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Evaluvating the Delivery Accuracy of Cyberknife Xsight Lung Tracking System Using Xlt Phantom

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ABSTRACT
Lung cancer is one of the most common cancers in the world. A cancerous tumour is a group of cancer cells that can grow into and destroy nearby tissue. The lungs are the part of respiratory system. Treating lung cancer has been challenge as the target move due to the continuous respiration movement. The Cyberknife Robotic Radiosurgery System (Accuray Incorporated, Sunnyvale, CA) can treat targets that move with respiration using the Synchrony® Respiratory Tracking System (Accuray Incorporated, Sunnyvale, CA). Alignment each treatment beam with the moving target is maintained in real time by moving the beam dynamically with target. The Synchrony system requires fiducial those are placed in or near the tumour to target the lesion and track it as it moves with respiration. The Xsight Lung Tracking System (XLTS) (Accuray Incorporated, Sunnyvale, CA) is a direct soft tissue tracking method for respiratory motion tracking of lung lesions that eliminate invasive fiducial implantation procedures, so that decreasing the treatment time and eliminating the risk of pneumothorax and other fiducial placement complications. The aim of the study is to evaluate the accuracy of the Xsight Lung Tracking System of Cyberknife using CIRA® XLT Phantom. XLT phantom is an anthropomorphic motion phantom which simulates respiratory motion of a human torso and provided radio chromic film-based test capability at locations inside the phantoms that correspond to typical lung tumour and critical structure locations in a patient. The results are well within the limit and the total target error is 0.92 mm and 1.32 mm for Fixed and Iris Collimator paths respectively.

Keywords: Xsight Lung Phantom, Fixed, Iris, Collimator & Lung Cancer

1. INTRODUCTION

1.1 OVER VIEW OF CYBERKNIFE

The CyberKnife VSI™ System represents a major advancement in non-invasive radiosurgery, combining precision, flexibility, and innovation to treat tumors anywhere in the body. Unlike traditional surgery, CyberKnife involves no cutting; it delivers high-dose external beam radiation with robotic precision.

Approved by the FDA in 2001, it initially gained slow traction and was mainly used for inoperable brain or spinal tumors. The system is a frameless, miniature robotic linear accelerator mounted on a robotic arm, capable of delivering radiation from thousands of angles. One of its key strengths is real-time image-guided radiotherapy (IGRT), where live tumor images are continuously matched with planning CT scans to ensure accuracy. Developed by Dr. John Adler at Stanford University, the CyberKnife aimed to overcome the limitations of rigid stereotactic frames, particularly for pediatric and extracranial tumors. Inspired by the Gamma Knife but seeking greater comfort and flexibility, Adler collaborated with experts across disciplines to create a system that allowed fractionated treatments without invasive frames. The system's development introduced the medical field to real-time image-guidance in radiation therapy, with stereoscopic x-ray imaging replacing early c-arm fluoroscopy. By 1999, CyberKnife received FDA clearance for treating head and neck lesions, and shortly thereafter expanded to spinal and extracranial tumors using fiducial tracking. CyberKnife continues to offer precise, patient-centered cancer care globally.

	Stereotactic Radiosurgery	**Conventional Radiation Therapy**
Method of treatment	Precisely target high dose radiation beam are delivered to a tumor from virtually unlimited angles using an advanced tracking technology	Low dose radiation beam is delivered to a tumor from various angles. Common type is Intensity Modulated Radiation Therapy (IMRT), External Beam Radiation Therapy (EBRT) And Image Guided Radiation Therapy (IGRT)
Duration of sessions	Session last 15-20 minutes	Session usually last 15-30 minutes
Length of treatment	Five or fewer outpatient session	Daily outpatient session for 6-7 weeks
Side effects	Patient experience few to know side effects, which may include fatigue	Side effects may include fatigue, nausea, hair loss and pigmentation of skin changes

Table: 1.1Comparisonsof SRS and Conventional Radiation Therapy.

1.2 CYBERKNIFE® BEAM DELIVERY & IMAGING

The CyberKnife system delivers radiation using a robotic head mounted on a 6 MV X-band linear accelerator. It features two types of collimators: Fixed and Iris. The Fixed collimators include 12 interchangeable circular collimators at a source-to-axis distance (SAD) of 80 cm, offering beam diameters from 5 to 60 mm. The Iris collimator automatically adjusts the aperture size and operates at a variable SAD between 65 to 100 cm. It consists of two stacked banks of six tungsten segments, forming a 12-sided variable aperture that produces beam profiles nearly identical to those from fixed collimators. This dual-bank design eliminates inter-segment leakage and allows the use of up to 12 aperture sizes within a single treatment path. As a Flattening Filter Free (FFF) machine, CyberKnife enables faster treatments by combining large beams for primary dose delivery and small beams for sculpting, thereby reducing monitor units (MU) and total treatment time. Imaging is a key feature, allowing frameless and real-time tracking. Two orthogonal kV x-ray sources, called Camera A and Camera B, are mounted on the ceiling and aligned with amorphous silicon detectors on the floor. These create an imaging center 92 cm from the floor. kV images are captured before and during treatment to continuously monitor and correct for patient movement, ensuring precise beam targeting throughout the session.

1.3 TRACKING SYSTEM IN CYBERKNIFE®

This plays a vital role in accurately locating and following the tumor throughout the treatment process. Its main purpose is to continuously determine the target's position—its bearing, range, and elevation and provide real-time updates to the control system for precise beam delivery. A good tracking system not only maintains constant contact with the target but also predicts its future position to ensure accurate dose delivery even during patient or tumor movement. CyberKnife incorporates multiple advanced tracking methods tailored to different anatomical regions. The 6D Skull Tracking system is a non-invasive, fiducial-free method specifically designed for intracranial targets, using the bony anatomy of the skull for reference. The Xsight Spine Tracking method is also non-invasive and uses the spine's bony landmarks, from the cervical to sacral region, to accurately track spinal lesions. Fiducial Tracking involves the implantation of small markers near or within the tumor, which can be tracked anywhere in the body. It is especially useful in soft tissues and can work with or without Synchrony. The Xsight Lung Tracking system enables real-time, direct visualization of lung tumors without fiducial markers, provided the tumor is clearly visible in both imaging planes. It relies on a well-defined Tumor Tracking Volume during planning to ensure accurate localization. These advanced tracking systems ensure high precision, reduce errors caused by motion, and support frameless, patient-friendly radiosurgery across various tumor sites.

1.4 LUNG CANCER

Lung cancer, also referred to as lung carcinoma, is a malignant tumor that arises from uncontrolled cell growth in the tissues of the lung. It has the potential to spread (metastasize) to nearby tissues or distant organs. The two primary classifications of lung cancer are small-cell lung carcinoma (SCLC) and non-small-cell lung carcinoma (NSCLC). Among these, NSCLC accounts for the majority of cases. Lung cancer typically manifests with symptoms such as persistent coughing (sometimes with blood), unintended weight loss, chest pain, and difficulty breathing. The condition generally has an onset around the age of 70. Tobacco smoking is the leading risk factor, responsible for approximately 85% of all cases, though 10–15% occur in non-smokers due to genetic predisposition or environmental exposures such as radon gas, asbestos, air pollution, or second-hand smoke. Diagnosing lung cancer involves imaging techniques like chest X-rays and CT scans, followed by a confirmatory biopsy using bronchoscopy or CT-guided methods. Early diagnosis plays a crucial role in improving outcomes. Preventive strategies include avoiding tobacco smoke and reducing exposure to environmental pollutants. Treatment varies based on the type and stage of cancer. SCLC typically responds well to chemotherapy and radiotherapy, while NSCLC may be surgically removed if detected early. In many cases, a combination of surgery, chemotherapy, and radiation therapy is used. The prognosis depends on multiple factors, including the stage at diagnosis and overall health of the patient. The five-year survival rate remains low due to late detection in most patients. Globally, lung cancer leads to approximately 1.7 million deaths annually. Ongoing research aims to improve early detection methods and develop targeted therapies. Advances in immunotherapy and personalized medicine have shown promise in improving survival rates. Despite medical progress, lung cancer remains one of the deadliest forms of cancer, underscoring the importance of awareness, prevention, and early screening.

1.5 STEREOTACTIC BODY RADIATION THERAPY

Stereotactic Body Radiation Therapy (SBRT) refers to a Stereotactic radiotherapy procedure for treating extra cranial tumor with ultrahigh dose per fraction, in a hypo-fractionated regimen of five or fewer fractions, SBRT has been mostly applied to the tumors in the spine, lung, liver, pancreas, kidney and prostate. Cyberknife is the best for Stereotactic Body Radiation Therapy (SBRT) treatment. In Cyberknife it depends on the two types of tracking system they are fiducial based tracking and Xsight lung tracking.

A. FIDUCIAL TRACKING

Fiducials are markers used to define a tumor's position during radiotherapy, ensuring accurate targeting throughout treatment. Gold seeds are commonly used as fiducials due to their radiopacity and biocompatibility. For effective tracking, fiducials must be placed rigidly, as any migration can significantly compromise the accuracy of the targeting system. A minimum of one fiducial is required to track translational movements, but migration cannot be detected with only one. With two fiducials, the system can detect that migration has occurred but cannot identify which marker has moved. To track rotational movements accurately, at least three fiducials are necessary. When implanting 4–6 fiducials, it's essential to maintain a minimum spacing of 20 mm between them while ensuring they are no more than 50–60 mm from the lesion. Additionally, the angle between fiducials should exceed 15° to enhance tracking reliability. All fiducials must be clearly visible in 45° oblique imaging views without overlapping, which is crucial for precise localization and tracking during treatment.

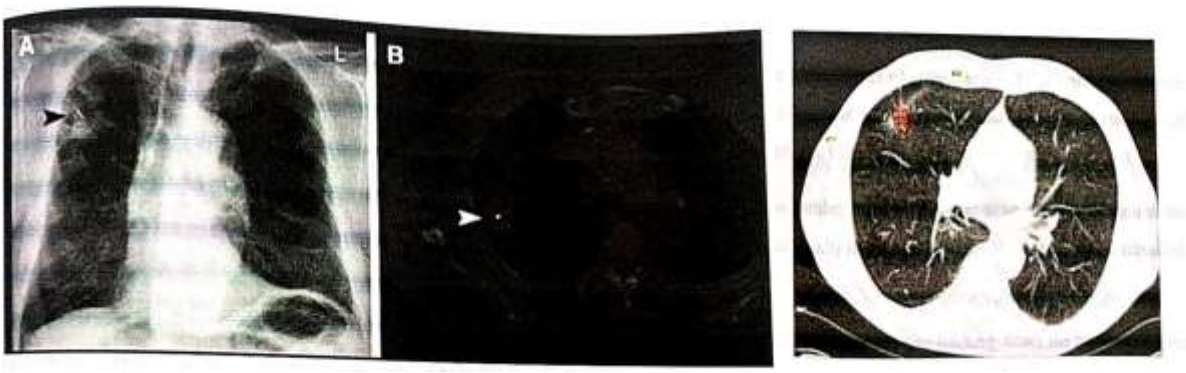

Figure:1.1 Placement of Fiducials and the fiducials, despite being 6 are not well placed, since only two fiducials (the closer to the lesion) are usable for tracking. Here it will be impossible to track rotations (just 2 fiducials available).

B. XSIGHT LUNG TRACKING SYSTEM

SYNCHRONY MODEL

The CyberKnife Robotic Radiosurgery System incorporates the advanced Synchrony Respiratory Tracking System (SRTS), designed to deliver real-time adjustments for lung tumor movements caused by respiration. This system enables a significant reduction in the planning target volume (PTV) margin by up to 44%, which subsequently decreases the normal tissue complication probability from 2.5% to as low as 0.1%. The PTV margins can vary between 2 mm and 8 mm, with 3–5 mm being the most common range, based on tumor movement.

During treatment, patients wear a snug vest equipped with three infrared LEDs on the front. These LEDs help track respiratory motion; at least one must remain active for the Synchrony system to operate. Orthogonal X-ray tubes provide real-time internal imaging, while three flashpoint cameras record the LED data at 26 Hz. Lung tumor tracking relies on spine tracking, so the tumor must be fully within the tracking volume without added margins. A volume of interest (VOI) encompassing the entire spine is used to generate a digital reconstruction radiograph (DRR) for accurate alignment. Once alignment is achieved, a Synchrony model is created, and treatment only begins after confirming patient safety and accurate tumor tracking.

Throughout treatment, X-rays are taken approximately every 10–50 seconds to validate tumor location. The system operates on a correlation function that relates LED motion to internal tumor motion using linear, quadratic, or dual-quadratic models. If the error between the predicted and actual tumor location exceeds 5 mm, treatment halts automatically.

The Synchrony system manages two main types of errors: correlation error (discrepancy between internal tumor and LED positions) and prediction error (used to account for the system's 115 ms response latency). Initially, 2 seconds of motion data is used to build a prediction model. Targeting accuracy also depends on tumor density, tissue contrast, and segmentation capability in X-ray images. The three major contributors to margin expansion during treatment include targeting error (difference between intended and actual beam location), correlation error (difference between predicted LED-based and X-ray-confirmed tumor positions), and prediction error (timing discrepancy in anticipated tumor motion).

The CyberKnife system continuously synchronizes beam delivery with tumor motion, ensuring precision throughout the respiratory cycle.

1.6 XSIGHT LUNG TRACKING PHANTOM

The Xsight Lung Tracking (XLT) Phantom, developed by Accuray in collaboration with CIRS, simulates realistic respiratory motion for CyberKnife system verification. It includes an anthropomorphic thorax with spine and ribs to replicate natural anatomical challenges in lung tumor tracking. A ball-cube rod actuator driven by a stepper motor enables accurate linear motion, while a surrogate platform mimics breathing patterns. The phantom allows radiographic validation using radiochromic film at lung tumor-representative locations. Its components are designed to work seamlessly with the Synchrony System for motion-tracking accuracy.

The XLT phantom features a single lung-equivalent epoxy dosimeter rod, 63.5 mm in diameter, with a 25 mm spherical target that holds two pre-cut Radio-chromic® films. The rod connects easily to the drive shaft for precise alignment. Accuray recommends a 16-bit grayscale or 48-bit color film scanner for accurate optical density and position analysis.

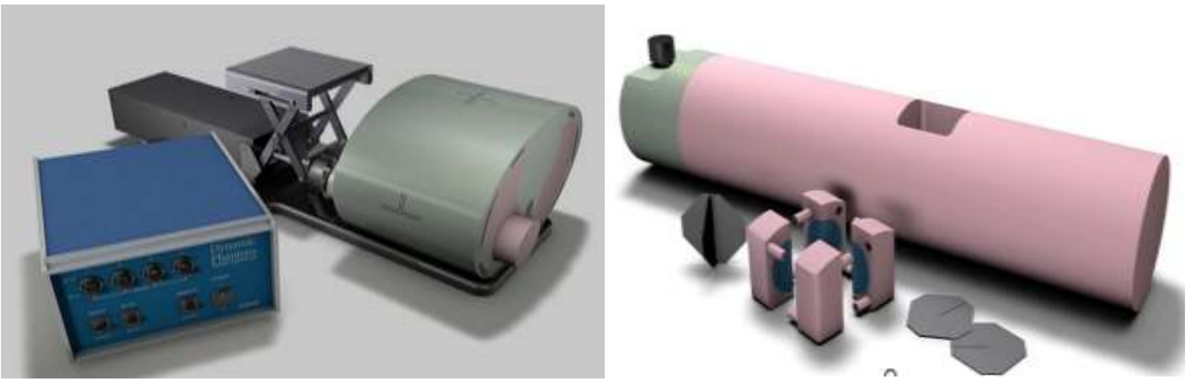

Figure: 1.2 Xsight® Lung Tracking Phantom Kit & Lung Phantom Ball Cube Rod

S.NO	Material	Density, g/cc	Electron Density x 10^23, per cc	Ratio to H20
1	Plastic Water® DT	1.04	3.35	1.003
2	XLT Lung	0.21	0.69	0.207
3	Cortical Bone	1.91	5.95	1.782
4	Trabecular Bone	1.20	3.86	1.156
5	Soft tissue target	1.06	3.43	1.028

Table: 1.2 Tissue Equivalent Phantoms

Overall Dimensions	67 cm X 32 cm X 28 cm
Overall, Weight	18.5 kg
Amplitude, IS	± 15 mm
Amplitude. Surrogate	± 25 mm
Max. Load Surrogate	1.4 kg
Motion Accuracy	± 0.1 mm
Cycle Time	5 secs
Waveforms	1-cos^4(1)

Table: 1.3 Phantom specifications

EPSON EXPRESS 10000XL & GAFCHROMIC EBT 2 DOSIMETER FILM

The EPSON Expression 10000XL is a 48-bit color flatbed scanner with 2400×4800 dpi resolution and 3.8 Dmax optical density for detailed scanning of films and transparencies. It supports USB 2.0, IEEE 1394, and optional network interfaces. Gafchromic EBT 2 film is a radiation-sensitive dosimeter film with a self-developing active layer between two durable polyester sheets. It can be immersed in water and handled under interior room light. For consistency, all films should be scanned at the same time interval after exposure.

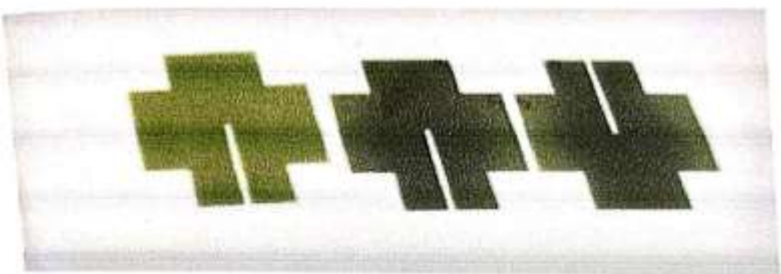

Figure: 1.3 Pre-cut Gafchromic EBT 2 Dosimeter Film

2. MATERIALS AND METHODS

The Xsight Lung Tracking (XLT) phantom was placed on a BrightSpeed Elite 16-slice CT scanner in a

Head First Supine (HFS) position. The Ball Cube Rod with a 25 mm spherical target (1.06 g/cc) and pre-cut Gafchromic EBT2 films was inserted into the phantom. The phantom was programmed to move with a 30 mm amplitude (inferior–superior direction) in a 5-second cycle. CT scans were acquired with 1.25 mm slice thickness, 120 kV, 350 mAs, pitch 1:1, and images were transferred to the Multiplan® TPS (v4.6). The target and spine tracking volumes were contoured and plans were created using the Xsight Lung Tracking algorithm with both Fixed and Iris collimators.
The deliverable plan was exported to the CyberKnife® system. The phantom was set up on the treatment couch with 3 external LED markers placed on the surrogate platform. The Synchrony Respiratory Tracking System (SRTS) captured motion, correlating internal tumor motion with LED marker movement. The Synchrony model was created using dual-quadratic (SI) and linear (AP, LR) motion curves with correlation errors < 4 mm. Treatment was delivered using the CyberKnife robot, synchronized with phantom motion. Live X-rays were taken every 30 seconds to verify tracking. Treatment was completed in 25 minutes.
After treatment, films were scanned using EPSON Expression 10000XL (300 dpi, 16-bit grayscale, TIFF format). Film analysis was done using Accuray's End-to-End Film Analyze® Software (v4.0) to verify dose distribution and delivery accuracy.

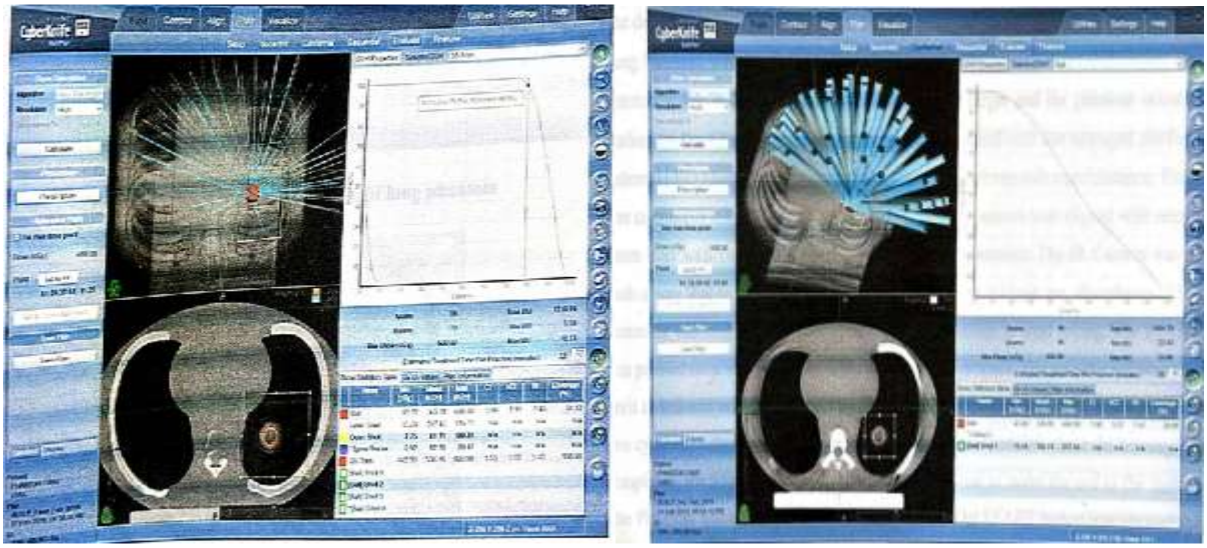

Figure: 2.1 Fixed & Iris plan for Xsight lung phantom

3. RESULT

The targeting accuracy of the CyberKnife system was assessed for both Fixed and Iris collimators. The measured values in lateral, anterior, and superior directions, along with the total targeting error, are shown in Table:3.1

No.	**Collimator**	**Direction**	**Image**	**Error (mm)**	**Total Targeting Error (mm)**	**Tolerance (mm)**
1	**FIXED**	Left	A/L Image	-0.40	**0.92**	
		Anterior	A/L Image	-0.27		
			A/S Image	0.61		
		Superior	A/S Image	0.81		

2	**IRIS**	Left	A/L Image	-1.03	**1.32**	**1.5**
		Anterior	A/L Image	-0.86		
			A/S Image	-0.60		
		Superior	A/S Image	-0.38		

Table:3.1 Result of Fixed and Iris Collimator

4. DISCUSSION

Timmerman R.D. discussed the advantages of fiducial-less respiratory motion tracking methods, supported by the work of Kuduvalli G. and Maurer C.R., who detailed the Xsight Lung Tracking System (XLTS). This system uniquely separates global patient alignment and local tumor tracking, beginning with spine-based positioning. Cotrutz C. and Hancock S.L. studied the accuracy of CyberKnife spinal radiosurgery, concluding that skeletal tracking improves alignment by accurately computing local displacements using X-ray and DRR image comparisons.

Woo-Chul Kim and A.B. Hee Keun Gwak confirmed that fiducial-less tracking in CyberKnife radiosurgery is both safe and effective for lung cancer, demonstrating minimal targeting error. Zhi-Yong Yang et al. evaluated total tracking error in the XLTS by analyzing system log files, confirming overall accuracy within 4 mm. Dongshan Fu et al. also validated XLTS as a non-invasive, accurate option for lung tumor treatment, achieving tracking precision better than 1.5 mm.

5. CONCLUSION

The targeting error of the CyberKnife XLTS with the Fixed Collimator path was within ±0.81 mm across all directions, with a total targeting error of 1.32 mm. For the Iris Collimator, the maximum individual directional error was less than ±1 mm, and the total targeting error was 0.92 mm. These results fall within the 1.5 mm tolerance limit set by the Accuray Customer Acceptance Test Protocol. This study confirms that the CyberKnife's XLTS provides sub-millimetric accuracy in tumor targeting. As a fiducial-free, real-time respiratory motion tracking system, it eliminates the need for invasive marker placement, reducing the risk of complications such as pneumothorax and significantly shortening treatment time. Therefore, the Xsight Lung Tracking System in the CyberKnife platform is a highly precise and non-invasive solution for accurate dose delivery to lung tumors**.**

Reference

1. Cyberknife [Internet]. En.wikipedia.org. 2019 [cited 12 March 2019]. Available from: https://en.wikipedia.org/wiki/Cyberknife
2. Yang Z, Chang Y, Liu H, Liu G, Li Q. Target margin design for real-time lung tumor tracking stereotactic body radiation therapy using CyberKnife Xsight Lung Tracking System. Scientific Reports. 2017.
3. Kong C, Geng H, Lam W, Yang B, Wong W, Ding Y et al. Investigation of Dosimetric Impact Arising from the CyberKnife Xsight Lung Tracking System using Different Synchrony Models. International Journal of Radiation OncologyBiologyPhysics. 2018.
4. Bahig H, Campeau M, Vu T, Doucet R, Béliveau Nadeau D, Fortin B et al. Predictive Parameters of CyberKnife Fiducial-less (XSight Lung) Applicability for Treatment of Early Non-Small Cell Lung Cancer: A Single-Center Experience. International Journal of Radiation OncologyBiologyPhysics. 2013;87.

5. Pepin E, Wu H, Zhang Y, Lord B. Correlation and prediction uncertainties in the CyberKnife Synchrony respiratory tracking system. Medical Physics. 2011.
6. Bahig H, Campeau M, Vu T, Doucet R, Béliveau Nadeau D, Fortin B et al. Predictive Parameters of CyberKnife Fiducial-less (XSight Lung) Applicability for Treatment of Early Non-Small Cell Lung Cancer: A Single-Center Experience. International Journal of Radiation OncologyBiologyPhysics. 2013.
7. CyberKnife® frameless image-guided stereotactic radiosurgery with the Synchrony™ Motion Tracking Module in the treatment of small lung tumors. Clinical Imaging. 2005.
8. Collins B, Malik S, Margolis M, Marshall M, Jamis-Dow C, Dieterich S et al. P-711 CyberKnife® frameless image-guided radiosurgery with the Synchrony™ motion tracking module in the definitive treatment of small peripheral lung tumors: The Georgetown University Hospital early experience. Lung Cancer. 2005.
9. CIRS Xsight lung tracking system manual book by Accuray.
10. Khan F.M. (2014). The Physics of Radiation Therapy. Philadelphia, USA: Lippincott Williams & Wilkins.
11. Here are some additional CyberKnife / XSight Lung Tracking System / Synchrony Motion Tracking related references in the same format:
12. Accuray Incorporated. CyberKnife® System Treatment Delivery Overview [Internet]. Sunnyvale, CA: Accuray Incorporated; 2020 [cited 17 June 2026]. Available from: https://www.accuray.com
13. Accuray Incorporated. CyberKnife® Robotic Radiosurgery System Technical Specifications [Internet]. Sunnyvale, CA: Accuray Incorporated; 2021 [cited 17 June 2026]. Available from: https://www.accuray.com
14. Kilby W, Dooley J, Kuduvalli G, Sayeh S, Maurer C. The CyberKnife® Robotic Radiosurgery System in 2010. *Technology in Cancer Research & Treatment*. 2010;9(5):433-452.
15. Adler J, Chang S, Murphy M, Doty J, Geis P, Hancock S. The CyberKnife®: A Frameless Robotic System for Radiosurgery. *Stereotactic and Functional Neurosurgery*. 1997;69(1-4):124-128.
16. Murphy M. Tracking Moving Organs in Real Time. *Seminars in Radiation Oncology*. 2004;14(1):91-100.
17. Hoogeman M, Prévost J, Nuyttens J, Pöll J, Levendag P, Heijmen B. Clinical Accuracy of the Respiratory Tumor Tracking System of the CyberKnife: Assessment by Analysis of Log Files. *International Journal of Radiation Oncology Biology Physics*. 2009;74(1):297-303.
18. Dieterich S, Gibbs I. The CyberKnife in Clinical Use: Current Roles, Future Expectations. *Frontiers of Radiation Therapy and Oncology*. 2011;43:181-194.
19. Keall P, Mageras G, Balter J, Emery R, Forster K, Jiang S et al. The Management of Respiratory Motion in Radiation Oncology Report of AAPM Task Group 76. *Medical Physics*. 2006;33(10):3874-3900.
20. Giraud P, Houle A. Respiratory Gating for Radiotherapy: Main Technical Aspects and Clinical Benefits. *ISRN Pulmonology*. 2013;2013:1-19.
21. Khan F.M., Gibbons J.P. (2014). Khan's The Physics of Radiation Therapy. 5th ed. Philadelphia, USA: Lippincott Williams & Wilkins.
22. Podgorsak E.B. (2016). Radiation Oncology Physics: A Handbook for Teachers and Students. Vienna: International Atomic Energy Agency (IAEA).

23. Hendee W.R., Ibbott G.S., Hendee E.G. (2013). Radiation Therapy Physics. 4th ed. Hoboken, New Jersey: Wiley-Blackwell.
24. These references are suitable for a CyberKnife XSight Lung Tracking System, Synchrony Motion Tracking, SBRT for Lung Tumors, and Radiation Therapy Physics thesis or project report.

REFERENCE

1. Cyberknife [Internet]. En.wikipedia.org, 2019 [cited 12 March 2019]. Available from: https://en.wikipedia.org/wiki/Cyberknife.
2. Yang Z, Chang Y, Liu H, Liu G, Li Q. Target margin design for real-time lung tumor tracking stereotactic body radiation therapy using CyberKnife Xsight Lung Tracking System. Scientific Reports. 2017.
3. Kong C, Geng H, Lam W, Yang B, Wong W, Ding Y et al. Investigation of Dosimetric Impact Arising from the Cyberknife Xsight Lung Tracking System using Different Synchrony Models. International Journal of Radiation Oncology Biology Physics. 2018.
4. Bahig H, Campeau M, Vu T, Doucet R, Béliveau Nadeau D, Fortin B et al. Predictive Parameters of CyberKnife Fiducial-less (XSight Lung) Applicability for Treatment of Early Non-Small Cell Lung Cancer: A Single-Center Experience. International Journal of Radiation Oncology Biology Physics. 2013;87.
5. Pepin E, Wu H, Zhang Y, Lord B. Correlation and prediction uncertainties in the CyberKnife Synchrony respiratory tracking system. Medical Physics. 2011.
6. Bahig H, Campeau M, Vu T, Doucet R, Béliveau Nadeau D, Fortin B et al. Predictive Parameters of CyberKnife Fiducial-less (XSight Lung) Applicability for Treatment of Early Non-Small Cell Lung Cancer: A Single-Center Experience. International Journal of Radiation Oncology* Biology* Physics. 2013.
7. CyberKnife® frameless image-guided stereotactic radiosurgery with the Synchrony™ᴍ Motion Tracking Module in the treatment of small lung tumors. Clinical Imaging. 2005-
8. Collins B, Malik S, Margolis M, Marshall M, Jamis-Dow C, Dieterich S et al. P-711 CyberKnife® frameless image-guided radiosurgery with the Synchronyᴛ™ motion tracking module in the definitive treatment of small peripheral lung tumors: Th Georgetown University Hospital early experience. Lung Cancer. 2005.
9. CIRS Xsight lung tracking system manual book by accuracy
10. Khan F.M. (2014). The physics of radiation therapy. Philadelphia, USA: LIPPINOCT WILLIAMS & MILKINS