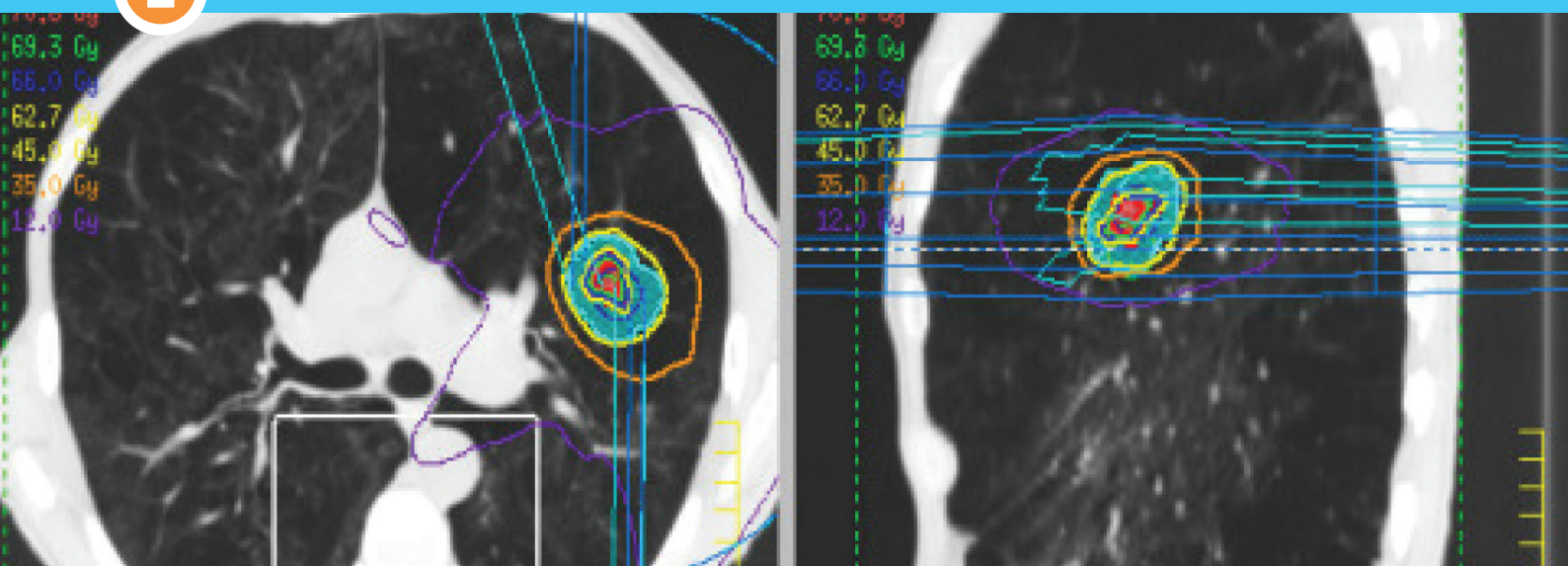


Lung SBRT in a patient with poor pulmonary function



CASE STUDY



**Delivered using Versa HD™ with
High Dose Rate mode and Symmetry™
4D image guidance**

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Summary

Patient demographics:

- 56 year old male with chronic obstructive pulmonary disease (COPD)
- Poor pulmonary function: $FEV_1 = 0.3$ L; diffusion capacity 34 %
- Pneumonia and dyspnoea

Treatment:

- 66 Gy delivered to GTV in 3 fractions, 2 fractions per week (PTV covered by 45 Gy)

Diagnosis:

- 3.9 cc (2 cm diameter) primary malignant lesion in upper lobe of left lung
- Staging T1bN0M0

Treatment planning and delivery system:

- Pinnacle treatment planning system version 9.2
- MOSAIQ® oncology information system version 2.5
- Elekta Versa HD™ with XVI Symmetry™ and 6 MV High Dose Rate (flattening filter free) mode

Patient history and diagnosis

A 56 year old male, a previous smoker until 2008 with chronic obstructive pulmonary disease (COPD), presented with pneumonia and dyspnoea. This patient had very poor pulmonary function, with a forced expiratory volume at around 10 % ($FEV_1 = 0.3$ L) and diffusion capacity at 34 %.

A diagnostic computed tomography (CT) scan (Brilliance CT Big Bore, Philips) revealed a 3.9 cc (2 cm diameter) lesion in the left upper lobe (figure 1). It was not possible to perform a biopsy due to the risk of lethal complications, however the lesion showed positive fluorodeoxyglucose (FDG) uptake and had increasing size on two consecutive PET-CT scans. The patient was diagnosed as having a primary malignant lesion of the lung with staging T1bN0M0. The patient was not a candidate for surgical resection due to poor lung function and, since malignancy was suspected, SBRT was the treatment of choice with 4D image guidance. The patient had received no previous treatment prior to radiotherapy and had a WHO performance status of 2.

The recommended standard treatment for early stage non-small cell lung cancer (NSCLC) in patients with no medical contraindications to operative intervention is surgical resection¹. However, as in this case, many lung cancer patients are not suitable for surgery due to the presence of underlying medical conditions. For patients who are unable to tolerate a lobectomy or segmentectomy, stereotactic body radiation therapy (SBRT) and surgical wedge resection are the preferred options to no therapy¹. SBRT is an alternative treatment for early stage inoperable lung cancer and has been shown to achieve local control and disease-free survival rates comparable to surgery with acceptable toxicity²⁻⁶.

Disclaimer:

This case study is based on the experience and application of a medical expert, and is intended as an illustration of an innovative use of Elekta solutions. It is not intended to promote or exclude any particular treatment approach to the management of a condition. Any such approach should be determined by a qualified medical practitioner.

It is important to note that radiation treatments, while usually beneficial, may also cause side effects that vary depending on the area being treated along with other medical circumstances. The most frequent side effects are typically temporary and may include, but are not limited to, skin redness and irritation, hair loss, respiratory, digestive, urinary or reproductive system irritation, rib, bone, joint or soft tissue (muscle) pain, fatigue, nausea and vomiting. In some patients, these side effects may be severe. Treatment sessions may also vary in frequency, complexity and duration. Finally, radiation treatments are not appropriate for all cancers, and their use along with the potential benefits and risks should be discussed before treatment

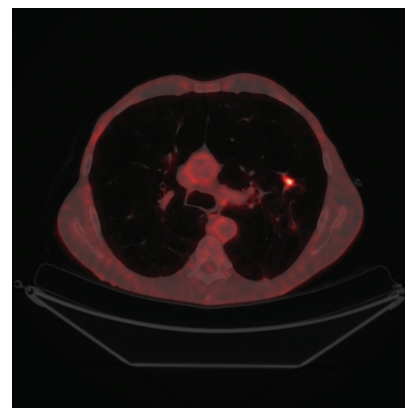


Figure 1. Diagnostic PET CT scan

Treatment planning

The planning CT scan and treatment delivery was performed with the patient in a head-first supine position, with arms raised above the head. Immobilization was achieved using a customized vacuum cushion (VacFix™, Par Scientific A/S). A helical 4D-CT scan was performed while the patient was free-breathing and the mid-ventilation phase was used for treatment planning. The patient did not receive any respiratory coaching before or during the treatment. The peak-to-peak tumor motion was 3 mm in all three directions.

Treatment planning was performed using the Pinnacle treatment planning system version 9.2 (Phillips Radiation Oncology Systems). A clinical target volume (CTV) was not applied. A planning target volume (PTV) margin was created directly from the gross target volume (GTV) by expanding 5 mm axially, and 10 mm in the superior/inferior axis. A 6 MV flattening filter free (FFF) volumetric modulated arc therapy (VMAT) plan for Versa HD™ was generated to deliver a prescribed dose of 66 Gy to the GTV in 3 fractions. The PTV was covered by 45 Gy and the GTV was covered by 95 % of 66 Gy (62.7 Gy), with parts of the GTV receiving at least 66 Gy and no upper limit on the maximum dose within the GTV. The plan included two VMAT arcs: 180 degrees to 340 degrees and 180 degrees to 0 degrees, both in the counter clockwise direction (figure 2). Critical structures to be avoided and dose constraints are shown in Table 1.

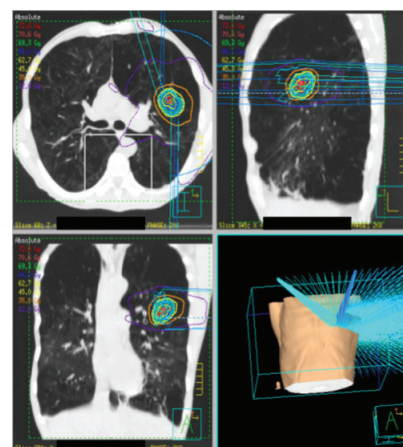


Figure 2. Lung SBRT treatment Plan

CRITICAL STRUCTURE	ACHIEVED DOSE CONSTRAINT	CRITERIA
Normal lung	V12=6 %	V12<30 %
Heart	D1cc=0.9 Gy	max. 1cc receives over 21 Gy
Spine	Dmax=11.1 Gy	Dmax=18 Gy
Esophagus	D1cc=20.0 Gy	max. 1 cc receives over 21 Gy

Table 1. Critical structures and dose constraints

For quality assurance, the plan was evaluated pre-treatment using a three-dimensional diode array (ArcCHECK®, Sun Nuclear). A pass rate of 98.3 % was achieved using a gamma index of 3 mm/3 %.

STEP	PROCEDURE	TIME
4D XVI scan (Symmetry™)	From kV beam on to reconstruction completed	2:30
XVI match	From reconstruction completed to MV beam on for the first arc	1:45
Treatment delivery of first VMAT arc (2445.9 MU)	From MV beam on to MV beam off	2:15
Preparation of new XVI scan	From MV beam off to kV beam on	0:40
4D XVI scan (Symmetry™)	From kV beam on to reconstruction completed	2:30
XVI match	From reconstruction completed to MV beam on for the second arc	1:45
Treatment delivery of second VMAT arc (2118.7 MU)	From MV beam on to MV beam off	1:55

Table 2. Treatment delivery workflow

Treatment delivery

The treatments were performed in December 2013, with all three fractions delivered within 8 days. A total of 4564.6 MU were delivered for each fraction. The first VMAT arc delivered 2445.9 MU and the second arc delivered 2118.7 MU (mean 2282.3 MU per beam).

Treatment was delivered with the patient in free breathing. A 4D-CBCT was acquired using XVI prior to each treatment arc using an in-house preset, and matched to the 4D-CBCT mean position using Elekta Symmetry.

Studies suggest that intrafraction image guidance and gross tumor volume (GTV) margins, based on 4D tumor and lung motion analysis, can reduce treatment errors⁷. An algorithm that combines 4D inverse CT planning (incorporating patient-specific respiratory motion information) and repetitive image-guidance during treatment to improve dose placement accuracy has been integrated into Elekta Symmetry to reduce exposure of healthy tissue and to facilitate safe dose escalation⁸⁻⁹.

Symmetry uses anatomically correlated 4D image guidance at the time of treatment to give volumetric visualization of respiratory motion and the ability to correct for baseline shifts. This supports free breathing during treatment delivery with reduced PTV margins.

The workflow for imaging and treatment delivery, including the time in minutes for each step, is shown in Table 2. The total treatment delivery time, including imaging, was 13 minutes and 20 seconds. Total MV beam-on-time to deliver 4564.6 MU using High Dose Rate mode and VMAT was 4 minutes and 10 seconds.

The XVI scanning protocol and treatment delivery beams were optimized so that the XVI scan stopped at 180 degrees and the treatment delivery started at 180 degrees, thereby minimizing the total treatment time. Similarly, the first treatment arc stopped at the angle where the next XVI scan started.

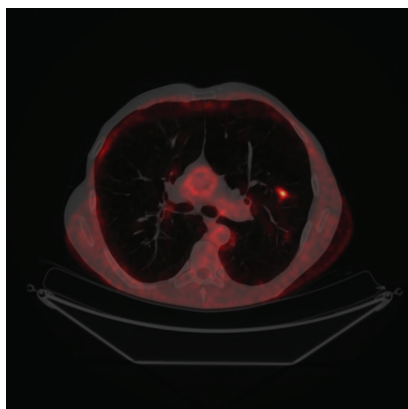


Figure 3. PET CT scan 1-month post treatment

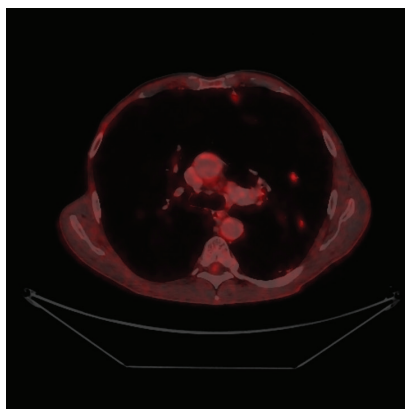


Figure 4. PET CT scan 4-months post treatment

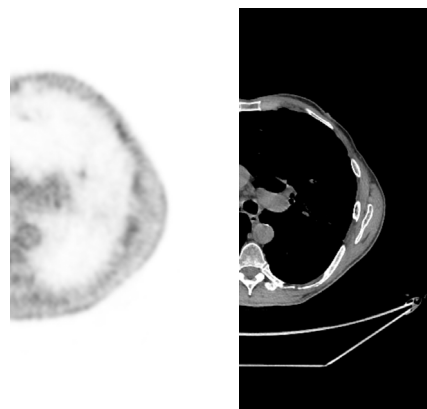


Figure 5. PET scan and CT scan 14-months post treatment.

Outcome and follow up

The patient completed lung SBRT successfully with no side effects observed up to four months following treatment. The tumour, which was measured at 15 mm in the planning CT scan (figure 2), was measured at 14 mm in the one month follow up scan (figure 3), 12 mm in the four month follow up scan (figure 4) and 8 mm in the 14 month scan (figure 5). No visible radiation-induced changes were observed in the lung tissue in follow up CT scans. This patient had very poor lung function (table 3) and emphysema throughout treatment and follow up.

At four and fourteen months follow up, no FDG uptake was observed on PET-CT, suggesting that local control was achieved.

Discussion and conclusion

This patient was a good candidate for lung SBRT. Even though he had very poor pulmonary function, the treatment was well tolerated, with no reported side effects. The daily use of online 4D imaging with XVI and Symmetry™ allowed the PTV margins to be reduced, compared to standard 2D verification of bony structures, and helped minimize irradiation of healthy lung tissue.

In general, treatment delivery times are reduced when using the higher dose rates that can be achieved with 6 MV FFF beams compared to standard 6 MV beams. The combination of VMAT and high dose rate mode (FFF) with Versa HD, shortened the treatment time and reduced the potential risk of intrafraction movement.

The aim of this treatment was to deliver definitive radiotherapy with minimal toxicity. Evaluations in the short follow-up period in which post-treatment PET-CT scans demonstrated no lesional FDG uptake, pulmonary function remained stable and clinical examinations were unchanged, suggest that this goal has been achieved.

TIME	FEV ₁ (LITRES)	% OF EXPECTED VALUE
First treatment fraction	0.44	12.9
One month follow up	0.32	9.4
Four month follow up	0.40	12.0
Fourteen month follow up	0.53	15.8

Table 3. Lung function at the time of treatment and up to 14 months after treatment

ABOUT ELEKTA

A human care company, Elekta pioneers significant innovations and clinical solutions harnessing both external and internal radiation therapy for treating cancer and brain disorders. Elekta provides intelligent and resource-efficient technologies that improve, prolong and save patient lives. We go beyond collaboration, seeking long-term relationships built on trust with a shared vision, and inspiring confidence among healthcare providers and their patients.

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