World's First Installation and Clinical Use of the TomoHD™ Treatment System at University Radiotherapy Antwerp

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Introduction

University Radiotherapy Antwerp installed two TomoTherapy® Hi·Art® treatment systems in 2007. Three years later, one of these has been replaced by the world's first clinical TomoHD™ treatment system. The *TomoHD* system contains many workflow-enhancing features and comes standard with both the TomoHelical™ and TomoDirect™ treatment modalities. A key standard feature of the *TomoHD* system is an updated computing cluster offering significant reductions in treatment planning time. Key features of the *TomoHD* system are given below. Our experience with installation and initial clinical use of the new system as well as comparisons with the original *Hi·Art* system removed, are described in this paper.

Installation and Acceptance

The *Hi·Art* treatment system replaced was removed one month before the installation of the *TomoHD* treatment system. As the footprint of each machine is identical, the bolts in the floor as well as the laser fixation could be reused. In order to have optimal benefit of the speed of the new cluster, a new fast fiber optic network was installed to connect the treatment machine and the planning stations.

Although the *TomoHD* system has more standard features than the *Hi·Art* system, the acceptance test procedure (ATP) was completed in TomoTherapy's standard five-day timeframe. The most significant additional consideration in this process is a beam data validation for the static gantry angles used during *TomoDirect* treatments. Specifically, dose profiles across the narrow beams formed by open MLC leaves are required.

The *TomoHD* system at University Radiotherapy Antwerp

Image courtesy of Thomas van Haute

Key features of the *TomoHD* treatment system

- *TomoHelical* and *TomoDirect* treatment modes
- High-performance 14-blade computing cluster
- Larger positioning control panels (LCD screens)
- 1.0, 2.5 and 5.0 cm beam widths
- Enhanced couch control and position control panels
- Automatic fine couch adjustments in x,y,z directions
- Connectivity with oncology information systems
- Patient data transfer between *TomoTherapy* systems
- Enhanced patient data storage options including to hospital network
- DICOM export of patient data
- TomoPortal™ application for remote plan and image guidance review
- Integrated Tomo™ Quality Assurance (TQA) software
- Integrated patient-operator intercom
- Reduced room size requirements
- Refined beam line including waveguide with integrated target
- Hardware configuration to enable future delivery enhancements

Planning with software version HD 1.0 and the new cluster

A new software version, HD 1.0, is associated with the *TomoHD* unit. This includes updated treatment planning software with a revised interface and many new features compared with previous versions. Additionally, a High Performance computing cluster (14 blade servers) is supplied with the *TomoHD* treatment system. Planning times are significantly reduced compared with previous generations of computing clusters. In particular, beamlet pre-calculation for *TomoHelical* plans is much faster than before and overall planning time for the *TomoDirect* modality is reduced compared with the *TomoHelical* modality.

With the new software version there is increased flexibility in setting optimization constraints. Now, up to three dose volume histogram (DVH) points can be defined per structure (organ-at-risk or target) where previously only one could be set. These are in addition to the existing ability to specify the maximum dose to organs-at-risk and targets, and minimum dose to targets. This change gives the optimizer more detailed information on the DVH curve it is trying to achieve for each structure. While this new functionality adds a level of control that did not previously exist, experience is required to take full advantage of it. A nice feature of the display is that small markers are placed on the DVH graph to indicate the DVH points specified. The planner can monitor progress in achieving these goals and shift the points to more appropriate locations if needed. Experience will help in initial placement of the DVH points for each structure at suitable dose/volume coordinates.

In order to examine differences in the planning and treatment processes between the *TomoHD* and *Hi·Art* systems, a comparative end-to-end test has been run on a phantom. For this test, *Hi·Art TomoHelical*, *TomoHD TomoHelical* and four-beam *TomoHD TomoDirect* plans were created with the same constraints, for a phantom with four regions of interest. A treatment dose of 60 Gy in 2 Gy fractions was chosen. After the different planning steps were evaluated, each plan was used to compare throughput on the *Hi·Art* and *TomoHD* systems.

Table 1 compares the time required for various steps in the planning process.

Step in Planning Process	Time (min:sec)		
	TomoHD Helical	*TomoHD* Direct	*Hi·Art* Helical
Beamlet calculation	4:58	4:11	54:00
Until 100 iterations complete	5:55	4:41	14:30
Until 300 iterations complete	17:14	14:18	41:20
Full dose calculation	1:24	0:28	1:22
Final dose	1:04	0:29	2:06

Table 1. Time taken for various steps in the planning process

The beamlet calculation time is reduced from 54 minutes on the *Hi·Art* treatment system to five minutes with the new *TomoHD* system hardware and software. Also, iterations during optimization ran 2.5 times faster on the *TomoHD* system. Furthermore, calculated beam delivery time is shorter for the *TomoHD TomoDirect* (4 min, 24 sec) and *TomoHD TomoHelical* (5 min, 14 sec) treatments than on the *Hi·Art TomoHelical* (7 min, 12 sec) treatment.

On the operator station, the *TomoHD* system software response is faster than the *Hi·Art's;* waiting time between pressing the start button and the actual irradiation is reduced from 25 seconds to 16 seconds for the MVCT imaging beam and from 59 seconds to 20 seconds for the treatment beam.

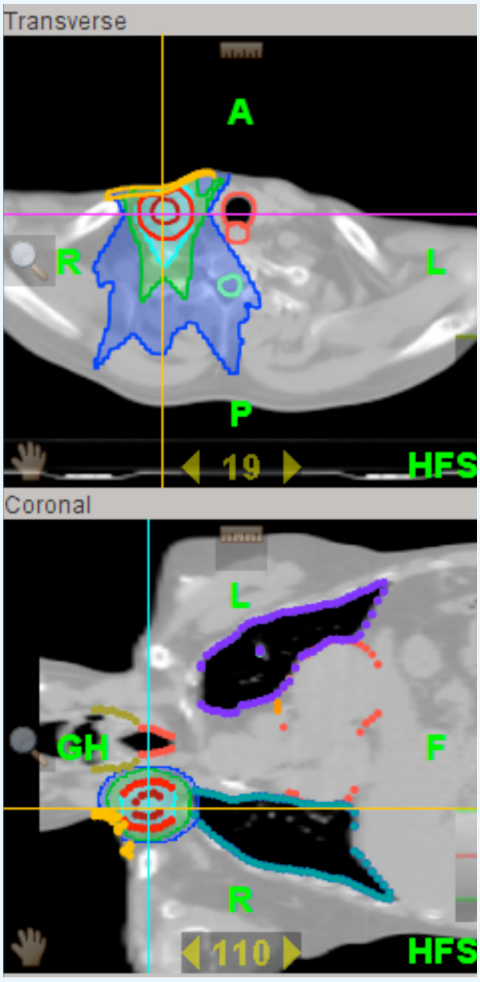
Together with the fully automatic couch, the quicker scan and the shorter treatment time, a total of four minutes is saved for the treatment procedure. If we project these differences on a normal working day, up to 15 percent more patients can be treated.

Table 2 compares the time required for various steps in the treatment process.

Step in Treatment Process	Time (min:sec)		
	TomoHD Helical	*TomoHD* Direct	*Hi·Art* Helical
Select plan+select scan	0:20	0:13	0:20
Scan	4:16	4:16	4:46
Start button image until actual beam on	0:16	0:16	0:25
Key-on until registration	0:08	0:08	0:17
Accept registration	0:05	0:05	0:05
Treatment	5:14*	4:24	7:12
Push start button until actual beam on	0:20	0:10	0:59
Key-of until patient list	0:01	0:01	0:01
Total time (without patient manipulation)	10:40	9:33	14:05

Table 2. Time taken for various steps in the treatment process

* Gantry rotation period has been reduced from 15 seconds to 12 seconds per rotation. This is a contributing factor to the reduction in treatment time between *Hi·Art TomoHelical* and *TomoHD TomoHelical* for this plan.



First clinical case

The first patient was treated with both *TomoHelical* and *TomoDirect* modes for two small metastases of an adenocarcinoma of the colon: one in the left lung and one in the right supraclavicular region. Each was prescribed 40 Gy in 10 fractions. Treatment plans using both treatment modes were created for each target. In the case of the *TomoDirect* modality, various beam arrangements were investigated.

As anticipated, the supraclavicular nodule benefited most from a three-beam (RAO, LAO, and AP) *TomoDirect* treatment, whereby dose to the esophagus and larynx could be kept to a very low level by avoiding having these structures in the beam path.

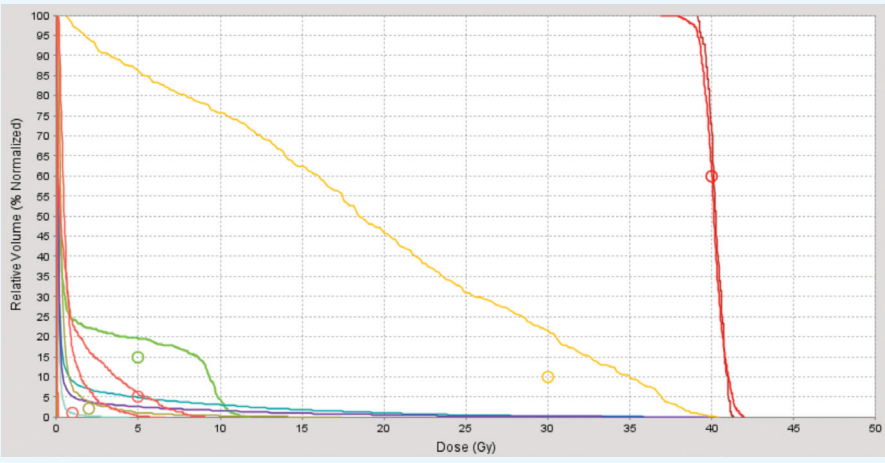
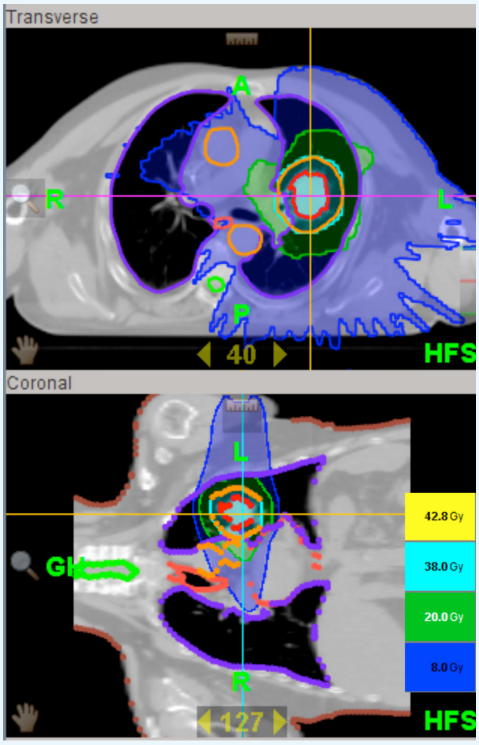


Figure 1. *TomoDirect* plan for the supraclavicular nodule



It was determined that the lung nodule would be best treated in *TomoHelical* mode. This mode provided good avoidance of critical organs such as the heart, as well as a uniform dose falloff around the target volume. The plan parameters and treatment times for each region are shown in Table 3.

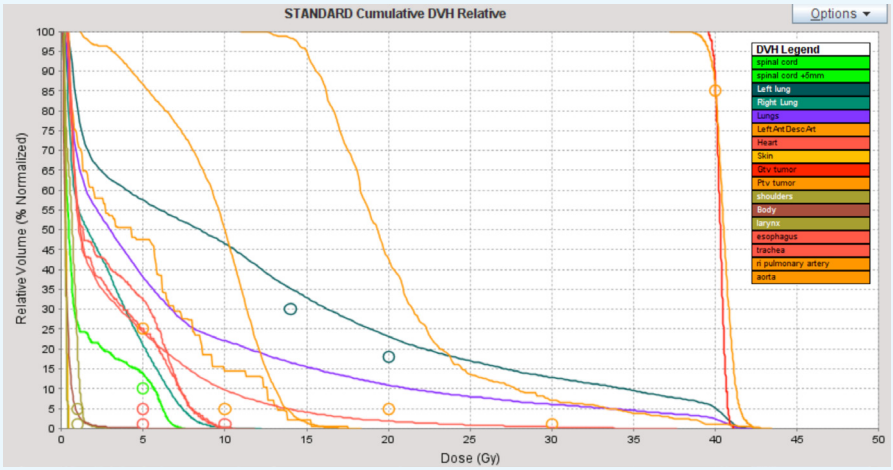


Figure 2. *TomoHelical plan* for the lung nodule

	Supraclavicular Nodule	Lung Nodule
Delivery Mode	*TomoDirect* (3 beams)	*TomoHelical*
Plan Mode	IMRT	IMRT
Field Width	2.5 cm	2.5 cm
Pitch	0.250	0.287
Modulation factor	1.965	2.447
Treatment time	3 min 31 sec	8 min 29 sec

Table 3. Delivery Parameters

Delivery quality assurance (DQA) and machine quality assurance

Before the actual delivery of the dose, both treatments were verified on the DQA station using the cheese phantom with Gafchromic film and ion chambers. Both techniques gave good results. The film dosimetry comparison is shown in Figure 3.

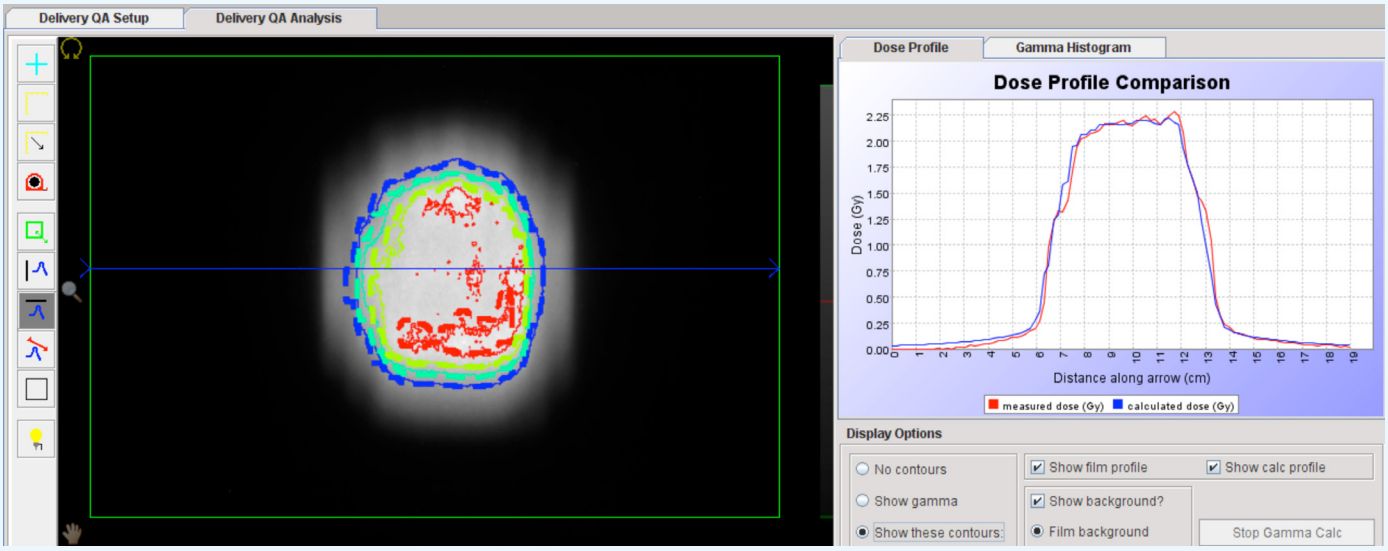


Figure 3. Delivery quality assurance results showing a comparison between measured and calculated doses

Treatment delivery

The delivery of the treatment by the radiographers went smoothly. *TomoHelical* treatment involves the same workflow on the *TomoHD* and *Hi·Art* systems and the delivery of the *TomoDirect* treatment was equally straightforward. The Operator Station screen indicates the treatment progress via icons displaying gantry movement and when the radiation starts for successive beams. *TomoDirect* treatment delivery proceeds in a similar fashion to fully-automated IMRT on a conventional linear accelerator. A feature of *TomoDirect* (as with *TomoHelical*) delivery is that very long volumes can be treated without field junctions: this was obviously not a consideration for this case but adds clinical flexibility relative to conventional systems.

Initial perceptions

The treatment of the first patients on the *TomoHD* treatment went so smoothly that we felt confident to increase the patient number continuously to 25 per day during the first month. This is only the beginning: we now continue to increase our overall patient throughput by investigating the best balance of *TomoHelical* and *TomoDirect* treatments.

Conclusions

The replacement of the *Hi·Art* treatment system by the new *TomoHD* treatment system took place without any problems. Firstly, the *TomoHD* unit fit into the footprint of the previous *Hi·Art* unit, which made installation easy. Also the commissioning and acceptance was as fast as with the *Hi·Art* system. After five days of acceptance testing, the world's first clinical *TomoHD* system was ready for clinical use. The radiographers easily adapted to the new user interface and the physicists were intrigued by the new planning system interface and features. The new hardware and software makes planning much faster and the three-control point system for DVHs allows more detailed planning. Better control leads to even better dose distributions and conformal avoidance, especially in complicated cases like head and neck treatments.

TomoDirect treatment plans turned out to be very fast and easy to create. The delivery of a *TomoDirect* treatment is straightforward and automated via the Operator Station. Based on the speed improvements in all stages of the planning and delivery process, the multi-disciplinary team at University Radiotherapy Antwerp agrees that more patients will have the chance to benefit from TomoTherapy℠ treatments because of the introduction of the *TomoHD* treatment system.