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Scientific Article

Clinical Factors That Affect Fiducial Tracking in Robotic SABR for Lung Tumors

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Purpose: SABR is a treatment option for patients with lung tumors that employs fiducials to track tumors during the breathing cycle. Currently, there is a paucity of data on how relative fiducial location and patient clinical characteristics affect fiducial tracking and clinical outcomes. This study aimed to identify factors that reduce the number of fiducials tracked with respiratory motion management during SABR.

Methods and Materials: An institutional review board−approved retrospective review was performed of patients receiving robotic SABR for lung tumors at our institution from 2016 to 2019. Clinical data including demographics, medical history, treatment data, and follow-up were collected. Fiducial geometries were obtained with Velocity contouring software and MATLAB. Mann-Whitney U, χ^2, and t tests were completed using MedCalc.

Results: A total of 73 patients with 77 treatments were identified. The χ^2 analysis revealed that chronic obstructive pulmonary disease was associated with having 3 or more fiducials tracked (P = .034). Tumors in lower lobes were associated with higher rates of uncertainty errors (P = .015). The number of fiducials tracked had no effect on local tumor control or overall survival, with a median of 36 months of follow-up. A total of 28 treatments had fiducial centroid data available for geometric analysis. The most common tracking errors were rigid body error (RBE; 57%) and spacing errors (36.4%). Spacing errors had a shorter average minimum interfiducial distance than nonspacing errors (1.0 cm vs 1.7 cm, respectively; P = .017). RBE treatments had a longer average maximum distance than non-RBE treatments (4.0 cm vs 3.0 cm; P = .022).

Conclusions: Greater motion in lower lobes can contribute to certain tracking errors that prevent more fiducials from being tracked. Maintaining interfiducial distance between experimentally determined guidelines may limit spacing errors and RBEs, the 2 most common tracking errors. An increased number of patients in a data set may result in stronger correlations between patient and tumor factors and outcomes.

Introduction

Lung cancer continues to be the leading cause of cancer-related deaths in the United States.[1] It is typically treated with lobectomy or wedge resection, but many

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patients present at a later stage, making surgery less favorable. In addition, many patients are not surgical candidates, owing to comorbidities like chronic obstructive pulmonary disease (COPD) or cardiovascular disease, which can exclude up to an estimated 25% of patients from surgical treatment.[2] SABR is a noninvasive treatment option that allows physicians to deliver high-dose radiation to precisely target tumor lesions. SABR has been found to have much higher rates of primary lung tumor control (97.6% at 3 years) in inoperable early-stage non-small cell lung cancer (NSCLC) patients compared with conventional radiation therapy.[3] The general approach of surgical resection for operable patients has been called into question by multiple studies using propensity-score matching methods to compare patients treated for early-stage NSCLC with either lobectomy or SABR. These studies revealed that both treatment options may produce similar clinical results.[4] In addition, SABR has been found to improve survival in oligometastatic NSCLC.[5]

One of the challenges with SABR is accurate tracking of tumor motion during treatment courses due to the elliptical motion of points within the lungs during the respiratory cycle.[6] In addition, we believe that patients with lung disease such as significant COPD or a history of lung cancer or procedure would have decreased tracking accuracy due to irregular breathing patterns or irregular motion of fiducials caused by lung injury. A few approaches to address this include minimizing target motion with immobilization devices, gating radiation beam delivery with the breathing cycles, treating the full extent of tumor motion, or using a dynamic system to follow the target lesion during the breathing cycle.[7] This study focuses on the use of CyberKnife from Accuray (Sunnyvale, California), a fully automatic robotic system that uses active tracking of fiducials placed in or near the lesion for accurate targeting during the breathing cycle.[8] The accuracy of this approach is highly dependent on tracking fidelity, which is affected by multiple variables, like fiducial geometries, number of fiducials, and clinical characteristics.

Fiducials can be placed via electromagnetic navigational bronchoscopy (ENB), which also allows for biopsy and fiducial placement by correlating the positioning of the tip of the bronchoscope to the 3-dimensional (3D) model of the patient's bronchial tree derived from a computerized tomography (CT) scan to improve the accuracy of biopsy sampling and fiducial placement. ENB has been shown to have similar fiducial retention rates compared with conventional percutaneous CT-guided placement, while demonstrating lower rates of procedural complications.[9] However, even with mapping based on planning scans, each patient has unique anatomic variation, which can limit optimal placement of fiducials and result in only 1 or 2 fiducials being tracked. In addition, the robotic system does not always detect every fiducial, owing to various errors in tracking.

The types of tracking errors encountered include rigid body, spacing, shadowing, collinearity, and uncertainty errors. Rigid body errors (RBEs) occur because of the dynamic nature of the lung parenchyma during the breathing cycle; an increased interfiducial distance would likely increase the variation of the fiducial geometry during inhalation/exhalation and contribute to error. On the other hand, spacing errors occur because of low interfiducial distance. High collinearity errors occur when fiducials are placed in a linear fashion relative to the detector, and uncertainty errors stem from poor fiducial identification/tracking by the fluoroscopic system. In addition, 3 or more fiducials allow for tracking of tumor rotation during breathing cycles. Currently, there are no specific evidence-based guidelines on optimal geometries for fiducial placement. However, despite the implementation of these criteria, many treatment courses continue to rely on less than 3 tracked fiducials, owing to any tracking errors. It can also be quite difficult for fiducials to be placed in an ideal geometry via bronchoscopy given the complexity of navigation around the lesion, and placing multiple fiducials via a transthoracic approach increases the risk of pneumothorax.[10] The goals of this study were to identify the most common sources of tracking errors encountered by the software, as well as clinical factors and fiducial placement locations that may be contributing to these tracking errors, and to determine which placement criteria can lead to optimal tracking.

Methods and Materials

Study population

Institutional approval was obtained under University and Medical Center Institutional Review Board number 15-001726. A retrospective review of patients who received SABR treatment with robotic SABR at Vidant Radiation Oncology from 2016 to 2019 was performed. The inclusion criteria for this study were treatment for primary lung cancer or metastatic lung cancers with CyberKnife SABR at Vidant Radiation Oncology, availability of fiducial tracking errors recorded by the therapists at the console on initial setup, and availability of planning 4-dimensional computerized tomography (4DCT) for calculation of tumor and fiducial geometry. In total, 79 patients with 83 treatment courses met inclusion criteria; 3 treatment courses without data on how many fiducials were placed and 3 treatment courses without data on how many fiducials were tracked were excluded, leaving 73 patients and 77 treatment courses. Before and after the exclusion criteria were applied, there were 13 metastatic lesions, meaning that the 6 excluded patients all had primary lesions. There were 2 patients with 2 treatment courses each and 1 patient with 3 treatment courses. One patient had 2 lesions on both sides of the lungs treated at the same time and then 1 lesion a year later. The other 2 patients had 2 lesions treated 1 year apart.

Treatment

Patients treated at our institution were placed in a supine position with arms at their sides, and precise positioning was obtained using the automated patient positioning system. A vest containing light-emitting markers was used to obtain an adjustable camera array. Orthogonal x-rays were then used to determine fiducial location. The camera array obtained from the vest and the fiducial locations obtained from the x-ray were used to develop an adaptive correlation model before treatment. At our institution, a 5-mm expansion around the gross tumor volume (GTV) on the exhalation as per manufacturer protocol is used for the planning target volume (PTV). While expansion of the PTV to more than 5 mm can mitigate errors from correlation, prediction, and targeting, this margin is sufficient to achieve a 95% dose coverage for SABR of the lung.[11] However, this may range between 3 mm and 7 mm to either avoid critical structures or for tumors with particularly large motion. This model, in conjunction with the camera array, was used during the treatment course by the system to adjust radiation delivery in real time through movements made by the linear accelerator.[12] Patients typically received 3 to 5 fractions with a total radiation delivery of 50 to 60 Gy.

Accuray recommends placing 3 to 6 fiducials for intrathoracic lesions between 2 and 6 cm apart with a minimum 15° angle between any 3 fiducials to avoid collinearity.[13] Pulmonologists at our institution guided by ENB follow this protocol by placing 1 fiducial within the tumor and an 3 additional fiducials within a 5 cm diameter around the central one. An additional fiducial may be placed if a fiducial is likely to migrate or if the tumor is in a difficult anatomic area for tracking. Additional fiducials are not placed if a risk of fiducial shadowing is expected on orthogonal views of the tracking system. In some cases, patients may have tumors in areas that are not readily reachable for fiducial placement with ENB, in which case fewer fiducials may be placed.

Our institution has been involved in improving fiducial placement, with the goal of improving accuracy and treatment outcomes.[14] As part of a quality improvement project in our department, we had asked for the principal tracking error which prevented at least 3 fiducials from being tracked by the radiation delivery system at the time of the initial treatment to be recorded by the radiation therapist during the study period. As long as at least 1 fiducial was tracked (the treating team believed this would allow for accurate respiratory tracking), treatment was allowed to proceed. During the treatment course, some parameters could be manipulated to alleviate errors, but large changes outside of the initial manufacturer guidelines were discouraged. Recording of tracking errors encountered was performed during the first fraction. Parameters from the first fraction are then used for rest of the treatment fractions. The majority of subsequent fractions had the same number of fiducials tracked as the first fraction from the initial day of setup.

Clinical data

Patient demographics were obtained, including patient age at treatment, race, and sex. Clinical characteristics analyzed included tumor location, smoking history, history of COPD, history of lung procedure, and history of lung cancer. Fiducial characteristics obtained included number of fiducials placed, number of fiducials tracked, and specific fiducial tracking errors. We also looked at outcomes of local recurrence and overall survival.

Clinical parameters

The tracking of 3 or more fiducials was chosen as a threshold for our calculations, as it allows for tumor tracking in the x, y, and z directions, as well as any rotation about those axes. The system cannot track rotation if less than 3 fiducials are tracked. Tracking rotations would be ideal for tumors that are irregularly shaped or when the fiducials are not in the exact center of the tumor. Normal percentages for pulmonary function tests were defined as greater than 80% for forced vital capacity, 80% for forced expiratory volume over 1 second, 80% for total lung capacity, and 60% for diffusing capacity for carbon monoxide.[15] Owing to incomplete pulmonary function test data, individual parameters were compared with fiducials tracked via χ^2 analysis. For tumor location, the right middle lobe was grouped with the right upper lobe for anatomic consistency. Local control was defined as no recurrence of tumors in the treated areas for the duration of the study. Three fiducials tracked was used as a cutoff, as this allows for tracking of translations along all 3 axes and rotations about all 3 axes.

Clinical statistics

To compare the various clinical characteristics and determine whether 3 or more fiducials were tracked, all 77 treated tumors were counted for statistical calculations. The χ^2 comparisons of patient demographics and clinical characteristics to fiducials tracked were performed using MedCalc version 19 (Ostend, Belgium). A P value of less than .05 was used to determine significance. Overall survival and local tumor control post treatment course were determined using Kaplan-Meier survival curves, comparing less than 3 versus 3 or more fiducials tracked. Multiple logistic regression including all factors was used to compare demographic data and clinical characteristics to successful tracking of 3 or more fiducials using Statistical Product and Service Solutions version 27 (Armonk, New York). Multiple logistic regression was also used to compare the number of fiducials placed with the number tracked.

Geometric data

Four-dimensional CT threshold contouring of the tumor and fiducials was available for 28 out of 77 treatments. Treatments with only 1 fiducial tracked were not included in the contouring procedure, as interfiducial distance would not be obtainable. Analysis was performed on data for either 10 phases of normal breathing or 3 phases (minimum, average, max) for the patients for whom multiple reconstructions on 4DCT were available.

Geometric parameters

Hounsfield unit thresholds of 1100 and −250 were used for identifying and contouring fiducials and lung tumors, respectively. Contouring was performed using Velocity from Varian (Palo Alto, California) software, and contours were exported into MATLAB R2019a (Natick, Massachusetts) as solid 3D objects. A program was written to extract center of mass data from fiducials, as well as quantification of interfiducial distance. Interfiducial distance was then compared with frequencies of error types. Mean, minimum, and maximum interfiducial distances were also compared among error-positive and error-negative treatments.

Geometric statistics

The data were analyzed for significance using the Mann-Whitney *U* test. χ^2 analysis was performed to identify error frequencies among treatments with 3 or more fiducials and less than 3 fiducials tracked, as well as to compare fiducial tracking and COPD frequency between patients with centroid data and those without. Additionally, *t* test analysis was used to identify the average fiducials placed and tracked between these groups.

Results

Clinical characteristics

Seventy-three patients with 77 treatments were identified in this study, with a median age of 60 (range, 37-90 years). Their demographic data are summarized in Table 1, along with *P* values from logistic regression comparing each demographic characteristic with whether 3 or more fiducials were tracked. All patients had 3 to 6

Table 1 Demographic data for study population with *P* values from logistic regression comparing these characteristics between <3 fiducials and ≥3 fiducials tracked

Demographics, n = 73			Value
Age, median (range)			69 (37-90)
Sex, no. (%)			
Male			33 (45.2%)
Female			40 (54.8%)
Race, no. (%)			
White			47 (64.4%)
Black			26 (35.6%)
Treatment characteristics, n = 77	**<3 Fiducials tracked (n = 55)**	**≥3 Fiducials tracked (n = 22)**	***P* value**
Age at treatment, median (range)	69 (55-90)	68 (37-89)	.238
Sex			.678
Male	23 (41.8%)	11 (50%)	
Female	32 (58.2%)	11 (50%)	
Race			1.00
White	34 (61.8%)	16 (72.7%)	
Black	21 (38.2%)	6 (27.3%)	

fiducials placed, with a median of 4. The logistic regression model for tracking 3 or more fiducials was not statistically significant (P = .309) compared with the null model, explaining 44.1% of the variation and predicting 60 (77.9%) cases. When controlling for age, sex, race, smoking history, tumor location, previous lung procedures, and prior lung cancer, patients with a history of COPD were 6.5 times more likely to have 3 or more fiducials tracked (P = .010) (Table 2). All other factors in multivariate analysis had no significant impact on the number of fiducials tracked. A subanalysis confirmed that COPD did not affect whether 3 or more fiducials were placed, isolating the significant finding to tracking (P = 1). Uncertainty errors occurred more often in the lower lobes (P = .015) (Table 3). Kaplan-Meier curves for overall survival and local tumor control over a median follow up of 2.5 years showed no significant difference between patients with less than 3 fiducials tracked and 3 or more fiducials tracked (P = .20 and P = .79, respectively) (Fig. 1).

Table 2 Clinical characteristics for study population with *P* values from logistic regression comparing these characteristics between <3 fiducials and ≥3 fiducials tracked

	<3 Fiducials tracked (n = 55)	≥3 Fiducials tracked (n = 22)	*P* value
Current or former smoker			.115
Yes	5 (9.1%)	4 (18.2%)	
No	50 (90.9%)	18 (81.8%)	
Tumor location			.905
RLL	9 (16.4%)	5 (22.7%)	
RML	4 (7.2%)	0 (0%)	
RUL	18 (32.7%)	9 (40.9%)	
LUL	14 (25.5%)	8 (36.4%)	
LLL	10 (18.2%)	0 (0%)	
Pulmonary function*			
FVC ≤ 80%	28 (70%)	6 (46.2%)	.193
FVC > 80%	12 (30%)	7 (53.8%)	
FEV_1 ≤ 80%	28 (71.8%)	9 (69.2%)	.648
FEV_1 > 80%	9 (23.1%)	4 (30.8%)	
TLC ≤ 80%	20 (55.6%)	5 (41.7%)	.404
TLC > 80%	16 (44.4%)	7 (53.8%)	
DLCO ≤ 60%	26 (68.4%)	8 (61.5%)	.649
DLCO > 60%	12 (31.6%)	5 (38.5%)	
History of COPD			.010
Yes	18 (32.7%)	13 (59.1%)	
No	37 (67.3%)	9 (40.9%)	
Major lung procedure			.158
Yes	15 (27.3%)	3 (13.6%)	
No	40 (72.7%)	19 (86.4%)	
Prior lung cancer			.609
Yes	19 (34.5%)	4 (18.2%)	
No	40 (72.7%)	19 (86.4%)	
Tumor origin			
Primary	47 (85.5%)	17 (77.3%)	
Metastatic	8 (14.5%)	5 (22.7%)	

Abbreviations: COPD = chronic obstructive pulmonary disease; DLCO = diffusing capacity for carbon monoxide; FEV_1 = forced expiratory volume over 1 second; FVC = forced vital capacity; LLL = left lower lobe; LUL = left upper lobe; RLL = right lower lobe; RML = right middle lobe; RUL = right upper lobe; TLC = total lung capacity.

* Only 51 patients had records of pulmonary function tests; some patients had missing values.

Table 3 Specific errors encountered compared between upper and lower lobes and *P* values from logistic regression

	Upper lobe, n = 52	Lower lobe, n = 25	*P* value
Error encountered			
Rigid body, n = 46	30 (57.7%)	16 (64%)	.600
	22 (42.3%)	9 (36%)	
Spacing, n = 29	17 (32.7%)	12 (48%)	.197
	35 (67.3%)	13 (52%)	
Uncertainty, n = 13	5 (9.6%)	8 (32%)	.015
	47 (91.4%)	17 (68%)	
Collinearity, n = 1	1 (1.9%)	0 (0%)	.485
	51 (98.1%)	25 (100%)	
Shadowing, n = 5	4 (7.7%)	1 (4%)	.538
	48 (92.3%)	24 (96%)	
Fiducials placed	**<3 Fiducials tracked (n = 55)**	**≥3 Fiducials tracked (n = 22)**	.309
3, n = 21	17 (30.9%)	4 (18.2%)	
4, n = 52	36 (65.5%)	16 (72.7%)	
5, n = 3	2 (3.6%)	1 (4.5%)	
8, n = 1	0 (0%)	1 (4.5%)	
Fiducials placed	**<3 Fiducials tracked (n = 55)**	**≥3 Fiducials tracked (n = 22)**	<.001
Error present	51 (92.7%)	11 (50%)	
Error absent	4 (7.3%)	11 (50%)	

Some treatments did not encounter any errors, while others had up to 4 errors. Logistic regression compared fiducials placed with those tracked, along with the χ^2 test of whether an error was encountered versus whether 3 or more fiducials were tracked.

Geometric parameters

Overall, RBEs were the most common type of error preventing fiducial tracking, found in 44 (57.1%) treatments, followed by spacing errors (28/77, 36.4%), uncertainty errors (12/77, 15.7%), fiducial shadowing errors (5/77, 6.5%), and high collinearity (1/77, 1.3%). These errors were found to be overrepresented in treatments with less than 3 fiducials tracked (70/77, 90.9%) compared with those with 3 or more fiducials tracked (53/77, 68.8%) (P = .01). In comparing treatments with and without centroid data available, the average number of fiducials placed and tracked and the frequency at which 3 or more fiducials were tracked did not differ significantly (P = .64, 0.47, and 0.15, respectively).

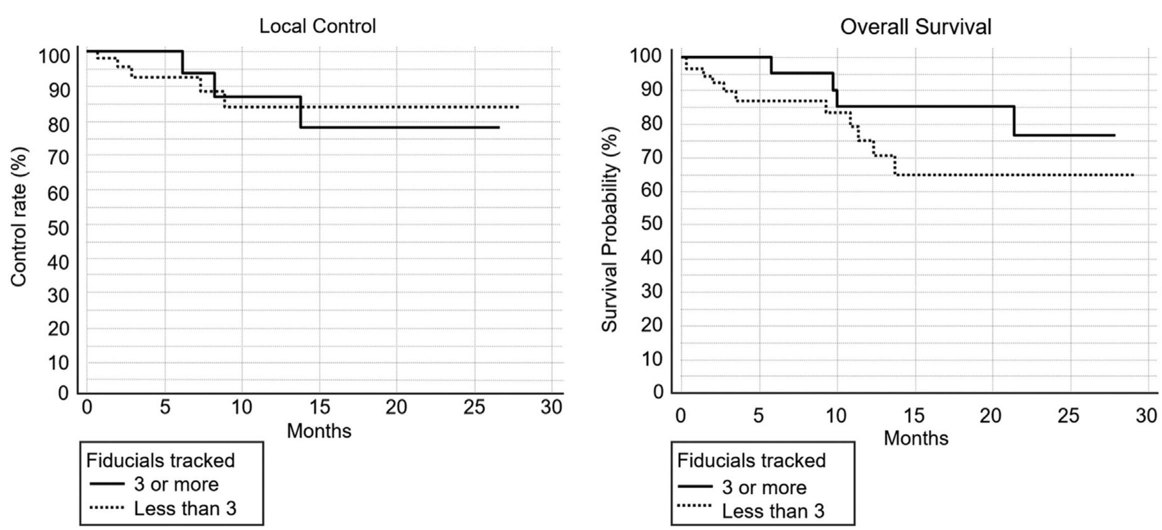

Figure 1 Kaplan-Meier curves for local control and overall survival.

Twenty-eight patients had fiducial centroid data available for geometry and error analysis; these data were not available for the remainder of the patients owing to periodic clearing of server caches at our institution. All of these patients had 1 treatment course each. Treatment courses in the centroid data group did have an increased frequency of COPD (16/27, 59%) compared with treatment courses without centroid data (17/50, 34%) (P = .03), which may be due to the low number of patients (27/28) with centroid data who also had COPD information available. Further analysis was performed on the 2 most common errors. The mean, minimum, and maximum interfiducial distances for spacing error-positive treatments were 1.0 cm, 0.1 cm, and 1.5 cm, respectively, while nonspacing error treatments had values of 1.7 cm, 0.6 cm, and 2.8 cm, respectively (P = .017 between means) (Fig. 2). For RBE-positive treatments, these values were 4.0 cm, 1.8 cm, and 7.0 cm, respectively, while non-RBE treatments had values of 3.0 cm, 1.0 cm, and 6.0 cm, respectively (P = .022 between means) (Fig. 3).

Discussion

Although SABR is an effective treatment option for patients with NSCLC, various fiducial tracking errors are encountered during treatment courses. This study analyzed how various demographic, clinical, and geometric factors affect tracking of fiducials in patients receiving SABR for NSCLC. Certain diseases like COPD were associated with a decreased rate of uncertainty errors, while following current manufacturer protocols did not improve overall outcomes or tumor remission. In addition, the data suggest that more specific guidelines on fiducial placement may be beneficial in improving tracking of fiducials.

Clinical characteristics

Surprisingly, our data showed that more fiducials could be tracked in patients with COPD than in patients without COPD. This could be due to worse lung compliance and elasticity caused by the disease process, which decreases movement of lung tissue during the breathing cycles. Although tumor location did not have a significant effect on whether 3 or more fiducials were tracked, uncertainty errors were associated with the lower lobes. This is likely due to normal physiology of the diaphragm and heart causing increased movement in these lobes from cardiac motion superimposed on lung motion. The lower lobes can also be associated with more difficult ENB-guided placement. Owing to the anatomy of the lungs, certain tumors in the lower lobes may be located anatomically superior to portions of the upper lobes, which may influence some outcomes when performing analysis by lobe. This surprising correlation between COPD and more fiducials tracked should be further investigated in prospective studies.

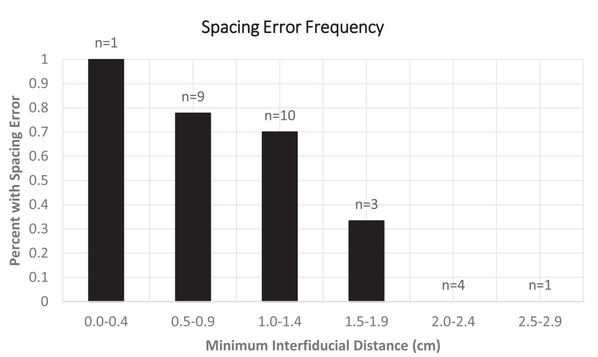

Figure 2 Relationship between minimum interfiducial distance and spacing error frequencies.

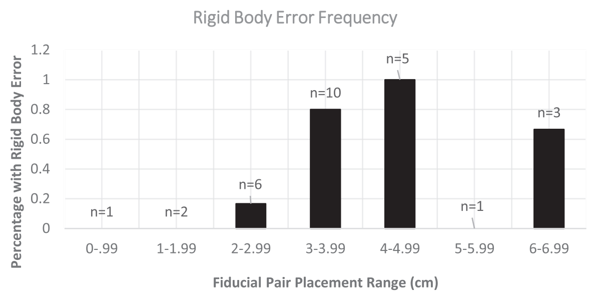

Figure 3 Relationship between maximum interfiducial distance and rigid body error frequencies.

Analysis of fiducials placed was limited, as most patients had 3 or 4 placed, but placement of 4 fiducials did not increase the likelihood of tracking 3 or more fiducials. This suggests that the number of fiducials tracked is influenced by other factors. Alternatively, 4 fiducials may not be enough to significantly increase the chances of tracking 4 fiducials, and future studies should analyze higher numbers of fiducials placed. Although we did not find any statistical significance with overall survival and local tumor control, our data set only had a median follow-up period of 2.5 years. Longer-term follow-up is needed to see if there is a difference between local recurrence and overall survival in our cohort.

Geometric parameters

Although placement and accurate tracking of all implanted placed fiducials appears to be optimal for SABR treatment of lung cancer, there are a few factors that can impact fiducial tracking. The 5 errors studied were overrepresented among treatment courses with less than 3 fiducials tracked, suggesting that they may influence which treatment courses have more than 3 fiducials tracked. Some treatment courses did have untracked fiducials without reporting an error, suggesting that other factors may also influence fiducial tracking. RBEs and spacing errors were the 2 most common sources of error identified by the software; these errors stem from interfiducial distance. Although minimizing errors will increase the likelihood of obtaining rotation tracking with at least 3 noncollinear fiducials with at least 15° of separation, RBEs in particular have been found to contribute to intrafraction underdosing of tumors.[16]

Figure 2 demonstrates that higher frequencies of spacing errors were present among treatment courses with lower minimum interfiducial distances. Spacing error probabilities drop to 0% with greater than 2.0 cm separation between fiducials. No spacing errors were identified in treatment courses where the minimum interfiducial distance was greater than 2.0 cm (n = 5). Given the low n value for treatment courses, further data may be required to support this relationship. Our data also showed a statistically significant increase in the mean maximum interfiducial distance in RBE-present versus RBE-absent treatment courses. Figure 3 shows that the incidence of RBE appears to increase with maximum interfiducial distance, particularly when greater than 2.9 cm. The deviation in this trend at distances greater than 4.9 cm is likely due to low n values at the larger distances.

Based on the trends identified in Figs. 2 and 3, fiducial placement between 2.0 and 3.0 cm apart may limit the 2 most common sources of error encountered by the software in fiducial tracking. In comparison, current manufacturer guidelines are much broader, (between 2.0 and 6.0 cm). Based on our results, we believe that there is scope for further study with more patients and longer follow-up times to optimize fiducial placement criteria.

Limitations

This study was limited primarily by its sample size. Although clinical characteristics were analyzed for all 77 treatment courses, centroid data were only available for 28 patients, and additional bias may have been introduced by this limited population. However, we found no significant difference in the number of fiducials placed and tracked or in the proportion with 3 or more fiducials tracked between the 2 groups. This subgroup of patients also had a higher rate of COPD than patients lacking available centroid data, which we believe is likely an artifact of a smaller sample size. In addition, our study was retrospective in nature and only correlations or hypotheses can be drawn from our results. A confounding variable for which we could not account was different pulmonologists placing fiducials, which can influence the numbers of fiducials placed and how they were placed around the lesion. Our study on fiducial geometries was also limited by available contouring data on only 28 treatment courses out of 77, which limited our ability to perform a meaningful multivariate analysis on the geometric analysis. In addition, the lack of availability of all phases of the breathing cycle for each treatment course meant that individual phases were used for analysis, as mentioned in the Methods and Materials section, which may introduce additional bias. The other forms of error, such as high collinearity, uncertainty, and shadowing errors, can be further investigated by studying which 3D fiducial geometries lead to a higher proportion of fiducials tracked.

Conclusion

Our retrospective study showed that fiducial tracking during SABR treatment of patients with lung tumors is affected by various clinical and technical factors. Greater motion in lower lobes can contribute to certain errors that prevent more fiducials from being tracked. Three or more fiducials tracked did not significantly impact local control or overall survival over a median 36-month follow-up. Placement within currently accepted guidelines (ie, more than 3 cm apart) may be contributing to the most common error: RBEs. Increased follow-up time may determine a relationship among improved fiducial tracking, number of fiducials tracked, and clinical outcomes. Further investigations may provide stronger data for protocols guiding fiducial placement to limit fiducial tracking errors and improve treatment outcomes.

Disclosures

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