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Quality Assurance for Radixact® ClearRT™ Helical kVCT Imaging

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Introduction and Overview

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Accuray Disclaimers and Disclosure

Medical Advice Disclaimer

Accuray Incorporated as a medical device manufacturer cannot and does not recommend specific treatment approaches. Individual results may vary.

Safety Statement

Most side effects of radiotherapy, including radiotherapy delivered with Accuray systems, are mild and temporary, often involving fatigue, nausea, and skin irritation. Side effects can be severe, however, leading to pain, alterations in normal body functions (for example, urinary or salivary function), deterioration of quality of life, permanent injury and even death. Side effects can occur during or shortly after radiation treatment or in the months and years following radiation. The nature and severity of side effects depend on many factors, including the size and location of the treated tumor, the treatment technique (for example, the radiation dose), the patient's general medical condition, to name a few. For more details about the side effects of your radiation therapy, and if treatment with an Accuray product is right for you, ask your doctor.

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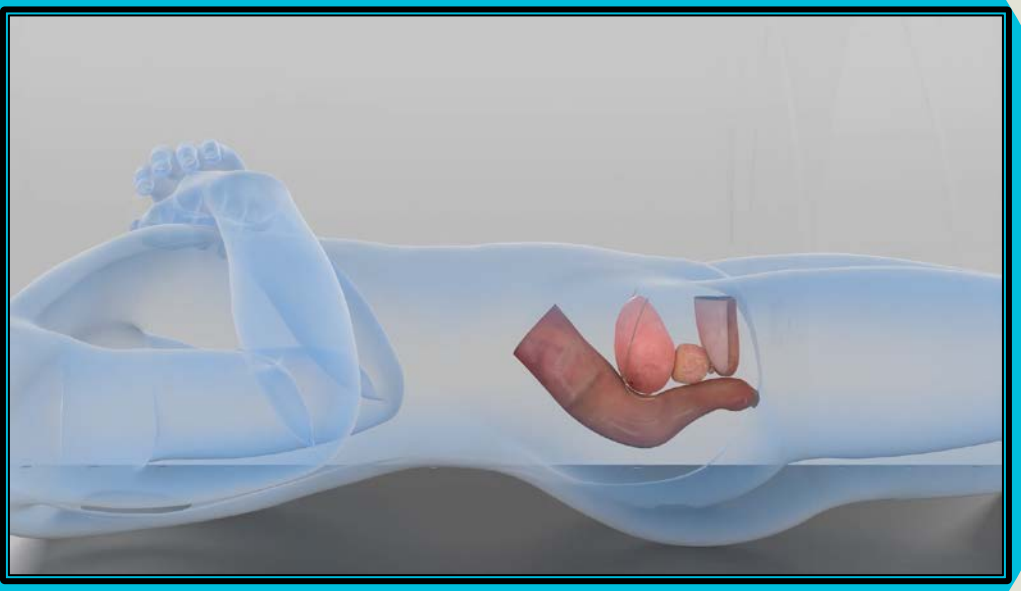
ClearRT™ Overview

ClearRT™ Helical Fan-beam kVCT

High-fidelity kVCT imaging enables clinicians to see more, know more, and do more



Acquisition method similar to diagnostic CT

Inherently fewer artifacts for better uniformity and fidelity

True-helical delivery platform

Expanded imaging flexibility

Integrated kV system for a seamless RT workflow

Simple guided 5-step delivery; Automated delivery adaptation and daily dose trending

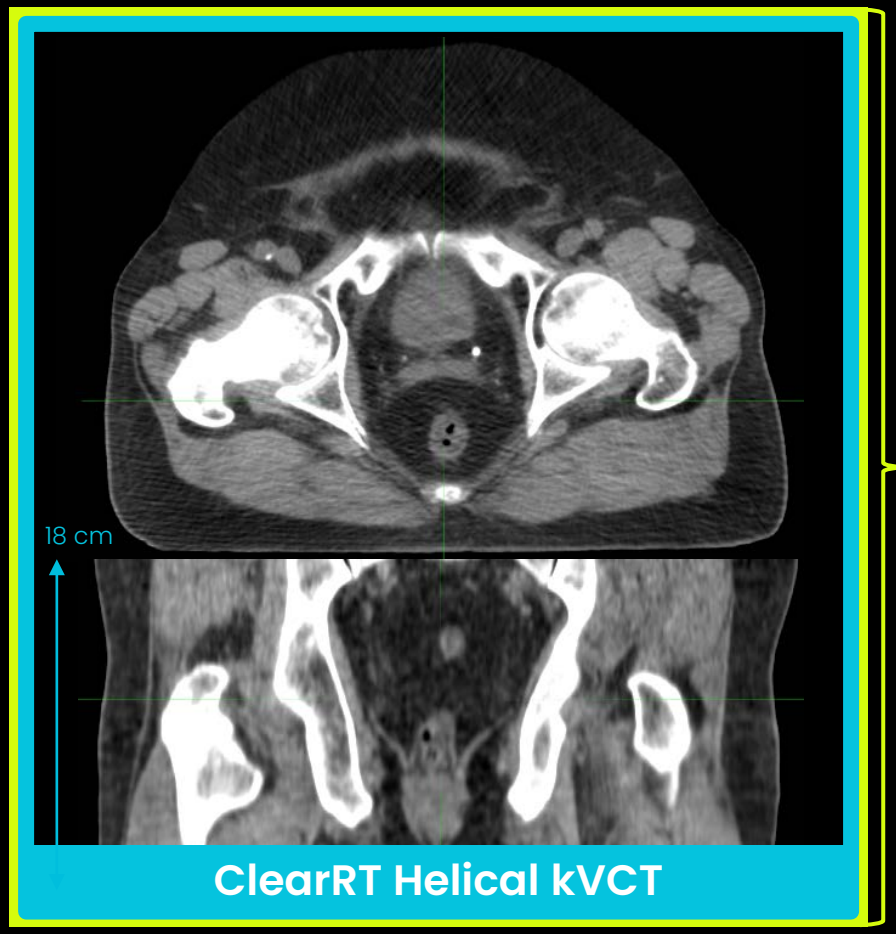
ClearRT™ Helical Fan-beam kVCT

Image fidelity approaching diagnostic quality*

CHALLENGE: Can you differentiate the image sets?

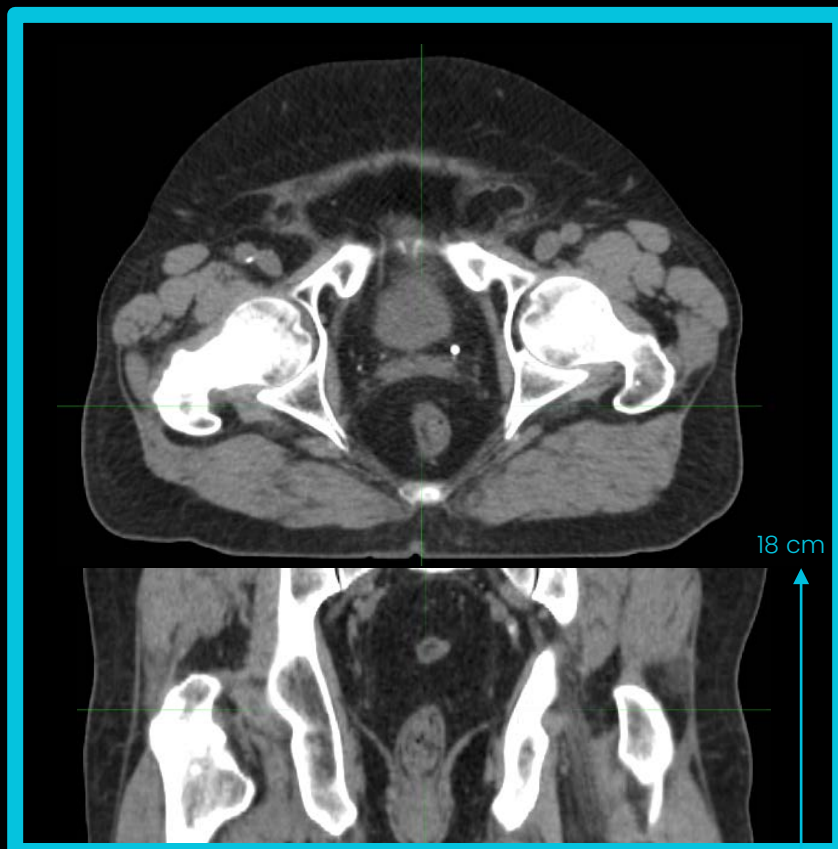
Which is the diagnostic CT as opposed to the ClearRT™ helical fan-beam kVCT?

WW 400 HU
WL 40 HU



ClearRT Helical kVCT

- Acquisition time = 49 s
- High level uniformity and HU consistency
- Excellent soft-tissue contrast and visualization
- Image quality consistent along the entire superior/inferior length



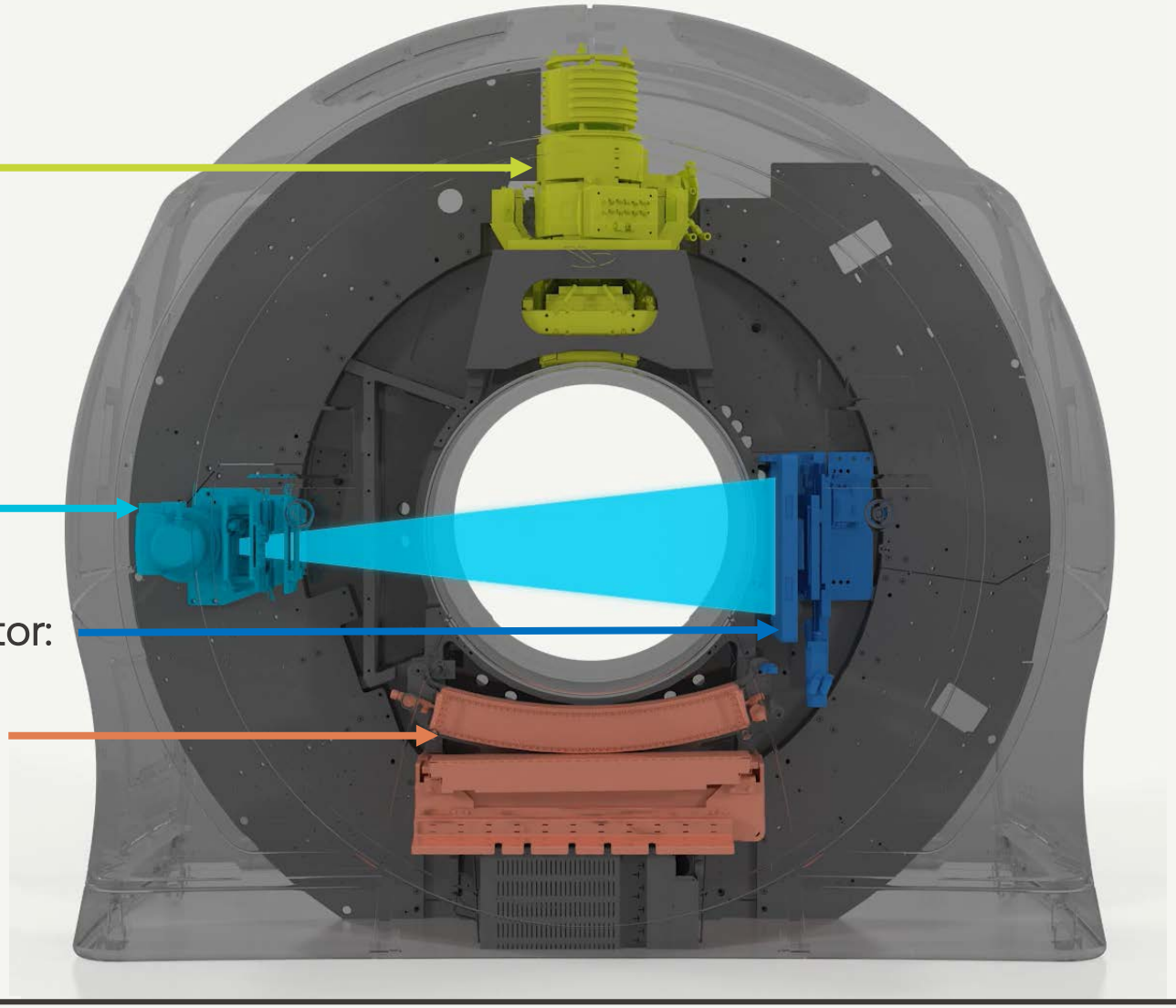
Diagnostic CT

*ClearRT kVCT images are not intended for diagnostic purposes

Images courtesy of Willis-Knighton Medical Center, Shreveport LA

Integrated kV Imaging System

Supports ClearRT™ Helical kVCT Imaging and Synchrony® Real-Time Delivery and PreciseART® Adaptation options

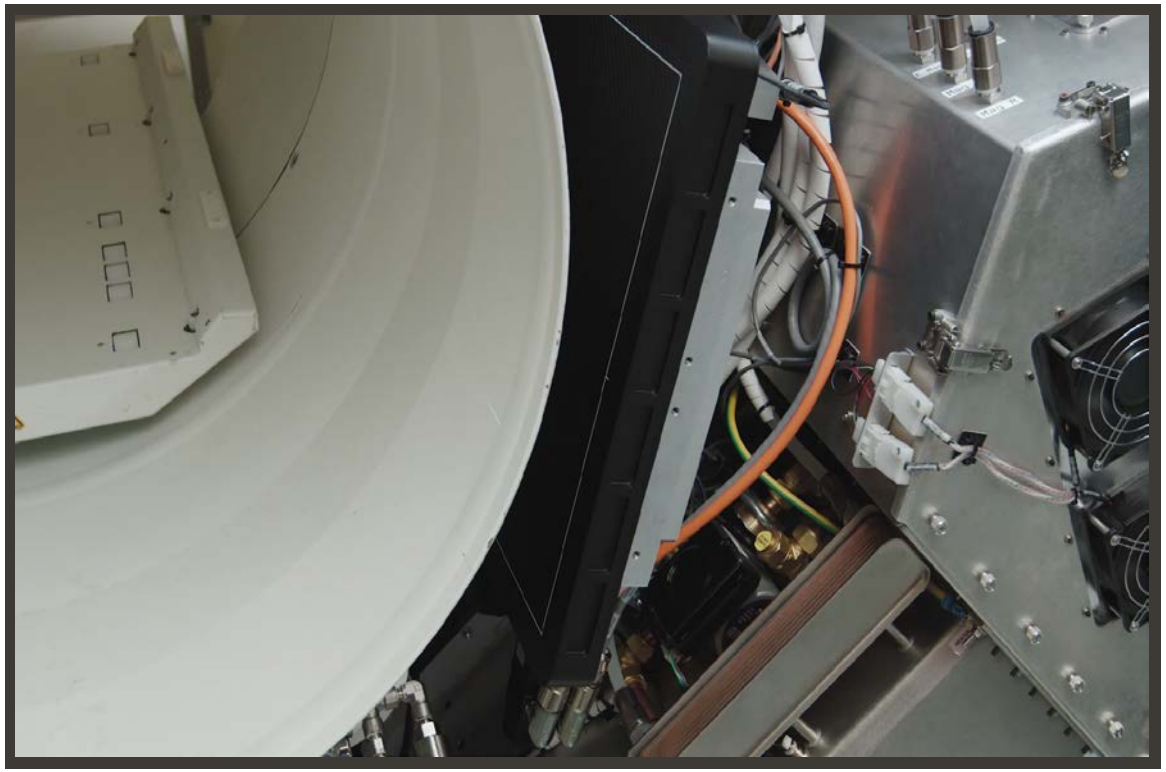


Purpose:

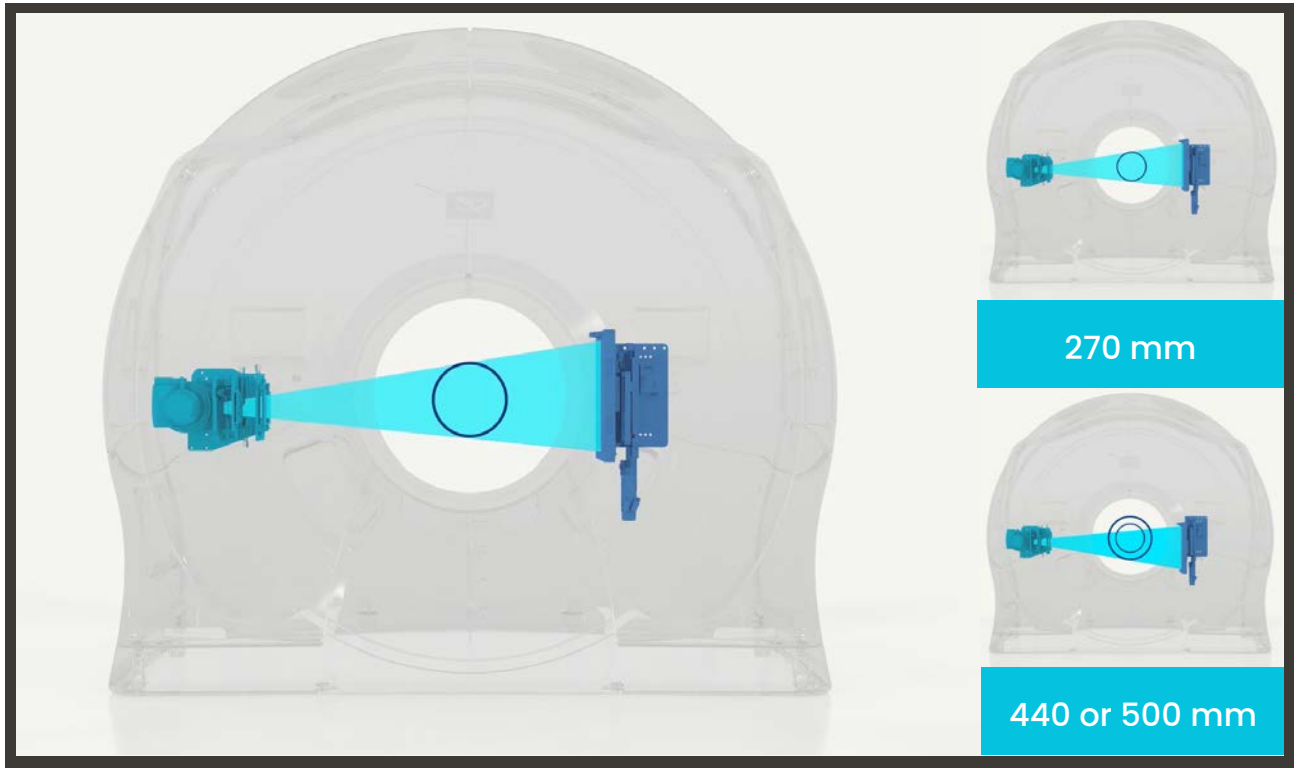
- Pre-treatment setup verification
- Planning and adaptive calculation at site's discretion

Up to a 50 cm Transverse Field of View (FOV)

Right-sized imaging for every patient



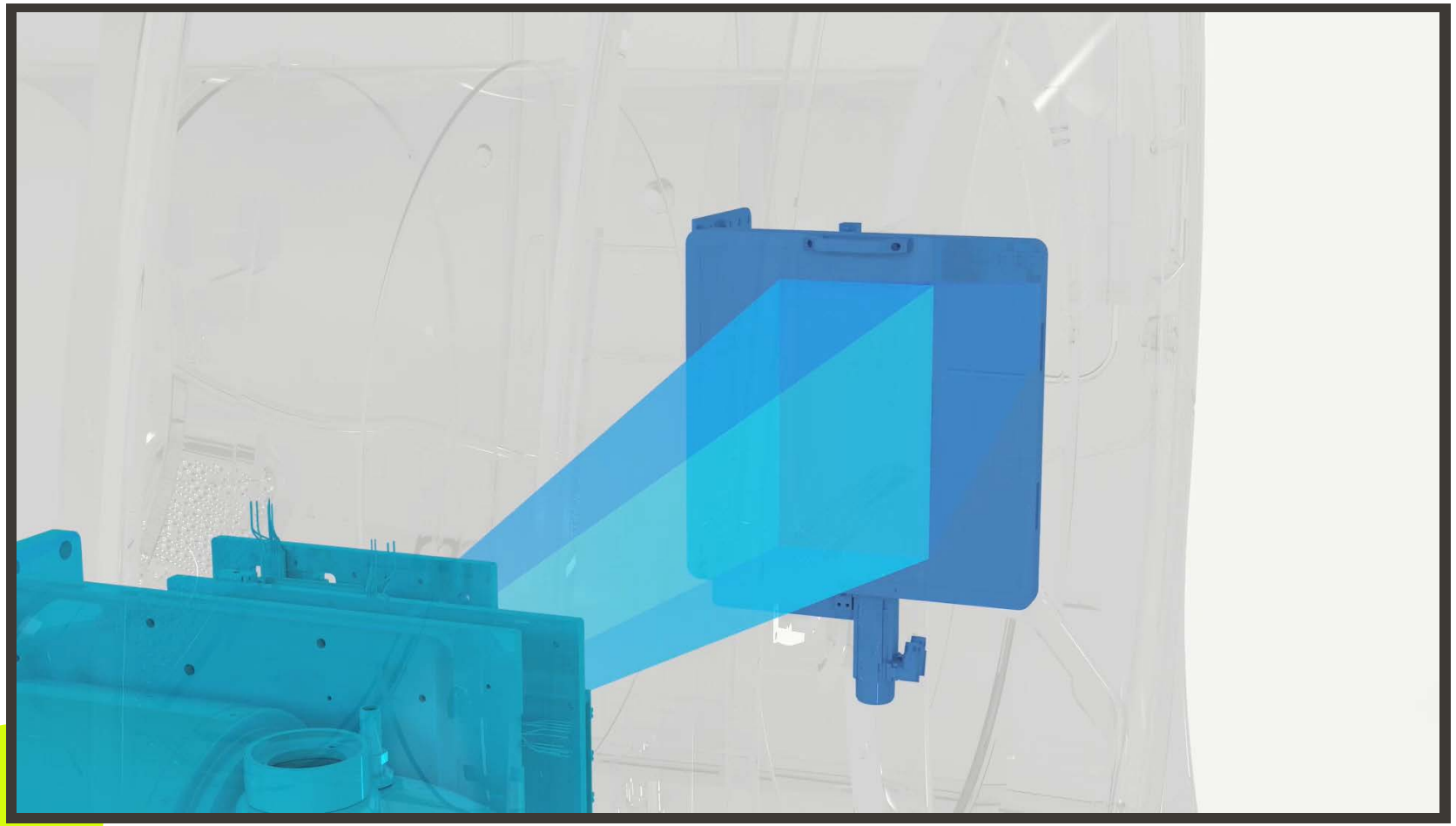
kV flat panel detector mounted on the gantry provides customizable FOV: 270 mm, 440 mm, and 500 mm



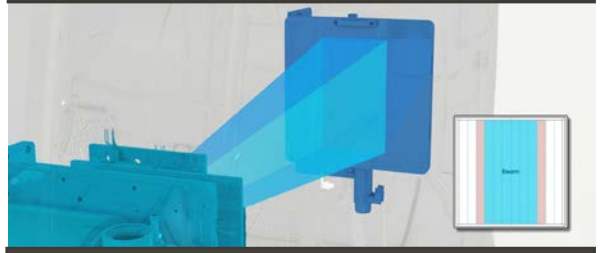
The kV detector translates laterally from a centered position toward the MV detector to expand the transverse FOV

Adjustable IEC-Y Fan-beam Width at Isocenter

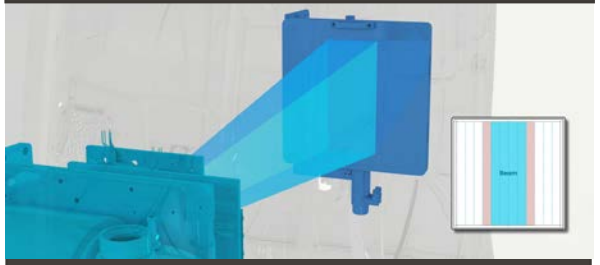
Wide fields increase scan speed. Narrow fields help reduce image scatter.



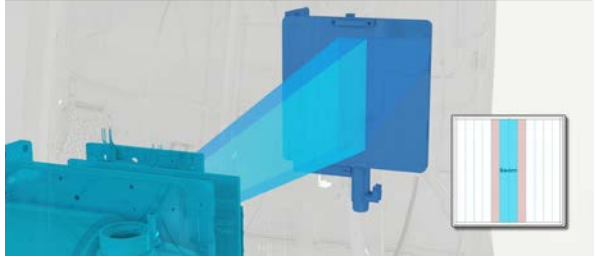
Course mode:
140 mm for 270/440mm FOV;
134 mm for 500 mm FOV



Normal mode:
100 mm

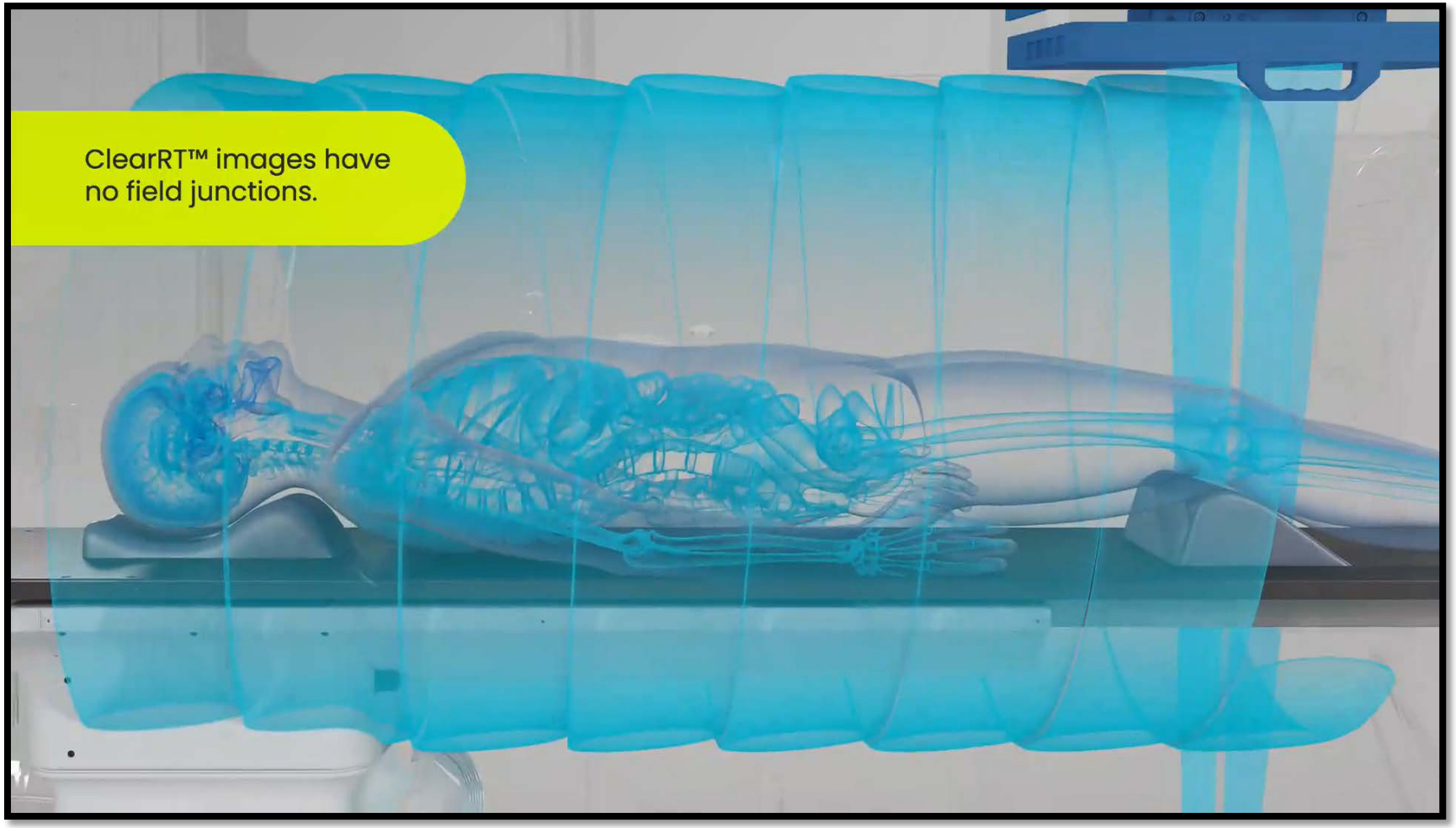


Fine mode:
50 mm



Exceptional Superior/Inferior Field of View (up to 135 cm)

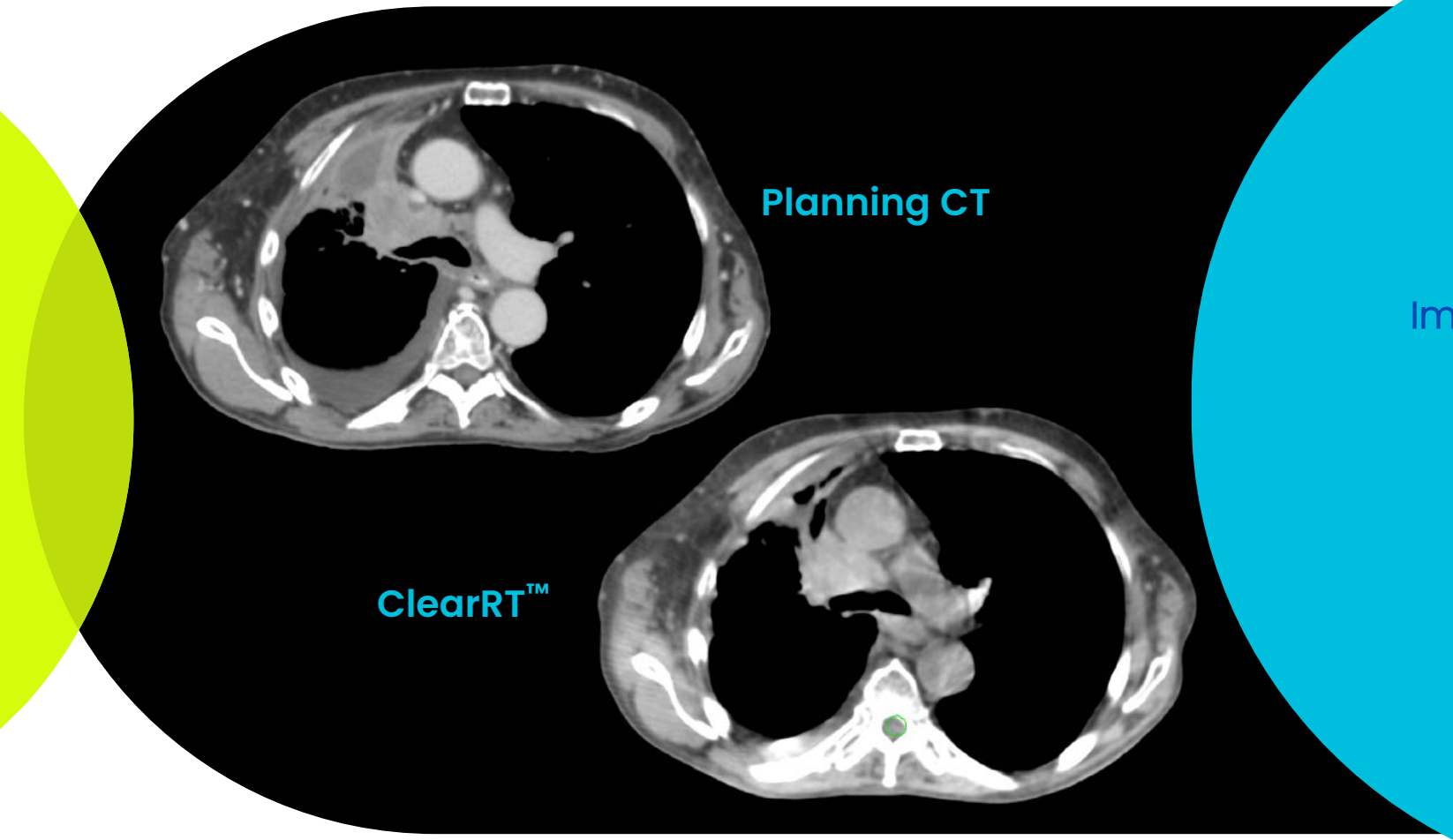
See all anatomy needed in a single scan length for patient registration and dose trending



- **Fast Acquisition: up to 1 m/min**
  Not limited to 1 minute per rotation like conventional RT systems
- **Imaging Dose: 0.4 – 4 cGy**
  Protocol-dependent

PATIENT CASE HIGHLIGHTS:

Lung Target

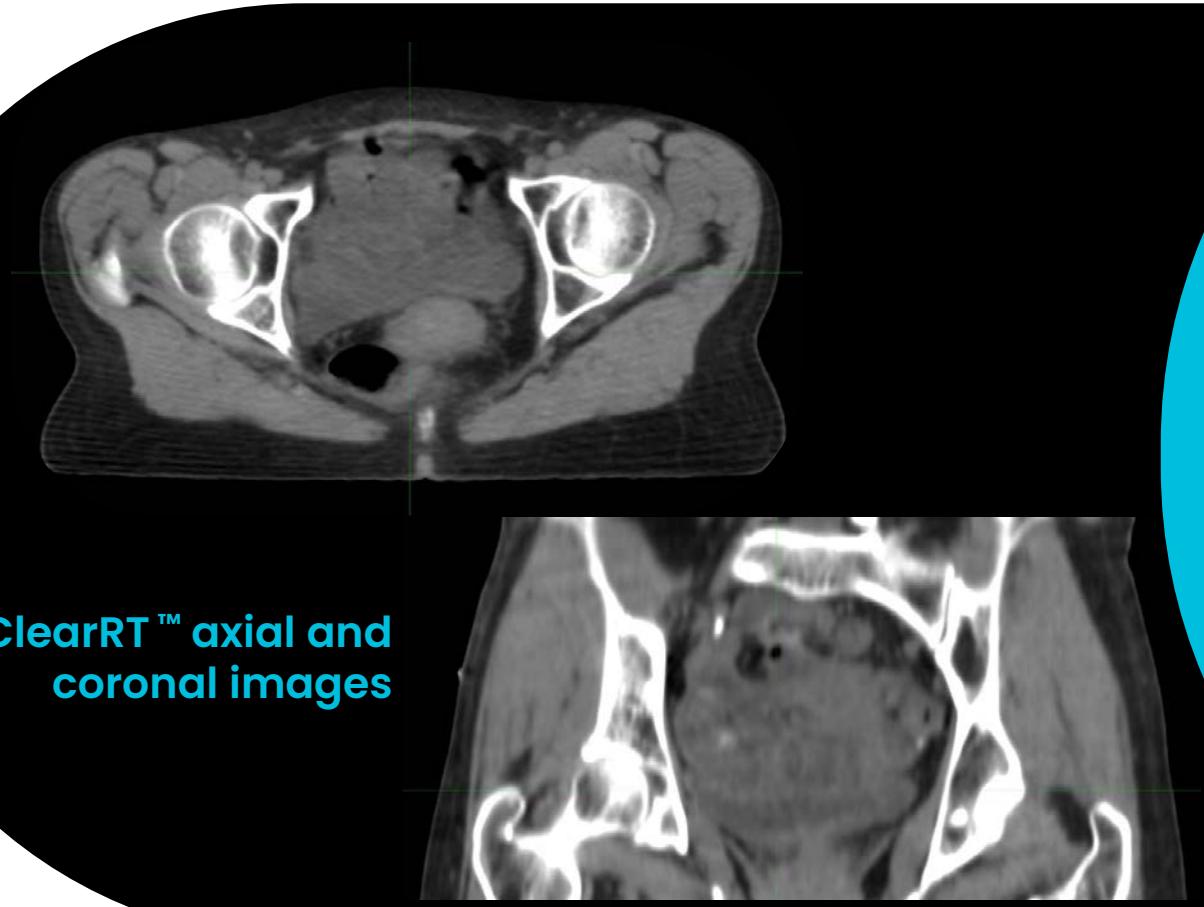


Clinical Indication	Lung
ClearRT Imaging Method	44 cm FOV Fine scan mode
$CTDI_{vol}$	1.2 cGy (32-cm CTDI phantom)
Acquisition Length	19 cm
Acquisition Time	49 seconds

Patient image and plan data provided by Willis-Knighton Cancer Center, Shreveport LA, USA

PATIENT CASE HIGHLIGHTS:

Cervical Cancer SBRT



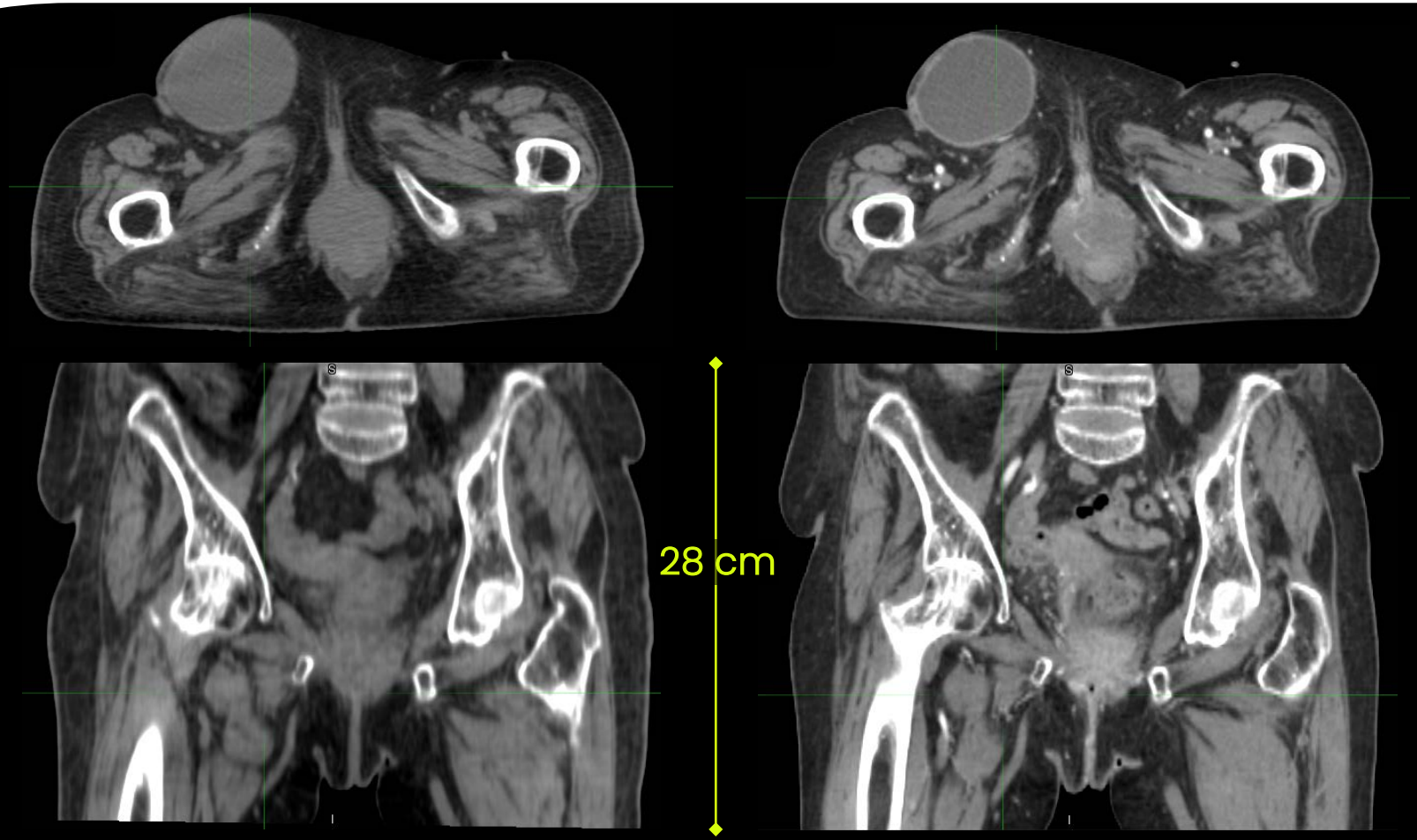
ClearRT ™ axial and coronal images

Clinical Indication	Stage IIB Cervical Cancer
Prescription	45 Gy 9 Gy x 5 fractions
ClearRT Imaging Method	44 cm FOV Fine scan mode
$CTDI_{vol}$	1.2 cGy (32-cm CTDI phantom)
Acquisition Length	16 cm
Acquisition Time	42 s

Patient image and plan data provided by Willis-Knighton Cancer Center, Shreveport LA, USA

PATIENT CASE HIGHLIGHTS:

Vulva



ClearRT™, Normal mode, <50 s
no contrast

Planning CT
with contrast

Patient image and plan data provided by Willis-Knighton Cancer Center, Shreveport LA, USA

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Image Quality Assurance for ClearRT ™

Quality Assurance

Routine QA

There is no additional required equipment for ClearRT™ Helical kVCT QA

- ClearRT™ helical kVCT imaging requires typical imaging QA, primarily related to kV/MV alignment, image quality, and image dose
  - A1SL ion chamber and the *Tomo*-Phantom HE with density and resolution plugs can be used for these activities (note you may wish to have an A1SL or other thimble-style ion chamber calibrated at kV energies)
- If you intend to use images for adaptive dose calculations (e.g., with in PreciseART®), a density model will need to be created
  - The Tomo-Phantom HE and the associated density plugs
  - Sun Nuclear Advanced Electron Density Phantom

Standard Quality Assurance Package

(INCLUDED WITH NEW RADIXACT® SYSTEMS)

This kit includes phantoms and ion chambers for routine machine and patient-specific QA tests specified by AAPM TG-148, as well as density model creation for planning and assessments of image quality.

Image Quality Check Schedule

- Daily
  - Set up a phantom with known shifts, acquire ClearRT™ image, register to planning image, and verify offsets
  - Apply offsets to couch and check couch position
- Weekly
  - kVCT Number Calibration, if calculating dose on kV images
- Monthly or semi-annually
  - Image quality: HU values, uniformity, noise, phantom diameter, artifacts, transverse spatial resolution, low contrast
  - kV to MV alignment
- Annually
  - Imaging dose

TQA™

ClearRT ™ Image Quality Tolerances

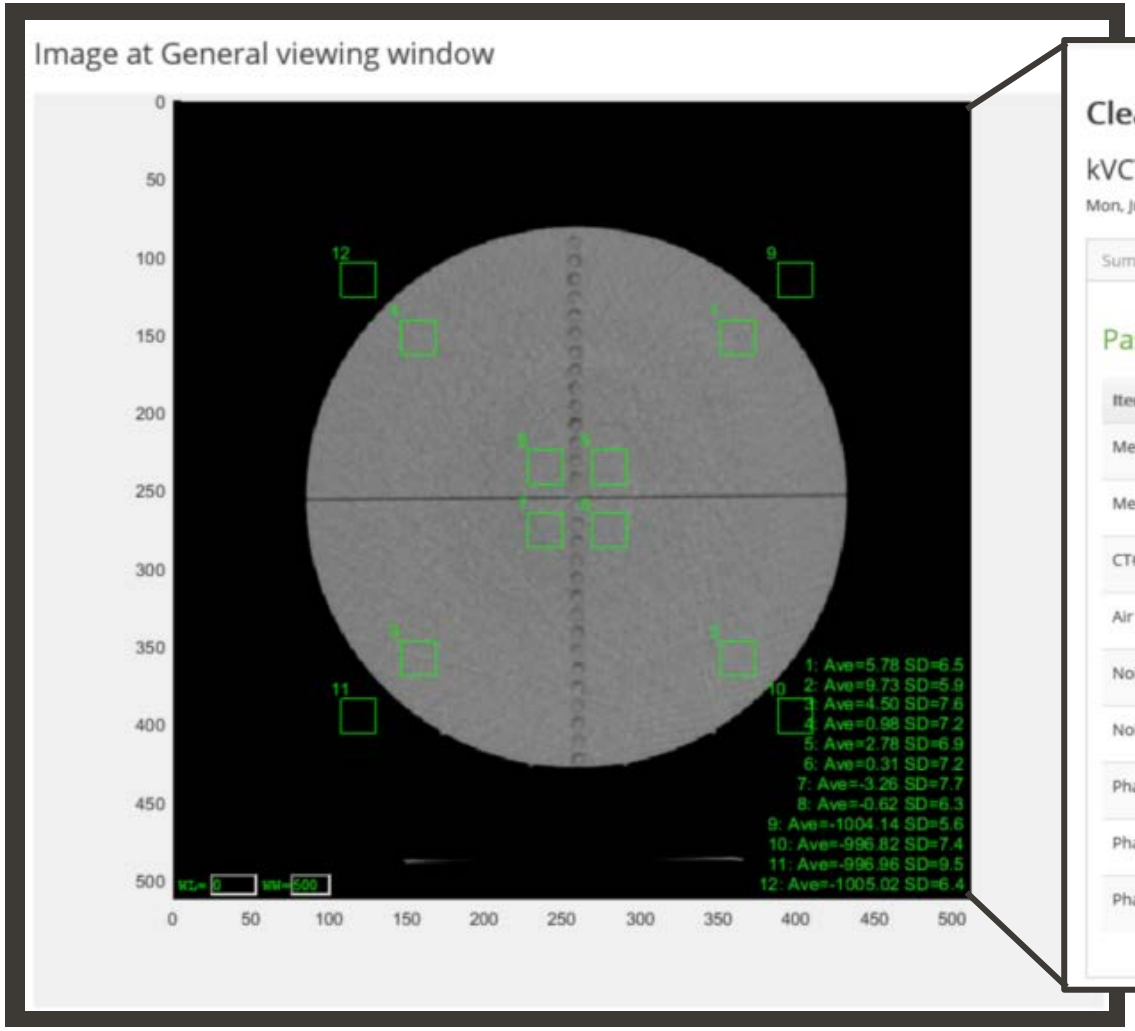
Parameter	Tolerance	Measurement Method	Protocol
Mean HU in TomoPhantom	within ± 15 HU of **Water HU** value in **Edit Machine: Linearity Settings**	TQA Image Quality analysis of kVCT Number Calibration images	**Thorax, large, 440 mm, fine**
Mean HU in air	-1000 ± 40 HU		
CT # Uniformity	≤ ± 25 HU		
Noise	≤ 20 HU		
Phantom diameter	300 ± 2 mm		
Artifacts	Subjectively free from excessive artifacts	Examine image	**Pelvis, large, 500 mm, fine**
Transverse spatial resolution	Can count five holes in second smallest row	Scan TomoPhantom with spatial resolution plug (holes must face outward)	**Head, small, 270 mm, fine**
Low contrast	Compare against baseline	Scan TomoPhantom with water plug; compare water HU to adjacent background HU	**Thorax, medium, 440 mm, fine**
kV to MV alignment	X, Y, Z offsets match within ±0.5 mm	Register ClearRT™ and CTrue™ images of same phantom setup	**Pelvis, large, 440 mm, normal**
Imaging dose	Consistent with expected values within ±50% or ±1 cGy, whichever is greater	Measure $CTDI_{vol,\ free\ air}$ with A1SL calibrated for kV energy	**All**

Weekly CT Number Calibration

- **CT Number Calibration** task on TDC supports kVCT and MVCT
- For dose calculation using ClearRT ™ images, run kVCT Number Calibration weekly to help stabilize HU values over time
- TomoPhantom setup:
  - Set up to the green lasers with the seam line oriented horizontally or vertically
  - Shift ±10 mm in Y to avoid kVCT artifacts from fiducials embedded in phantom surface
  - Examine images for non-uniformities in the ROIs
- Automatically processed by TQA

TQA™ (Total Quality Assurance) Image QA Module

Facilitates image quality verification checks



ClearRT™ Helical kVCT

Accuray, Inc.
Training T4
1240 Deming Way
Madison, WI
USA

kVCT Image QA

Mon, Jun 06, 2022, 09:38:57 AM 4010040 Pass

Summary | Results | Graphs | Images | Files | Stats | Misc

Pass

Item Name	Status	Value	Unit	Low Fail	Low Pass	High Pass	High Fail	Tolerances
Mean CT# (Central ROIs)	●	-0.50059	HU	-50	-25	50	75	
Mean CT# (Peripheral ROIs)	●	5.0696	HU	-50	-25	50	75	
CT# Uniformity (Center ROIs - Peripheral ROIs)	●	-5.5702	HU	-50	-25	25	50	
Air CT#	●	-1000.7	HU	-1024	-1020	920	960	
Noise (Center ROI)	●	7.1396	HU	5	7	20	40	
Noise (Peripheral ROIs)	●	7.0466	HU	5	7	20	40	
Phantom Lateral Offset	●	2.0026	mm	-20	-10	10	20	
Phantom Vertical Offset	●	1.4573	mm	-20	-10	10	20	
Phantom Diameter	●	299.92	mm	290	295	305	310	

Artifacts

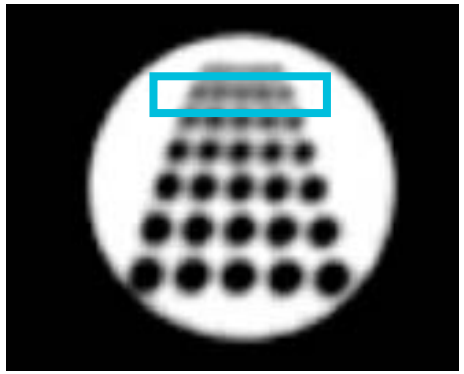
Parameter	Tolerance	Measurement Method	Protocol
Artifacts	Subjectively free from excessive artifacts	Examine image	Pelvis, Large, Fine

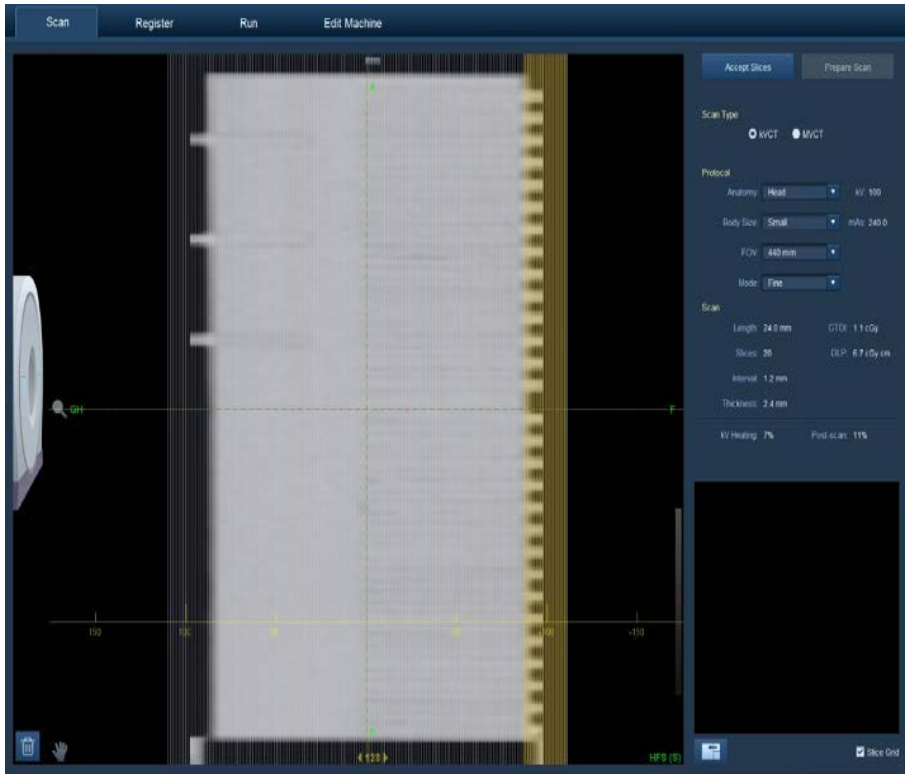
- ClearRT ™ images can be subject to artifacts, for example:
  - If high-density materials are present
  - If the phantom diameter exceeds the scan FOV
  - If the phantom is not centered
  - If there are large longitudinal density discontinuities
- Tolerances for image quality tests only apply to the specified protocols and when the provided setup instructions are followed
- Go to a slice in the uniform section and make sure there are no major artifacts, such as rings, bands, or groups of streaks
  - A major artifact would exhibit dark grey or bright white image regions
  - Typical ClearRT images may still exhibit minor streak artifacts

Transverse Plane Resolution

Parameter	Tolerance	Measurement Method	Protocol
Transverse spatial resolution	Can count five holes in second smallest row	Scan TomoPhantom with spatial resolution plug (holes must face outward)	**Head, Small, Fine**

- Specified spatial resolution only applies to the 270 mm FOV
- Resolution plug holes must face outward to avoid transverse truncation artifacts
- Run the scan and verify that the holes in the second smallest row are countable

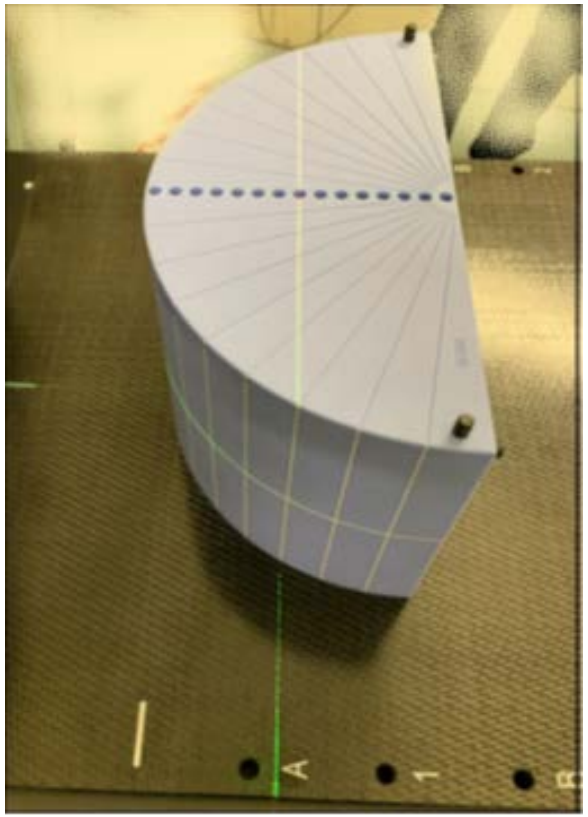




MV to kV Alignment

Parameter	Tolerance	Measurement Method	Protocol
kV to MV alignment	X, Y, Z offsets match within ±0.5 mm	Register ClearRT™ and CTrue™ images of same phantom setup	**Pelvis, Large, Normal**

- Scan the TomoPhantom twice without disturbing the setup:
  - MVCT protocol: **Fine** mode and 1-mm slice interval
  - kVCT protocol: **Pelvis, Large, Normal**
- On the **Register** tab, align each image to the green lasers and record the offsets
- More robust method:
  - Set half the cheese phantom on its face with the empty ion chamber holes aligned longitudinally
  - Use the **Acquire Planning Image** workflow to acquire the MVCT image
  - Create a plan
  - Scan the ClearRT kVCT image against that plan
  - Register the kVCT to MVCT
- X, Y, Z offsets should agree within ±0.5 mm

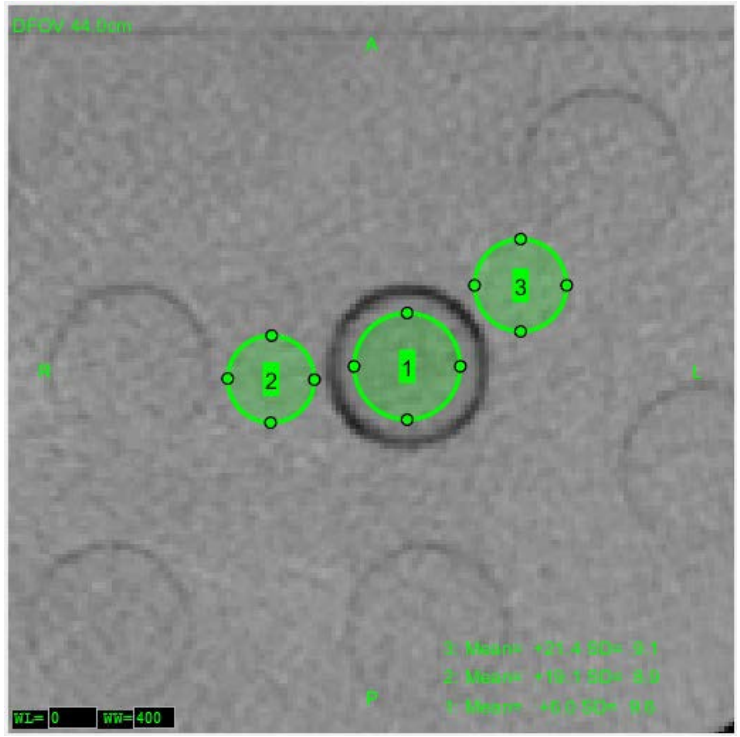


Low Contrast

Parameter	Tolerance	Measurement Method	Protocol
Low contrast	Compare against baseline	Scan TomoPhantom with water plug; compare water HU to adjacent background HU	Thorax, Medium, Fine

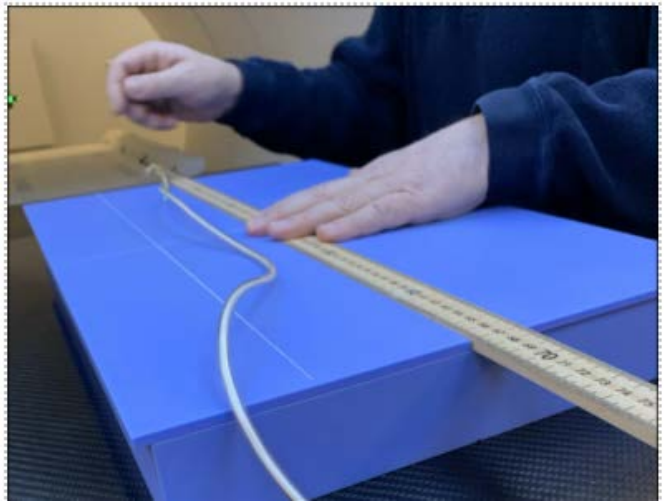
- Choose an image slice that includes the water plug
- Draw three ROIs of similar radius:
  - ROI #1 inside the water plug
  - ROIs #2 and #3 adjacent to the water plug
- Evaluate the mean of the CT numbers in the ROIs
- Calculate low contrast and compare against baseline established at commissioning:

$$Low\ contrast = \frac{ROI\#2 + ROI\#3}{2} - ROI\#1$$



CT Dose

- Components of $CTDI_{vol}$ include:
  - Measurements in free air
  - Measurements in a CTDI phantom with a pencil ion chamber
- The IEC quantity $CTDI_{free\ air}$ can be expressed as: $CTDI_{free\ air} = pitch \int_{-\tau}^{+\tau} R(t)dt$
  - $R(t)$ is the instantaneous dose rate
  - $\pm \tau$ spans the time for the probe to move through the beam
- Define: $CTDI_{vol,free\ air} = \frac{CTDI_{free\ air}}{pitch} = \int_{-\tau}^{+\tau} R(t)dt$
  - $CTDI_{vol,free\ air}$ is the cumulative charge measured for a clinical helical scan as a small ion chamber traverses the beam
  - Accuray provides $CTDI_{vol,\ free\ air}$ measurements for reference
  - The A1SL can be used with appropriate calibration
  - Measurements of $CTDI_{vol,\ free\ air}$ should be consistent with the values in the *Physics Essentials Guide*



ClearRT™ Helical Fan-beam kVCT

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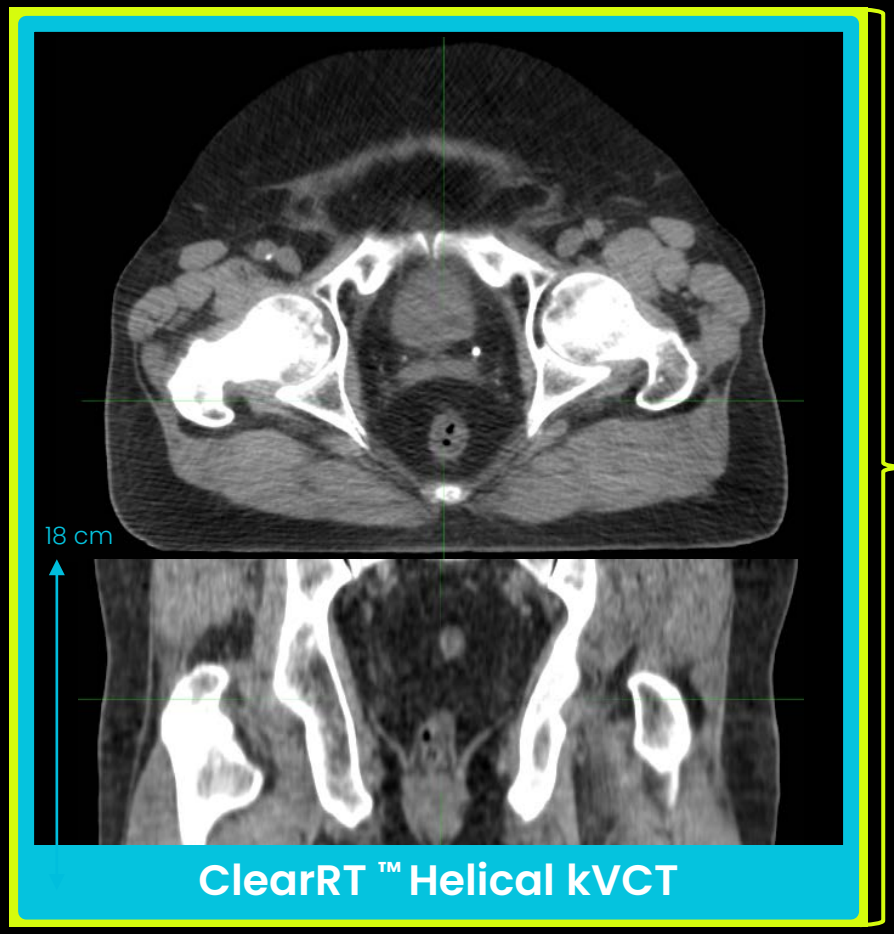

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Diagnostic CT

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Images courtesy of Willis-Knighton Medical Center, Shreveport LA

ClearRT™ Helical kVCT

Thank you

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