Technical Study

High definition dynamic radiosurgery (HDRS) with Elekta Versa HD™ and Monaco®

A multi-institutional study measuring Intracranial Stereotactic Radiosurgery accuracy with a PseudoPatient™ phantom

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Summary

Phantom:
RTsafe PseudoPatient™

TPS:
Monaco®

Delivery System:
Versa HD™ (with XVI and HexaPOD™ evo RT system)

Simulated Plan:
- 6x brain metastatic targets (6–25 mm)
- 1x larger QA target close to brainstem
- Isocenter at centroid of targets
- Dose to targets = 8 Gy
- 5x non-coplanar arcs (lateral, vertex, 315° and 45°)

1. Introduction

The combined use of Elekta Versa HD (equipped with Agility™) and Monaco, together with advanced image guidance and patient positioning (enabled by XVI and HexaPOD evo RT system) allows High definition dynamic radiosurgery (HDRS). A multi-institutional study was designed to measure the end-to-end accuracy of the HDRS workflow to deliver a single isocenter, multiple brain metastases VMAT plan.

This validation project was performed at Farrer Park Hospital in Singapore. Farrer Park Hospital is a private tertiary healthcare institute and was the first hospital in Southeast Asia to use Elekta Versa HD.

Equipped with this state-of-the-art linear accelerator, the hospital's radiation oncology department offers a wide range of radiation therapy techniques, including 3D-CRT, IGRT, IMRT, VMAT and SRS/SRT, as well as HDR brachytherapy. In addition, the department offers treatments using Elekta Active Breathing Coordinator™ for the non-invasive, internal immobilization of anatomies affected by respiratory motion, and Elekta Fraxion™ for patient-specific cranial immobilization. This site uses Monaco version 5.11.02 treatment planning software and MOSAIQ® version 2.64.167 oncology information system.

2. Materials and Methods

A patient-derived, multiple brain metastases CT data set of the phantom was provided as the model for the study. Six targets, ranging from 6–25 mm in diameter, were distributed in the brain (including at the periphery) to test the effects of rotation on localization accuracy across the brain. A seventh, larger target near the brainstem was included for quality assurance (QA) purposes.

3D dosimetry was performed using the RTsafe PseudoPatient gel phantom (RTsafe P.C., Athens, Greece). In addition, two nearly identical phantoms were provided to accommodate different detectors (an A16 ionization chamber and a film cassette) at the location of the larger QA target.

Planning

The HDRS treatment plan was created in Monaco version 5.11.02. The isocenter was positioned at the centroid of the targets. Five non-coplanar VMAT arcs were used (lateral, vertex, 315° and 45°) to deliver 8 Gy to the six targets, with peak doses remaining less than 12 Gy. A homogeneous dose of 8 Gy was planned for the QA target. Target penalty, quadratic overdose and conformality objectives were used for IMRT constraints. A 1 mm dose calculation grid setting was used with 1% statistical uncertainty per calculation of dose to medium. In the five single arcs, 180 control points were allowed with 0.5 cm minimum segment width, and medium fluence smoothing was used.

Quality assurance

Before delivery of the plan to the PseudoPatient phantom, plan QA was performed with Mobius3DFX (M3D) QA software and measured using a 20 cm slabs phantom with Gafchromic EBT3 film. An overview of the QA results is shown in Table 1.

ROI Overview

	TPS Name	Volume	3D Gamma (3.0%/2 mm)	Mean Dose				Density Override
				TPS	M3D	Delivered	% Diff	
	FilmTarget	5.48 cc	85.1%	8.524 Gy	8.779 Gy	8.805 Gy	2.25%	None
	IC_final	0.07 cc	95.2%	8.605 Gy	8.855 Gy	8.826 Gy	1.77%	None
	skin	3351 cc	100%	1.092 Gy	1.093 Gy	1.112 Gy	0.16%	None
	T1-13 mm	0.71 cc	93.4%	9.542 Gy	9.902 Gy	9.988 Gy	3.57%	None
	T2-21 mm	2.59 cc	99.9%	9.987 Gy	10.052 Gy	10.129 Gy	1.13%	None
	T3 ring	40.8 cc	100%	1.851 Gy	1.795 Gy	1.854 Gy	0.02%	None
	T3-6 mm	0.06 cc	100%	9.424 Gy	9.192 Gy	9.296 Gy	-1.02%	None
	T4-25 mm	5.18 cc	95.7%	10.094 Gy	10.318 Gy	10.364 Gy	2.16%	None
	T5-9 mm	0.13 cc	100%	9.639 Gy	9.409 Gy	9.42 Gy	-1.75%	None
	T6-17 mm	2.14 cc	100%	9.829 Gy	9.687 Gy	9.797 Gy	-0.25%	None
	targets	12 cc	97.7%	9.824 Gy	9.927 Gy	9.995 Gy	1.37%	None

Table 1.
Overview of plan QA results (% diff are delivered vs. TPS)

In addition, in-house film dosimetry analysis was performed using FilmQA Pro software. With 2D gamma criteria of 2%/2 mm, a passing rate (gamma index < 1) of 96.9% was achieved (Figure 1).

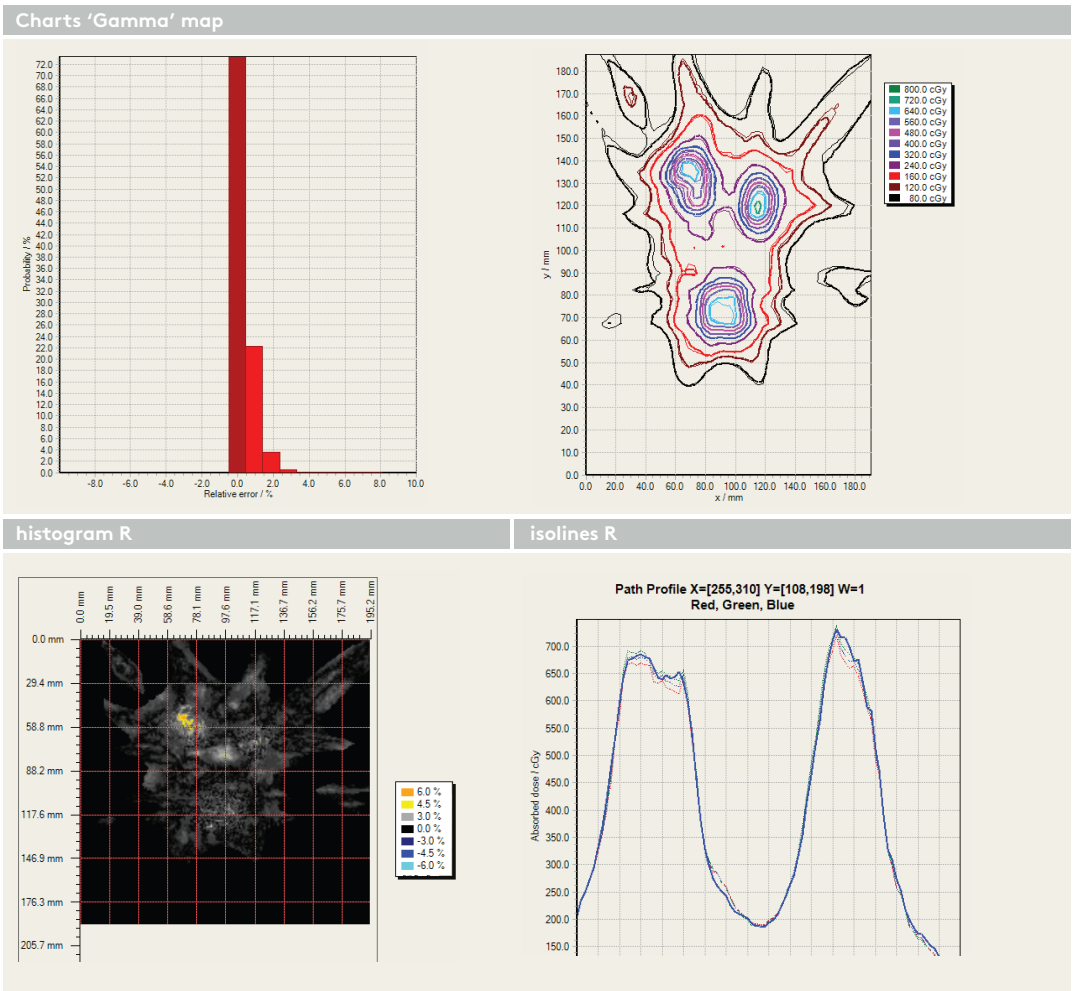

Figure 1.
FilmQA Pro QA results

Delivery

The patient-derived CT data set was sent to MOSAIQ record and verify system and imported to XVI. The isocenter was confirmed and the registration clipbox was set to cover the entire skull. The gel phantom was set up on the treatment table using Fraxion, including a customized headrest and a thermoplastic mask that was connected to the iBeam® evo Couchtop using the Fraxion Linac Tabletop Adapter (2DoF) (Figure 2). A VolumeView cone beam CT (CBCT) scan was acquired using XVI, and corrections were made using a combination of the 2DoF adapter and HexaPOD evo RT System (6DoF). A second VolumeView image was acquired to ensure positional accuracy before the five arcs were delivered.

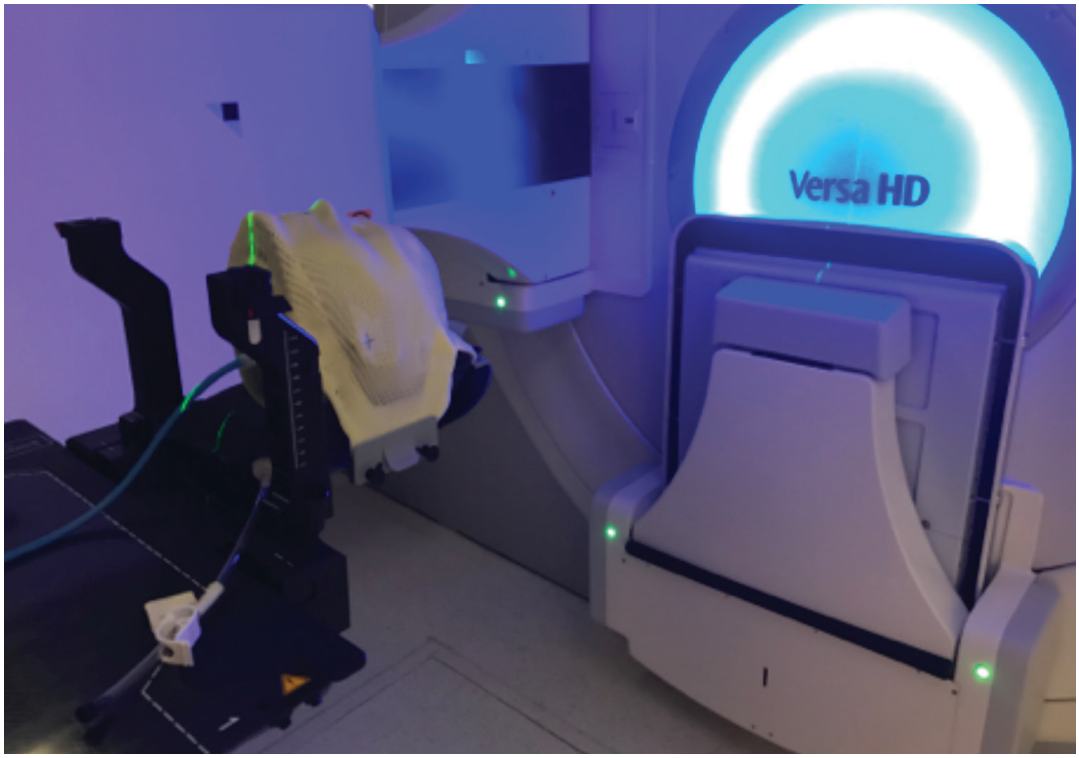

Figure 2.
PseudoPatient phantom set up for treatment delivery

The process was repeated for the ionization chamber and film insert phantoms. The PTW Semiflex Ionization Chamber 31010 was cross-calibrated before use. Gafchromic EBT3 film (batch calibrated at a secondary standard laboratory) was used for the film phantom measurement.

After irradiation, the gel phantom was scanned on a 1.5 T MRI unit, following the protocol developed and recommended by the gel producer (RTsafe P.C.). The resulting scan was fused with the patient-derived CT data set for analysis. Quantitative analysis was performed with 3D gamma analysis and dose profile analysis. The film was also scanned and compared to the calculated dose distributions.

3. Results

Ion Chamber

The dose to the QA target measured by the ionization chamber was 859.4 cGy. By comparison, the mean dose in the ion chamber region of the patient-derived CT dose calculation was 881.6 cGy. This represents a difference of 2.6%, which is a sufficient level of agreement for an end-to-end test at our institution.

Film Analysis

Comparing the film-measured and TPS-calculated dose distributions (Figure 3), the gamma analysis passing rate (gamma index < 1) with 2%/2 mm criteria was 96.52%.

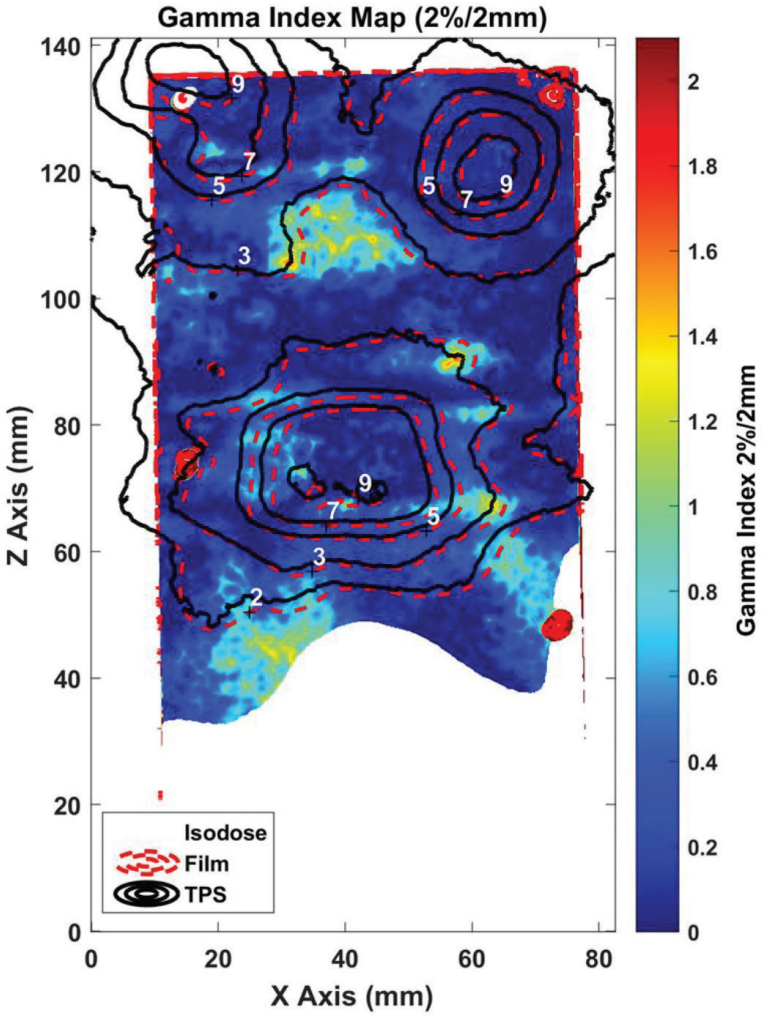

Figure 3.
2D comparison between film-measured and TPS-calculated dose distributions using passing criteria of 2%/2 mm

Gel Phantom Analysis

Dose profiles and 3D gamma analyses were compared between gel-measured and TPS-calculated dose distributions. Figure 4 shows sample gel phantom MRI scan slices with corresponding dose profile comparisons and 1D gamma analysis along the profiles (5%, 2 mm). The high dose regions (darker areas) can be seen as the dose conforms to the target contours. For the QA target, the 3D gamma analysis passing rate (gamma index < 1) with criteria of 3%/2 mm was 95.02%. Using criteria of 5%/2 mm, the passing rate for all targets was > 96%.

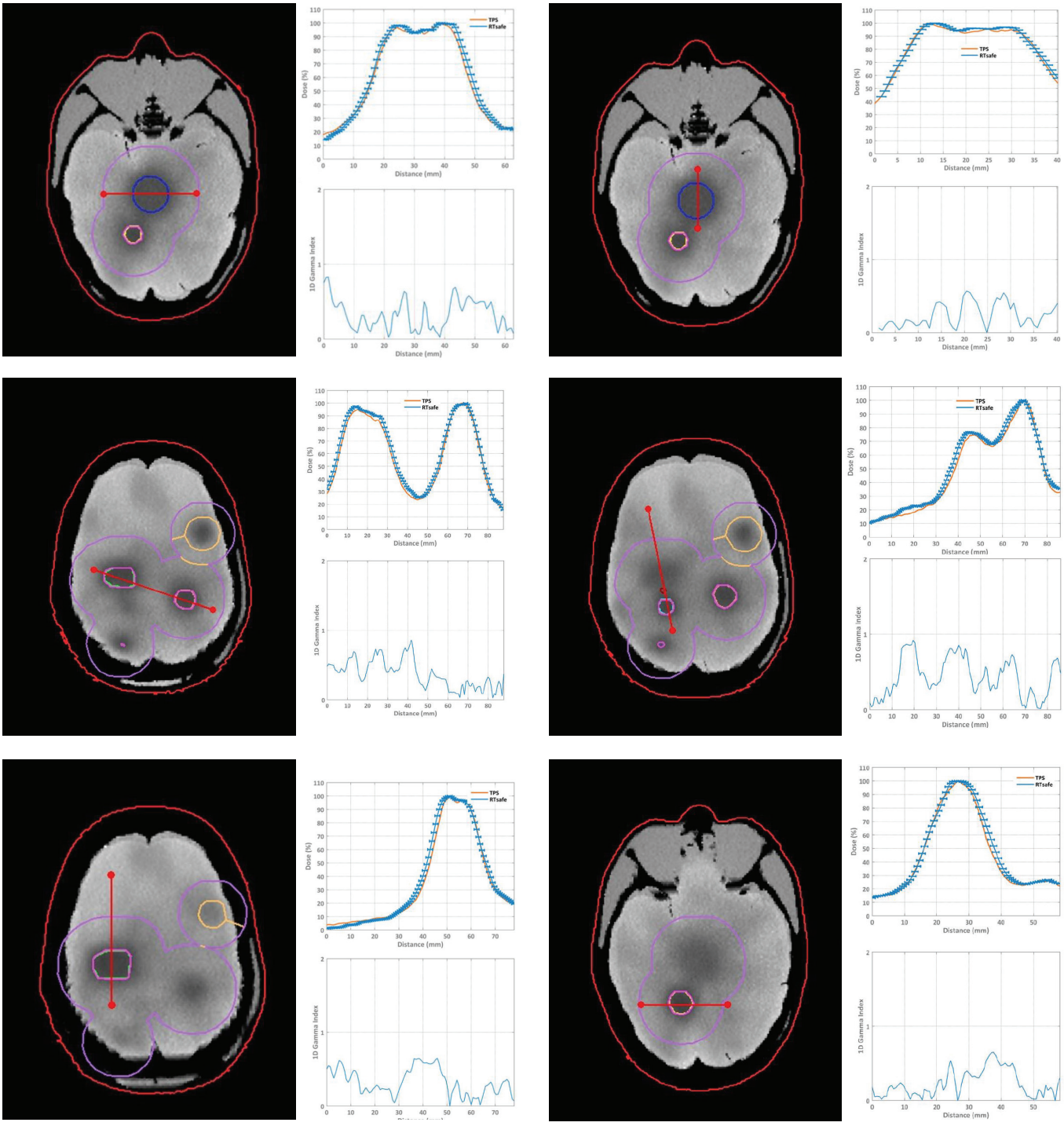

Figure 4.
Sample gel phantom MRI scan slices with corresponding dose profile comparisons and 1D gamma analysis calculations using passing criteria of 5%, 2 mm

4. Discussion and Conclusions

As part of a multi-institutional study, the results at this site demonstrate the suitability of Versa HD and Monaco for accurate and efficient High definition dynamic radiosurgery.

During phantom set up, the initial CBCT indicated significant rotation and tilt that could not be corrected using HexaPOD alone (Figure 5). However, this was able to be corrected using a combination of the Fraxion Linac Tabletop Adapter (2DoF), which corrected for part of the rotation and tilt, and HexaPOD evo RT System, which completed the shift with 6DoF.

The high degree of end-to-end accuracy demonstrated in this validation project reflects the precision of the entire system. It is the combined effect of a number of elements, including: Monaco's high-definition modulation to achieve steep dose gradients and conformality using IntelliBeam to support up to 1024 control points per beam and dynamic jaw tracking to achieve virtual leaf widths; dose calculation accuracy for multiple and small lesions with the Monte Carlo dose calculation algorithm, multicriterial optimization (MCO) and exceptionally low MLC leakage; the physical and dynamic capabilities of the Agility MLC; image guidance and precise patient positioning using XVI, HexaPOD evo RT System and, in this case, Fraxion.

In our opinion, the precision and capabilities of the major components along the beam line, such as the flattening filters, jaws and Agility MLC, as well as Monaco with the Monte Carlo algorithm, are extremely important for providing a safe and homogenous solution to cancer centers globally. By ensuring high geometric and dosimetric accuracy, and reproducibility across multiple sites, this increases clinical confidence and provides additional assurance to our clinicians and patients.

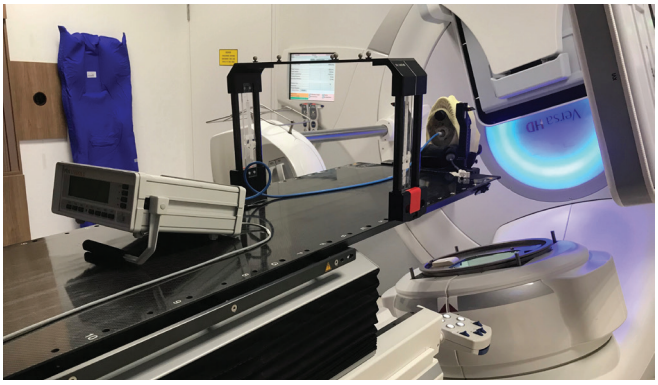

Figure 5.

Disclaimer

This publication 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 cause side effects that vary depending on the clinical site 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.

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Our nearly 4,000 employees worldwide are committed to ensuring everyone in the world with cancer has access to—and benefits from—more precise, personalized radiotherapy treatments.

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