Schematic overview of the CyberKnife system aimed at defining the patient reference frame (blue), the planes concerning the Digital Reconstructed Radiographs and the live radiograph acquisition (green) and the planes of the target projections (red). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

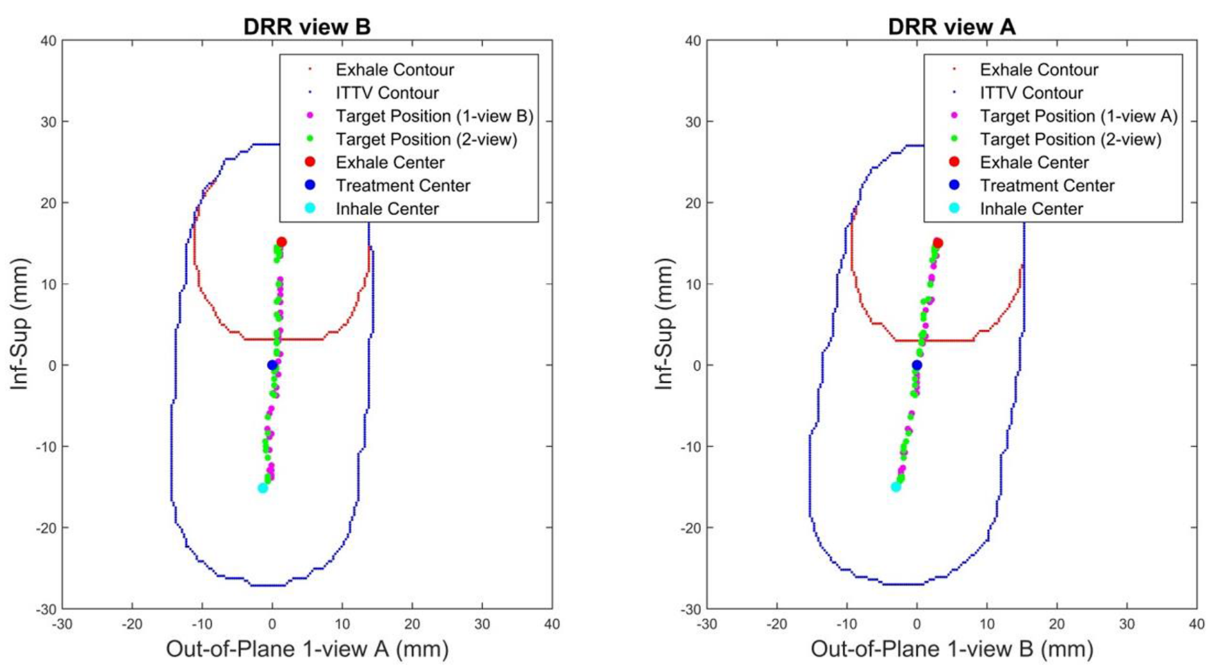

Fig. 2. Plot of the validation test data.

center position in the CT scan. Furthermore, the assumption of a reliable CT model is less important in 2-view treatments as the planning inaccuracies can be compensated by the real time tracking. For all these reasons, the 2-view-based data were studied in the out-of-plane perspective giving particular attention to the critical role of the biphasic breath-hold CT scans.

2.2. Actual and planned target positions

The actual target motion in 2-view treatments can be determined retrospectively by GTV coordinates stored in logfiles, such as those generated by direct target detection of imaging system (ModelPoints.log). In ModelPoints.log files, sampling of the respiratory cycle is typically every 60 s as image acquisitions. Although the duration of these hypo-fractionated treatment sessions is long enough to consider each fraction as a stand-alone treatment, treatments with the largest number of fractions can influence too strongly the population-based result, thus we decided to analyze data correlated to whole treatments. Furthermore, the image-guided system cannot correct completely inter-fractional misalignment in 1-view treatments. In addition we analyzed only data generated within the temporal interval between the first and the last delivered beam, as defined in *ERsiData*.log files.

The coordinates (X,Y,Z) in *ModelPoints*.log files are expressed according to patient reference frame and correspond to superior-to-inferior (SI), right-to-left (RL) and posterior-to-anterior (PA) directions respectively, as illustrated by blue axes in Fig. 1. We projected these GTV coordinates onto the 2D image planes translated to the geometric isocenter (red axes in Fig. 1). The transformation of (X,Y,Z) in the pair of coordinates (P_{viewA}, IS) and (P_{viewB}, IS) was performed as follows:

$$P_{viewA} = \frac{Z+Y}{\sqrt{2}} \qquad out-of-plane\ direction\ for 1-view\ B \tag{1}$$

$$P_{viewB} = -\frac{Z-Y}{\sqrt{2}} \qquad out-of-plane\ direction\ for\ 1-view\ A \tag{2}$$

$$IS = -X \qquad Inf - Sup\ direction\ in\ common\ for\ both\ the\ views \tag{3}$$

where A and B are the conventional name to each couple of X-ray tube and image detector. Eqs. (1) and (2) were derived through simple geometric properties. The negative sign in Eqs. (2) and (3) takes into account the right-to-left and inferior-to-superior orientation of the horizontal and vertical axes in the Digital Reconstructed Radiographs (DRRs) displayed by TPS.

We represented on the same plane of the projected data the contours related to ITV and GTV in exhale phase, as defined in simulation planning (see Fig. 2). These contours are stored in available.*dat* files and reproduce those displayed in *DRR review* planning step. The center of each volume was determined as the average of coordinates of the maximum extensions of the contour. Since ITV is the envelope of GTVs, the center of GTV in inhale phase was considered symmetrical to exhale center respect to the ITV one. This representation assumed an ellipsoidal or at least regular design of GTV. Lastly, some corrections were applied. First of all, the contours were resized by a factor 0.75 in order to take into account that DRR planes are farther than geometric isocenter from the X-ray tubes (see Fig. 1) and hence that the radiograph objects result enlarged. This operation was needed to compare directly the distribution of the projected GTV positions with the contours. The scale factor had been estimated by the ratio between the nominal and radiographic size of a well-known object test (a ball insert simulating lung lesions in the Xsight® Lung Tracking Phantom, CIRS, Norfolk, Virginia, USA) placed at the geometric isocenter. Then all the contour and center points were shifted so that the ITV center was repositioned at the imaging center, as it occurs during the full-image-guided patient alignment in 2-view treatments. In this way, the actual and planned GTV positions were represented onto the same plane preserving the reciprocal spatial metric with respect to the imaging center. Unlike Descovich *et al.* [20], it was taken into account that ITV and the mean position of GTV during the treatment were not aligned.

2.3. Localization accuracy

The whole analysis of log data was performed by a home-made software in MATLAB® (R2015a – academic use license, The MathWorks Inc., Natick, MA, USA) which also enabled to represent data in graphic plots. A set of 2-view based logfiles was a source of data for two different 1-view scenarios, so a total of 72 treatments were investigated.

The extent of target motion over all the fractions of every treatment was calculated as the difference between the maximum and minimum GTV positions along the 3D-coordinates and the out-of-plane direction. Then, we focused only on the hypothetical out-of-plane direction and the software created for each treatment the frequency histograms of P_{viewA} and P_{viewB} defined by Eqs. (1) and (2). Then it verified that the ITV, which was automatically calculated by TPS, covered at least the 95% of the position distributions. When the test failed, the program applied a *cost function*, which expanded symmetrically the limits in out-of-plane direction through incremental steps of 1 mm until the ideal coverage was reached. An extra-margin was computed in order to determine the expansion that ensured the acceptable localization accuracy for the 95% of the margin population. The results were observed analyzing only the GTV barycenter positions described by logfile data, but they can be extended to all target voxels in the hypothesis of rigid body.

2.4. Intra-fractional and inter-fractional components of localization uncertainty

Treatments were analyzed again in order to study graphically the intra-fractional and inter-fractional variability of target motion. Each fraction was examined classifying position data into four groups according to their acquisition time. Then, for each treatment, the target position was associated with the fraction of belonging. In both cases data were plotted in the plane of target projections as described above.

Data from 2-view source could take advantage from the full-image-guided patient positioning in the first treatment fraction. This operation not performed in 1-view modality (and 0-view neither) could generate a localization uncertainty out of the previous analysis. In order to derive the entity and frequency of the additional shift in 2-view case, the treatment couch positions stored in *DeliveryResult.xml* file were studied retrospectively. The absolute couch positions before the first fraction of each treatment were plotted in order to recognize graphically every phase of the patient alignment.

2.5. Validation test

A validation test was performed in order to verify the accuracy of the home-made software to reproduce right contours and target positions from logfile data generated in a well-known situation. We used for this purpose the Xsight® Lung Tracking Phantom (CIRS, Norfolk, Virginia, USA) which underwent the whole lung workflow. The available phantom was able to simulate a lung lesion movement of 30 mm only in inferior-superior direction. As a consequence the phantom was slightly tilted and yawed on the CT couch as well as on the treatment couch in order to produce other components of motion. Exhale and inhale CT scans were performed stopping phantom motion and setting manually the lesion insert at the corresponding extreme position. Three identical isocentric plans were prepared selecting different tracking modality (2 view, 1-view-A, 1-view-B) and then were delivered one after the other. 2-view log data were projected onto image planes by means of Eqs. (1) and (2), whereas the projection of 1-view log data was calculated simply as the square root of 2 multiplied by the Z-coordinate (posterior-to-anterior direction) in view A case or by the opposite of the Z-coordinate in view B case. A small correction was applied to 1-view log data in order to take into account the different location of treatment center respect to 2-view case as calculated by TPS. Lastly, a visual check of the data plot was performed to make sure the matching between 2 and view and 1-view based target positions and to confirm the software capability to reproduce the TTV and ITTV contours as displayed in the related *DRR review* step of MultiPlan.

3. Results

3.1. Validation

Fig. 2 shows the result of the validation test. Red, blue and cyan points represent the exhale, treatment and inhale centers respectively, while green and magenta points are the actual target positions based on 2-view and 1-view data. The real position distributions were well aligned and included within planned extreme positions. Furthermore, the home-made software reproduced reliably the contours displayed in DRR review.

During this test session it was observed that the DRRs generated by Multiplan (version 5.2) are centered on the target in exhale phase, whereas live radiographs are centered on the ITV center. Because of this misalignment, the lesion insert in the phantom, which was always visible in both views, moved out of the planned ITV contours displayed on the live radiographs of the treatment monitor. Consequently, the target could not be monitored during the treatment session through a direct comparison of the planned and actual extension of motion, not even when in a real 1-view treatment the target is identified in both the views for some phases of the respiratory cycle, as sometimes occurs.

3.2. Localization accuracy

The extent of target motion over a whole treatment is reported in Table 3. Targets in lower lobe showed an important movement in superior-inferior direction. The out-of-plane component was comparable to RL and PA ones.

Table 3
Extent of target motion along 3D and out-of-plane directions over a whole treatment. Mean values and their standard deviations were determined through logfile analysis of 36 selected patients treated in 2-view modality. Minimum and maximum values are reported within square brackets.

Component of motion	Extent of target motion (mm)	
	Upper lobe	Lower lobe
Superior-Inferior	10 ± 7 [2–29]	19 ± 10 [3–46]
Right-Left	6 ± 4 [1–15]	8 ± 6 [3–23]
Posterior-Anterior	10 ± 6 [2–22]	11 ± 5 [4–25]
Out-of-plane direction	8 ± 5 [2–19]	9 ± 5 [3–25]

Fig. 3 summarizes the expansion from ITV needed to reach the coverage of at least 95% of the target position distribution in out-of-plane direction for each of the 72 scenarios. The planned internal margin was conservative or adequate in only 5 cases. The population-based margins were listed in Table 4. A smaller margin was defined for the upper lobe group.

3.3. Intra-fractional and inter-fractional components of localization uncertainty

Underestimation of target motion and inter-fractional variability were observed. Fig. 4 illustrates four different representative situations. In Fig. 4(a) the actual movement extent along out-of-plane direction was included between the exhale and inhale centers as expected, whereas in Fig. 4(b) the most of target positions resulted outside the planned limits. Fig. 4(c) shows position data of a single fraction classified according to the quarter of belonging and it is evident that the fourth quarter followed a different pattern in comparison with the rest of the fraction. Fig. 4(d) illustrates in the same plot the target positions of each treatment fraction: the third fraction confirmed the CT model, unlike the first and second ones which were placed elsewhere.

In Fig. 5 the absolute couch positions before the first fraction of a typical 2-view treatment is depicted. In the same way, for all the treatments, each couch movement was clearly associated with the corresponding phase of the patient alignment. The additional shift from lung treatment center alignment to ITV center alignment (fourth phase in Fig. 5) was absent in most of cases. In particular, this additional shift characteristic of a full-image-guided alignment was recognized in the 23% of the selected cases and was on average 4.5 ± 3.5 mm in out-of-plane direction (shift minimum of 0.4 mm and maximum of 13.4 mm).

Table 4
Population-based definition of extra-internal margin along the *out-of-plane* direction for treatments in 1-view tracking modality.

Tumor location	N° of treatment cases	Extra-internal margin	Coverage
Upper lobe	40	5 mm	97.5%
Lower lobe	32	6 mm	96.9%
Total	72	6 mm	98.6%

4. Discussion

The validation test with XLT Phantom confirmed the reliability of the technique and applying it in a situation less ideal than the phantom case we could see that most of the times the target position distribution exceeds ITV borders, as represented in Fig. 4(b). Localization uncertainties in out-of-plane direction cannot be compensated by dynamic tracking, thus an extra-margin to the ITV created from biphasic breath-hold CT scans was necessary in most cases, as shown in Fig. 3 and resumed in Table 4. Ricotti *et al.* [23] used 4D-CT model and noticed that in this situation the amplitude of target movement was not significantly different between planning and treatment scenarios. They also observed that an out-of-plane expansion of 5 mm ensured at least the 95% of CTV coverage in the 85% of 1-view cases. The common result was the requirement of a large margin in out-of-plane direction.

The margins reported in Table 4 incorporated not only the amplitude underestimation but also the intra-fractional and inter-fractional variability. Fig. 4(c) is an example of the unpredictable variation of the target motion due to a change in breath pattern or to a patient movement during the fraction, whereas Fig. 4(d) represents the target variability because of a patient misalignment. It should be remarked that in a real 1-view scenario the inter-fractional variability in SI can be compensated by dynamic tracking but not when it occurs also in out-of-plane direction as in Fig. 4(d). This kind of uncertainties can be detected only by a graphic method conserving the reciprocal metric

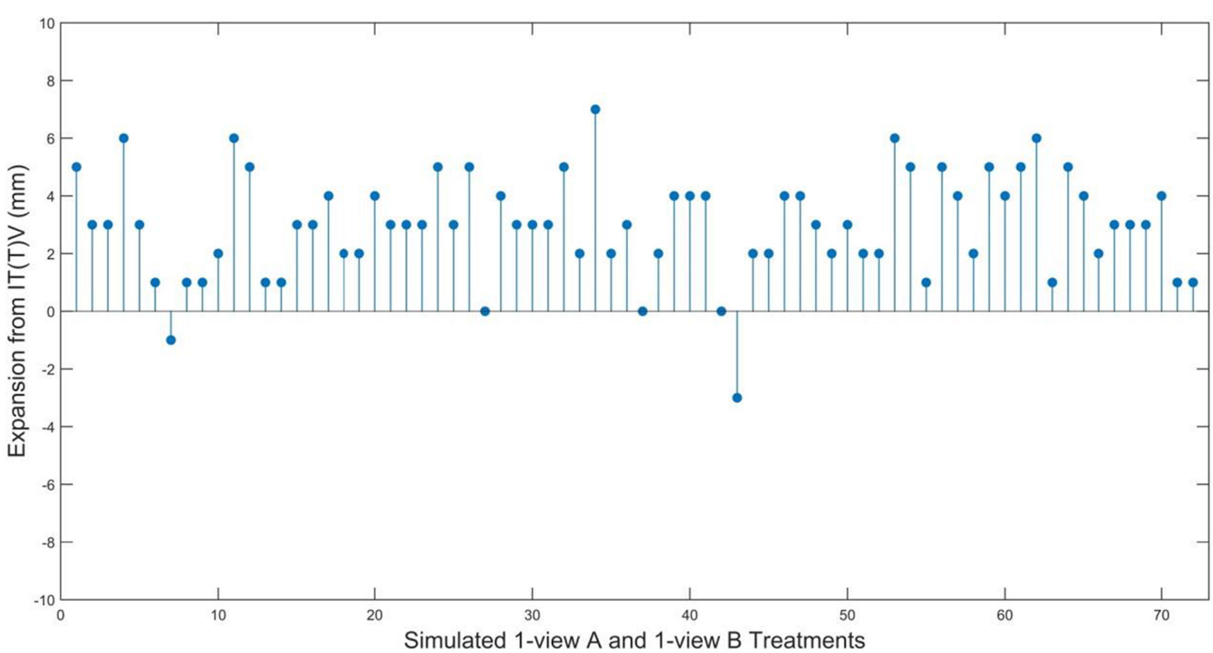

Fig. 3. Expansion from the Internal Target Volume (ITV) in the *out-of-plane* direction. Negative values indicate a conservative estimation of the planned internal margin.

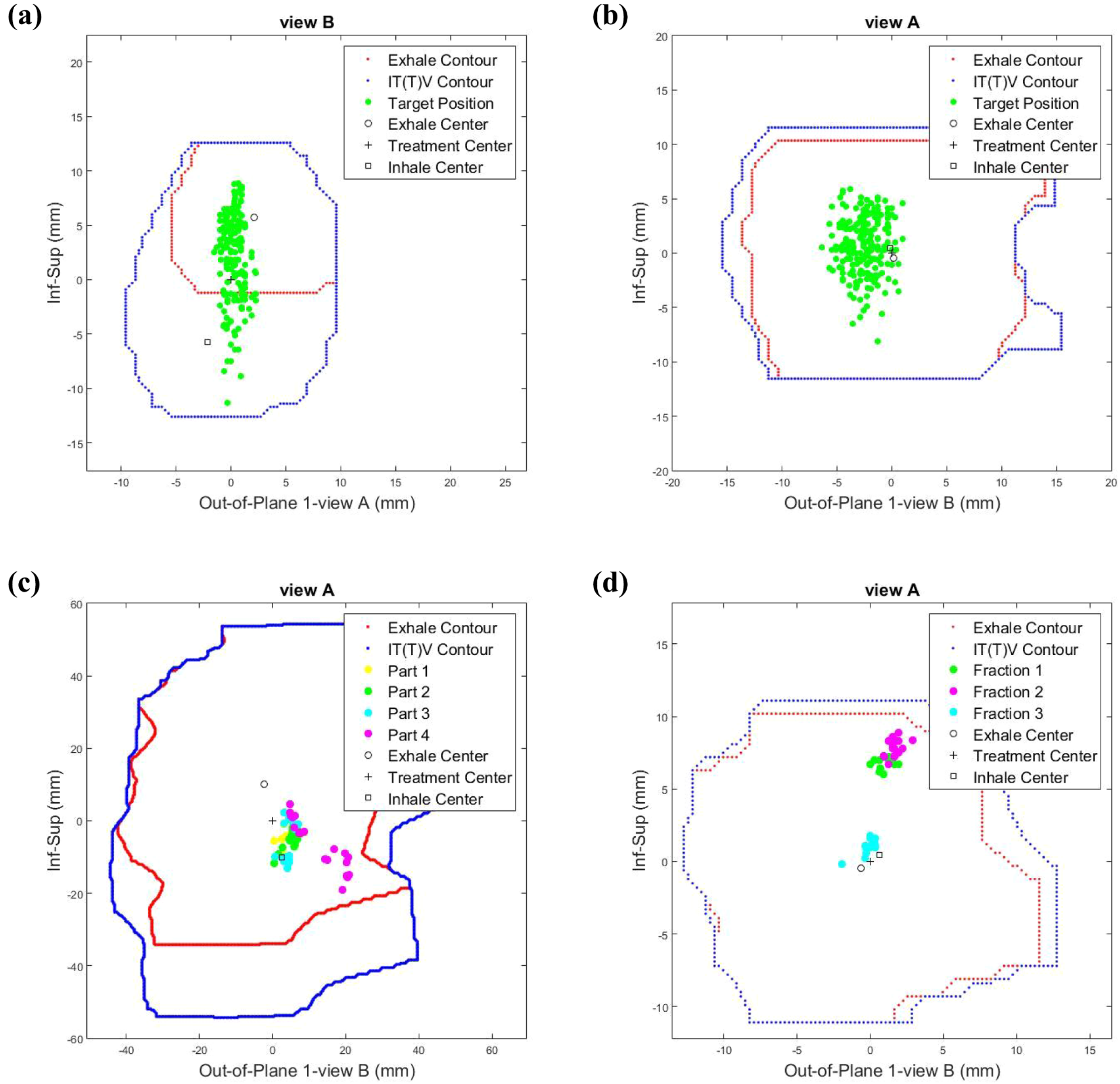

Fig. 4. Four different representative situations of out-of-plane variability. (a) Example of a conservative internal margin in out-of-plane direction (b) Large underestimation of the target motion amplitude in out-of-plane direction too. (c) Fraction data divided according to time quarter of belonging: intra-fractional variability. (d) Treatment data divided according to fraction of belonging: inter-fractional variability.

between actual and planned positions. The values of the motion extent tabulated in Table 3 were greater than those reported in the work of Dieterich and Suh [28] precisely because we studied the GTV motion over the entire treatments and not over separated fractions. The inter-fractional variability cannot be neglected in 1-view treatments.

On the other hand, the margins listed in Table 4 did not consider that 23% of the selected data had been achieved by means of an additional image-guided shift in the patient positioning unlike a real 1-view scenario. The entity of this supplementary localization uncertainty can be extremely large (up to 13.4 mm in our patient sample) so it represents a critical aspect for 1-view case, although it affects only some treatments. The additional shift occurs probably when the patient immobilization technique was not adequate or the spine-ITV center distance was not planned correctly, another reason to consider unreliable the biphasic breath-hold CT scans. In order to reduce this kind of uncertainty, it is important to give particular attention to the patient immobilization phase and improve the techniques of CT scan rather than increase the margins listed in Table 4. Note that the variation of the spine-ITV relative distance has never been identified in previous works as a variable of localization uncertainty, although it is a common issue with the 0-view tracking modality.

Some intrinsic limits of the method should be considered. First of all, there is a possible dependency of results on 2-view nature of data. In fact, the patient sample was populated with cases which would be very critical for actual 1-view treatments, such as small lesions (< 15 mm) or tumors with negligible expected motion (see Fig. 4(b)). Secondly, the use of *ModelPoints*.log files led inevitably to overestimate the time that the target spent at the extreme positions with respect to the middle positions, because X-ray acquisitions sample regularly at the same frequency each segment of the respiratory cycle. Descovich *et al.* [20] assessed that this fact could entail a final overestimation of 0.65 mm compared to the margin resulted by data from correlation model. Lastly, the population-based margin definition is notoriously dependent on the patient sample size [24]. It might be remarked that the treatment accuracy includes also other components of uncertainty which are outside the aim of this work, such as those investigated in delivery quality assurance programs [25,26] and the accuracy of the dose calculation algorithm implemented in the TPS [27].

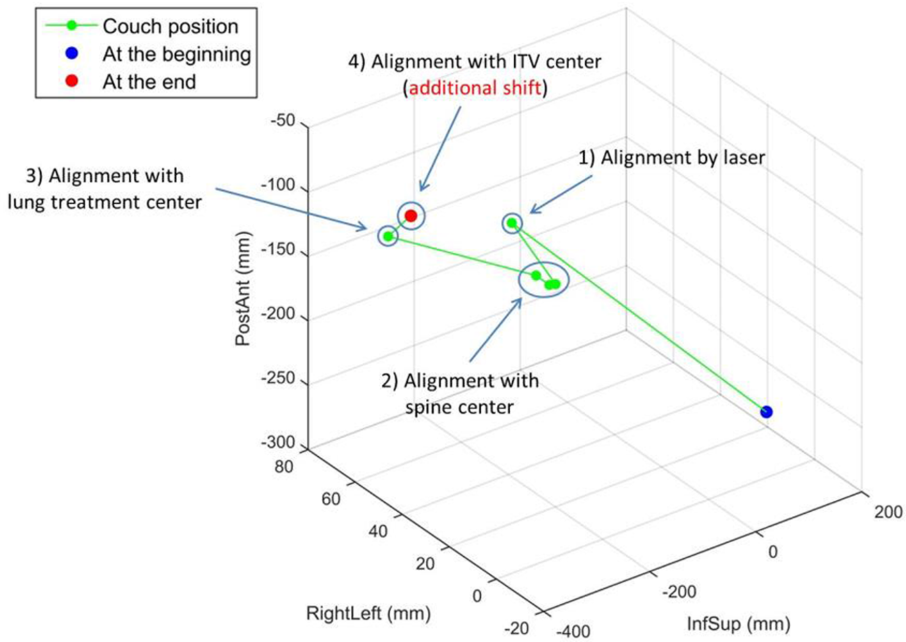

Fig. 5. Absolute positions of the treatment couch during the patient alignment in a typical 2-view treatment.

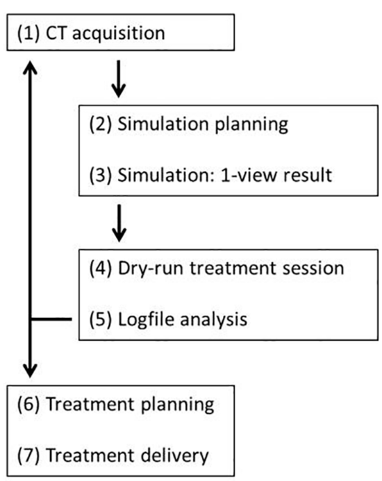

Fig. 6. Lung treatment workflow adapted to take advantage of 1-view data in order to define customized margin in out-of-plane direction for selected patient subgroups.

5. Conclusion

We defined the population-based internal margins specifically for CyberKnife treatments with 1-view tracking highlighting the different components of localization uncertainty. ITVs obtained from biphasic breath-hold CT acquisitions resulted most of the time smaller than the extent of target movement. The graphic method of comparison preserving metric between actual and planned positions was a useful tool, suitable to provide assistance also in the clinical practice. The download of the current treatment data, the logfile preparation and the software analysis needed indeed less than ten minutes in total.

Fig. 6 outlines a revisited workflow in relation to the possibility of a 1-view logfile analysis integrated in the clinical routine. If the simulation session establishes the result “1-view”, a treatment session without therapeutic beams but with only radiography acquisitions (called *dry-run treatment session* by Pepin *et al.* [14]) could be performed in order to generate logfiles and hence to get patient-related information for customized margin definition from the only one view. However, it must be taken into account that the known target motion along *in-plane* direction is not directly correlated to *out-of-plane* movement. As future development of our work, predictive parameters should be studied in depth and combined with the information from 1-view data in order to increase our confidence level about this class of treatments.

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