Customer Perspective

# Versa HD™ and Monaco® Dynamic Conformal Arc Therapy (DCAT) enable lung SABR to be delivered in less than two minutes


## Contributors

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Canterbury District Health Board
Te Poari Hauora ō Waitaha

# About

## Canterbury District Health Board (CDHB) Radiation Oncology Department

### Location

Christchurch Hospital
Christchurch, New Zealand

### Staff

**9** Radiation Oncologists

**10** Radiation Oncology Medical Physicists (FTE)

**40** Radiation Therapists (FTE)

### Patients

**2,200** patients/year

### Technology

**1** Elekta Versa HD™ linear accelerator with HexaPOD™ evo RT

**3** Elekta Synergy® linear accelerators

**2** Elekta Active Breathing Coordinator™ system

**1** Siemens CT Simulator

**1** HDR Brachytherapy System

Monaco® TPS Version 5.11

- **2** Workstations
- **5** Monaco Servers
- **2** Monaco Sim Servers

MOSAIQ® OIS version 2.6

## Background

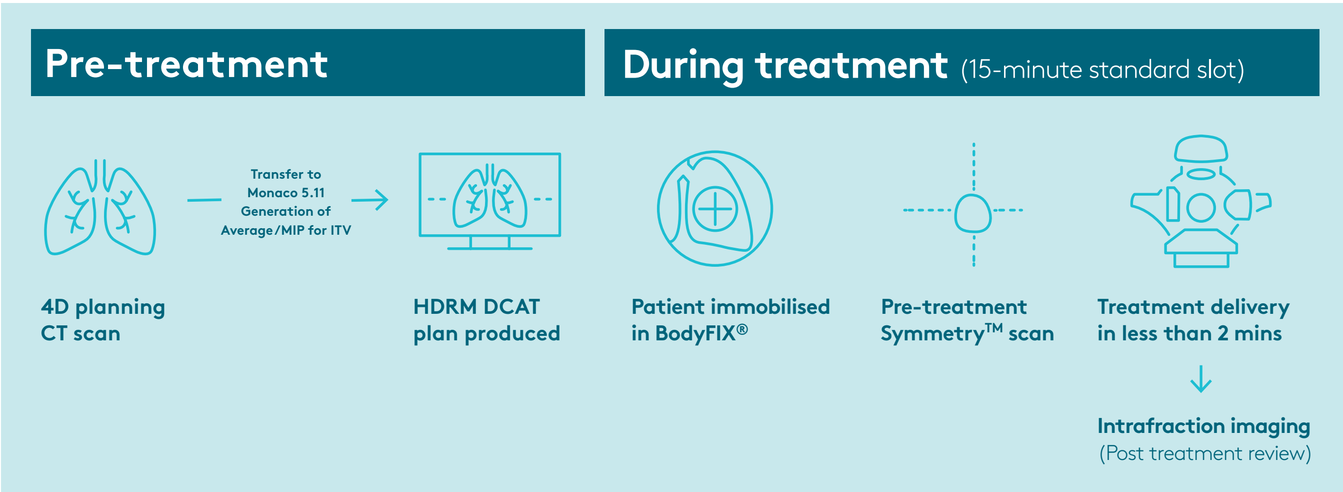
**Christchurch Hospital is the largest tertiary, teaching and research hospital in New Zealand's South Island and home to the Canterbury District Health Board (CDHB) Radiation Oncology Department. The department offers a wide range of radiation therapy treatments, including specialized techniques such as stereotactic ablative body radiotherapy (SABR), total body irradiation (TBI) and HDR brachytherapy.**

The department's SABR lung program began in 2013. At that time, SABR for lung cancer at Christchurch Hospital was performed using a 3D conformal radiotherapy (CRT) method with eight to nine noncoplanar beams. This method required patients to be on the treatment table for around one hour including pre-treatment, mid-treatment and post-treatment imaging—which limited suitable patients to those who could tolerate this long treatment time.

In 2016, the department obtained a Versa HD linear accelerator with Agility MLC and flattening filter free (FFF) High Dose Rate mode (HDRM), and they upgraded their treatment planning system to Monaco version 5.11. At this point, with the additional capabilities these technologies offered, the team at Christchurch Hospital began to use Monaco DCAT for SABR lung patients.

## SABR lung in a standard treatment slot

The new SABR lung workflow with Monaco DCAT at Christchurch Hospital involves the following steps:




"The CHISEL trial has shown that SABR lung is superior to conventional radiotherapy for the treatment of inoperable non-small cell lung cancer[1] [NSCLC] and we are seeing an increasing number of patients who would benefit from SABR lung clinically," comments Andy Cousins, PhD, Radiation Oncology Physics Team Leader. "Previously, SABR lung patients had to be able to tolerate 45 to 60 minutes on the treatment table. This restricted the treatment to fitter patients, who were few in number considering most of them were already unsuitable for surgery, and many required analgesics.

"With Monaco DCAT and Versa HD, treatment time has been reduced significantly," he continues. "SABR lung can now be delivered in a standard 15-minute time slot including imaging, without the need for analgesics. This means we can treat just about any small NSCLC tumor today using SABR—and many patients are being referred for SABR lung as a first-choice treatment."

## A robust planning process

The SABR lung DCAT planning process at Christchurch Hospital is as follows: A 4D planning CT scan is obtained to determine the positions of the tumor throughout the breathing cycle. These images are exported to Monaco 5.11 and the ITV is drawn on the maximum intensity projection (MIP) image dataset, which encompasses the entire tumor trajectory. The ITV is translated onto the average intensity projection (AvgIP) image dataset. The AvgIP shows the average position of the tumor and the rest of the body such as the patient contour, heart and healthy lung for dose calculation using Monaco DCAT and segment shape optimization (SSO), and also serves as the reference dataset for IGRT.

"The calculation speed is incredibly quick," comments Dr. Cousins, "which means the overall planning time is very short. In addition, we have set up a SABR lung planning template in Monaco, which also speeds up planning time."

Monaco DCAT with variable dose rate (VDR) and SSO produces an inversely optimized DCAT plan. Plan quality is improved by incorporating VDR, which can increase or decrease the dose rate being delivered throughout the arc. SSO optimizes segment weights, control point widths and MLC positions at the periphery of the segments to achieve lower organs-at-risk (OAR) doses and enhanced target conformality. This degree of modulation achievable by Monaco DCAT is similar to Volumetric Modulated Arc Therapy (VMAT). However, unlike VMAT, the entire target remains within the aperture throughout the arc during delivery. This eliminates MLC interplay issues associated with small segmented apertures and allows confidence that the moving target is receiving the full dose during treatment delivery.

While Monaco DCAT optimization and sequencing capabilities deliver high quality plans and ensure robust dose delivery to moving targets, the open nature of DCAT segments allows higher dose rates to be utilized. The leveraging of HDRM on Versa HD ensures that treatment delivery is also very efficient.

"Since DCAT is a very conformal treatment, the organs-at-risk and healthy tissue don't get much dose. We can achieve high-quality plans with only a few constraints. Also, since out-of-field dose is considerably less with unflattened beams, the use of High Dose Rate Mode helps to further spare healthy tissue."

**Andy Cousins, PhD**
Radiation Oncology Physics Team Leader

SABR lung treatment at Christchurch Hospital delivers either 48 Gy in four fractions or 45 Gy in three fractions according to ESTRO Advisory Committee on Radiation Oncology Practice (ACROP) guidelines[2]. The margins currently used are 1.0 cm in the superior/inferior direction and 0.5 cm everywhere else, as recommended in the CHISEL trial[1]. Constraints used follow the guidelines shown in Table 1, and the treatment of lung metastases follows the SAFRON II trial protocol[3].

| OAR | Supported |
|---|---|
| **Skin** | RTOG 0813 (2015)[4] |
| **Trachea and proximal bronchus** | Hanna, GG et al (2017)[5] |
| **Lung V5 and V10** | Chang, JY et al (2014)[6] |
| **Lung, other** | CHISEL trial protocol (2019)[1] |
| **Other OAR** | CHISEL trial protocol (2019)[1] (except chest wall: V30 reduced from 70 cc to 30 cc) |

**Table 1.** SABR lung OAR constraint guidelines used at Christchurch Hospital

"Monaco DCAT provides the coverage without using VMAT," Dr. Cousins says. "The plans are easy and efficient to produce and are very robust for quality assurance [QA]."

For QA purposes, a high density ArcCheck® measurement is performed with global gamma criteria of 3%/2 mm and an absolute dose of over 95%. In addition, point dose is measured at the isocenter in a homogeneous phantom with a small ion chamber, with measured dose within 1% of the planned dose.

## Rapid treatment delivery

For treatment delivery, the patient is set up in a BodyFIX® full body vacuum bag. A Symmetry™ 4D CBCT is acquired to check the ITV and patient position, and automatic table adjustments are performed, if necessary, prior to starting treatment.

A 4D Symmetry scan is performed during treatment delivery. This eliminates the need for post-treatment CBCT imaging, which means the patient can dismount as soon as the treatment is finished.

"For SABR lung using DCAT and HDRM, our typical beam-on time to deliver 15 Gy is just 1.5 minutes," comments Dr. Cousins. "Imaging is acquired in just two to three minutes with an additional one to two minutes for analysis, so it is very fast.

"The patient is on the table typically for 15 minutes, including setup and imaging, which is much easier to tolerate," he continues. "We can book patients into a normal 15-minute treatment slot—rather than requiring three or four slots—so there is no interference with scheduling and we can treat more patients during the day.

"In addition, the presence of a consultant is only required at the first fraction now and only if issues arise for subsequent fractions," he adds. "Previously, they would have been present for every fraction, so using DCAT for SABR lung also saves on consultant time."

## Advanced imaging techniques

The team at Christchurch Hospital has been using Symmetry 4D CBCT for the management of respiratory motion since 2013. Symmetry provides anatomically correlated 4D image guidance at the time of treatment, providing volumetric visualization of moving tumors. No surrogates or external markers are required as Symmetry uses anatomical information contained within the projection data itself to automatically sort the projection images into the relevant phase "bins".

The daily tumor position is then determined automatically by registering each phase to the reference image. By calculating displacement vectors for each registration, XVI understands the tumor trajectory and position of that specific day.

"When we started our SABR lung program, this seemed the ideal site to use Symmetry," Dr. Cousins comments. "Because we were performing a 4D planning CT scan using a different method—real-time position monitoring [rpm] using a box on the stomach to monitor breathing—we first verified that the ITVs produced were reproducible, on phantoms and patients. When we were satisfied the ITVs were the same, we implemented Symmetry for our SABR lung patients.

"Previously, we would have used 3D CBCT imaging," he continues. "With Symmetry we obtain a lot more information. Some small tumors that are not visible using 3D CBCT can be seen using Symmetry. In addition, we can see the tumor moving and we can check that the patient's breathing pattern hasn't changed since the planning CT scan. It also provides us with confidence about the accuracy of our treatments by accounting for baseline drift."

Symmetry also provides valuable visual validation for the radiation therapists present at the time of treatment delivery.

"Symmetry gives us confidence that the movement captured in the 4D planning CT is accurate," says Hayley Bennett, Radiation Therapist. "The vast majority of lesions move within the contoured ITV—very few move outside of this. It also fits easily into the workflow. We choose a clockwise or counter-clockwise Symmetry scan based on the side of the lesion. This makes the transition from the end of the Symmetry scan to the start of DCAT quick and easy."

Recently, the department also started to use 4D intrafraction imaging. This allows them to evaluate field coverage during treatment delivery and eliminates the need for a post-treatment CBCT scan, which reduces time on the table for the patient. Offline analysis of these images will also form part of a departmental study to explore the potential of margin reduction for SABR lung. They hope to be able to use this data to safely reduce the lung target margin to an isotropic 0.5 cm.

"The combination of Symmetry and intrafraction imaging gives us confidence that we're treating what we planned to treat," Dr. Cousins says. "We know where the tumor is located every day, for every fraction. We would not perform SABR lung treatments without it."

## Case example

A 72-year-old female patient with stage IA NSCLC in the left lower lobe was prescribed 48 Gy in four fractions. The tumor was positioned very posteriorly in the lobe, abutting the chest wall.

Particular challenges for this patient included keeping the skin dose in tolerance, since the patient was very thin, and the proximity of the tumor to the spinal cord.

An "avoid" structure was created and included in the IMRT constraints for optimization to limit the dose posteriorly. The spinal cord was also included in the prescription. Two beams were used: one full arc and one 210° partial clockwise arc from 180°, which avoided lateral dose to the spinal cord. Since coverage was good, the plan was also scaled down by 5% to further reduce skin and spinal cord dose. The combination of the beam arrangement and constraints enabled the skin tolerance to be upheld and the spinal cord dose to be as low as possible (10.5 Gy), while still allowing 98% of the PTV to receive 95% of the prescribed dose (45.6 Gy). The patient plan and cost functions are shown in Figure 1.

The patient was treated in July 2017. A follow-up CT scan one year after treatment showed complete resolution of the tumor. A repeat CT scan in 2019 showed no recurrence and the patient remains well.

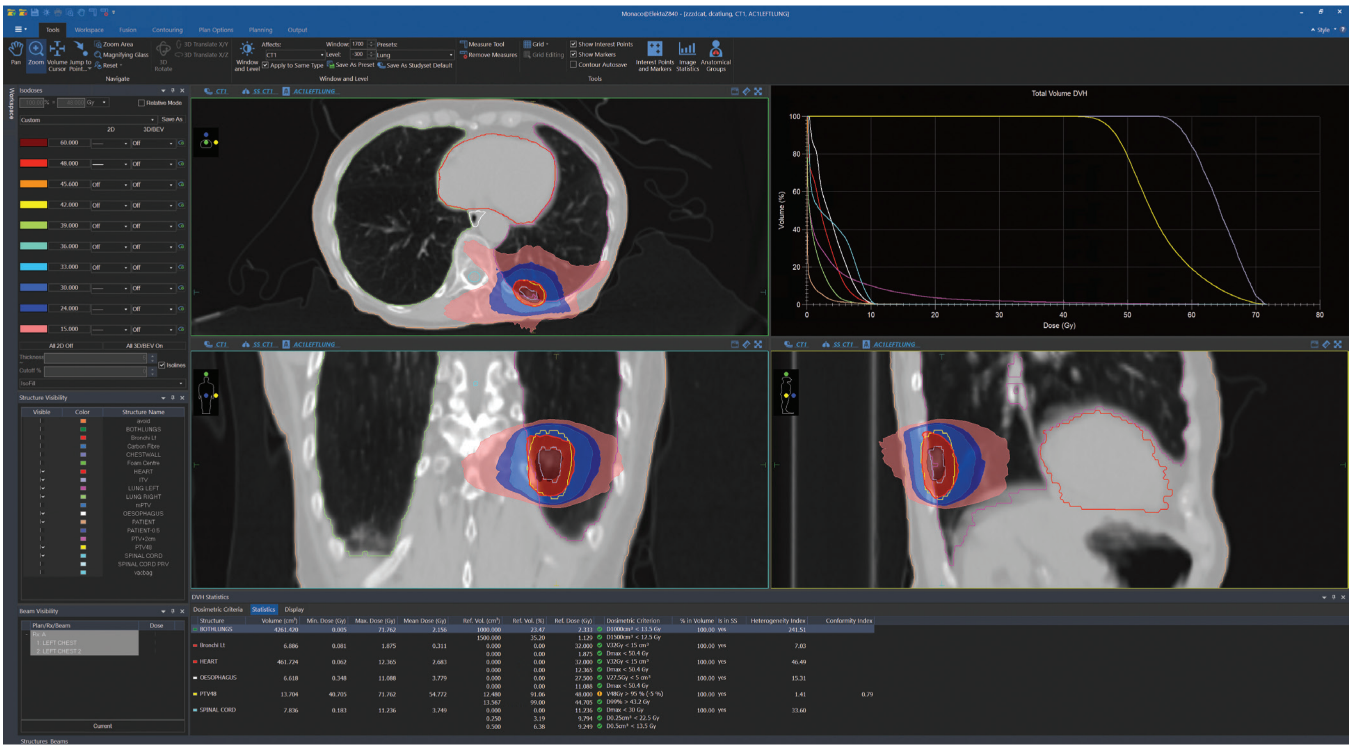



**Figure 1.** SABR lung DCAT plan for the treatment of NSCLC in lower left lobe

## Beam Information

| Seq. | Description | Treatment Unit | Modality | Energy | Gantry (deg) | Coll. (deg) | Couch (deg) | Isocenter X (cm) | Y (cm) | Z (cm) | # of Segs | MU/Fx |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Left Chest | CDHBAgility v1 | Photon | 6.0 FFF | 180.0/-360.0 | 10.0 | 0.0 | 6.00 | 5.40 | 15.00 | 70 | 1336.61 |
| 2 | Left Chest 2 | CDHBAgility v1 | Photon | 6.0 FFF | 330.0/210.0 | 10.0 | 0.0 | 6.00 | 5.40 | 15.00 | 49 | 519.18 |
| | | | | | | | | | | **Total:** | 119 | 1855.79 |

| Structure Name | Cost Function | Enabled | Status | Manual | Weight | Threshold Gy | Multi-criterial | Iso Constraint | Iso Effect | Relative Impact | Clear | Total Volume DVH | Auto Flash |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PTV48 | Target Penalty | On | On | No | 1.00 | | Off | 48.000 | 0.000 | | No | Yes | No |
| | Min Vol: 98.00% Surf Marg: No All Voxel Opt: No | | | | | | | | | | | | |
| Spinal Cord PRV | Serial | On | On | No | 0.03 | | Off | 10.000 | 0.000 | | No | Yes | No |
| | Power Law Exp: 10.00 EUD: 10.000 Gy Shrink Marg: 0.00 cm All Voxel Opt: No | | | | | | | | | | | | |
| Skin Surface Avoidance Structure | Serial | On | On | No | 1.25 | | Off | 24.500 | 0.000 | | No | Yes | No |
| | Power Law Exp: 13.00 EUD: 24.500 Gy Shrink Marg: 0.00 cm All Voxel Opt: No | | | | | | | | | | | | |
| Patient | Conformality | On | On | No | 8.39 | | Off | 0.38 | 0.00 | | No | Yes | No |
| | All Voxel Opt: Yes | | | | | | | | | | | | |
| | Quadratic Overdose | On | On | No | 10.13 | 48.000 | Off | 0.050 | 0.000 | | No | Yes | No |
| | Max Dose: 48.000 Gy RMS Excess: 0.050 Gy Shrink Marg: 0.00 cm All Voxel Opt: No | | | | | | | | | | | | |
| | | On | On | No | 0.01 | 24.000 | Off | 0.300 | 0.000 | | No | Yes | No |
| | Max Dose: 24.000 Gy RMS Excess: 0.300 Gy Shrink Marg: 1.60 cm All Voxel Opt: No | | | | | | | | | | | | |

# Conclusions

"Monaco DCAT has allowed the option of SABR lung treatment for patients who wouldn't have been able to tolerate it previously due to the long treatment times," Dr. Cousins says. "We are certainly treating more patients using this technique. Some of our lung surgeons are very keen for patients to have SABR lung, often as a first choice."

Radiation Oncologist Dr. Chris Harrington comments, "SABR lung is more effective and more convenient for patients than conventionally fractionated radiation treatment. Symmetry assures that tumor motion with breathing is accounted for in the treated volume, while DCAT and FFF provide a much quicker treatment time, which improves patient comfort and increases patient throughput. Few patients report more than minor side effects."

"In the future, we'd like to expand our use of SABR for other soft tissue sites," Dr. Cousins concludes. "Our experience with SABR lung and imaging will help enormously with that. We are hoping to start a trial on pancreas soon—our imaging solutions give us the confidence to do this as it could well involve a moving target."

### References


1. Ball D, et al. Stereotactic ablative radiotherapy versus standard radiotherapy in stage 1 non-small-cell lung cancer (TROG 09.02 CHISEL): A phase 3, open-label, randomised controlled trial. Lancet Oncol. 2019;20(4):494–503.
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3. TROG 13.01/ALTG 13.001. Stereotactic ablative fractionated radiotherapy versus radiosurgery for oligometastatic neoplasia to the lung: a randomised phase II trial (SAFRON II) protocol amendment 5: 10 August 2017.
4. RTOG 0813 trial protocol version date June 8, 2015.
5. Hann GG, Murray L, Patel R, et al. UK consensus on normal tissue dose constraints for stereotactic radiotherapy. Clin Oncol. 2018;30(1):5-14.
6. Chang JY, Li QQ, Xu QY, et al. Stereotactic ablative radiation therapy for centrally located early stage or isolated parenchymal recurrences of non-small cell lung cancer: How to fly in a "no fly zone". Int J Radiat Oncol Biol Phys. 2014;88(5):1120–28.

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