Aquilion Exceed LB: An AI-powered CT system designed to transform radiation therapy CT simulation

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Introduction

Cancer is the second leading cause of death globally, resulting in 9.5 million lives lost in 2018 alone.[1] By 2040 cancer cases and deaths are estimated to reach 29.5 and 16.3 million, respectively.[2] Radiation therapy (RT) is a potent weapon in the arsenal against cancer with an estimated 50% of cancer patients receiving radiation therapy.[3] Advancing the efficacy of radiation therapy involves making radiation delivery as personalized, accurate, and precise as possible - and it all begins with a CT simulation. The introduction of the Aquilion Exceed LB CT scanner is designed to meet the increasing demands on CT simulation accuracy and workflow. The Aquilion Exceed LB offers the industry's widest bore at 90 cm, a full 90 cm extended field of view, a 70 cm true field of view, 4 cm of longitudinal detector coverage and the power of Deep Learning artificial intelligence to maximize image quality for treatment planning.[4]

The 90 cm Aquilion Exceed LB can help clinicians create accurate and precise treatment plans by delivering excellent image quality and uncompromised patient positioning that is fast and easy for all patient sizes and set-ups. The Aquilion Exceed LB is augmented by Canon's standard diagnostic suite of features, including Single Energy Metal Artifact Reduction (SEMAR), AIDR 3D for fast iterative reconstruction, and PURE ViSION Optics for optimized imaging performance.[5] All these features, combined with Canon's Advanced intelligent Clear-IQ Engine (AiCE) Deep Learning reconstruction algorithm (DLR), deliver extraordinary image quality for accurate and precise CT simulations and treatment plans.

The cost and space-efficient Aquilion Exceed LB also offers intelligent workflow, made possible by easy patient positioning, fast scanning, and connectivity with third-party devices for contouring, motion management, patient marking, and treatment planning.

Key Aquilion Exceed LB features:

- Industry's largest
  - Bore size: 90 cm
  - Scan field-of-view (SFOV): 70 cm
  - Edge-to-edge extended FOV: 90 cm*
- Up to 4 cm longitudinal detector coverage.
- Thin 0.5 mm acquired slice thickness.
- AiCE DLR* for CT
- 4D Respiratory gated CT imaging*
- Premium CT Technologies: PURE ViSION Optics, SEMAR, AIDR 3D
- Integration with virtual simulation and contouring applications
- Lateral Slide

SEE THE BIG PICTURE

The Aquilion Exceed LB is TG-66 compliant and offers a number of unique and advanced features to help achieve optimal patient positioning and superb image quality—all designed to make CT simulation as accurate as possible for every patient, every time.

* Option

Accuracy in Patient Positioning

Accurate and reproducible patient positioning that is consistent between CT simulation and radiation treatment delivery is vital to providing optimal patient care. Narrow CT bores that block equipment or cause discomfort for the patient can compromise patient set-up consistency between the CT scanner and the treatment delivery system.[6,7,8] The Aquilion Exceed LB provides the industry's widest bore size at 90 cm, removing barriers imposed by smaller bore sizes. For example, a lung tumor near the lung apices require the arms positioned and supported such that the tumor is accessible for treatment (Figure 1).

Accuracy in Imaging

Accurate delivery of radiation to target tumors, while sparing Organs-at-Risk (OAR), is imperative to achieving the best treatment outcomes for patients. CT simulators must consistently produce high quality images with accurate geometrical and anatomical information to be used in virtual simulations and dose calculations of treatment plans.[6,9,10] Low noise, high spatial resolution images can help segmentation algorithms to achieve improved delineation of targets and surrounding critical structures minimizing uncertainties in contouring (Figure 2), calculation of gross target volumes and subsequently treatment plans.[11,12,13] Excellent image quality may also assist radiation oncologists to better visualize tumor changes, confidently distinguish low contrast lesions and disease extension, and better resolve brachytherapy seeds. Finally, high quality images may reduce uncertainties in patient positioning verification and Hounsfield Unit (HU) accuracy, potentially leading to more accurate electron density values or stopping-power ratio maps for dose calculations.

Key factors that affect image quality and HU accuracy include: truncation of the imaged object due to restricted scan FOV[14] , noise, poor spatial resolution and low contrast detectability, metal[15] and motion[16] related artifacts. The Aquilion Exceed LB is designed to provide excellent image quality for CT simulations with the deployment of the largest scan FOV in the industry at 70 cm and edge-to-edge extended FOV at 90 cm, AiCE DLR, respiratory management with 4D-CT capabilities, and other Premium CT technologies that include Canon's PURE ViSION Optics technology, SEMAR, and AIDR 3D.

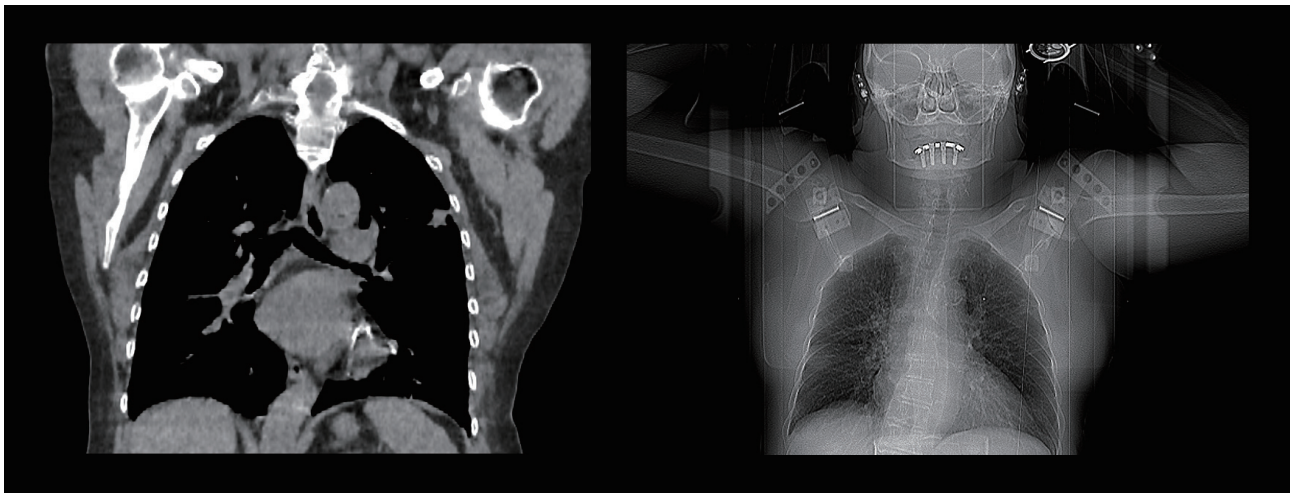

Figure 1 Coronal image of the chest with a small tumor in the upper lobe of the left lung. The AP scanogram displays the treatment and simulation position.

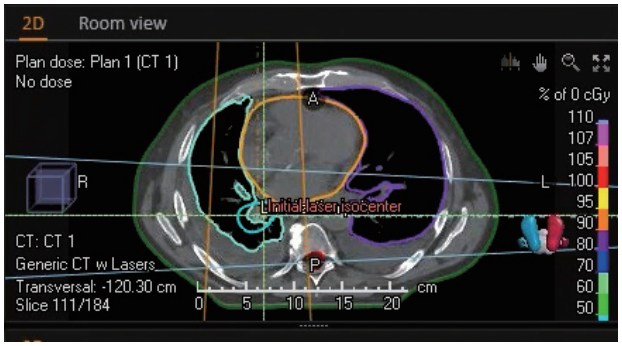

Figure 2 Precise contouring with Aquilion Exceed LB's high image quality.

Scan FOV and extended FOV

The Aquilion Exceed LB's 90 cm bore size is accompanied by both the industry's largest true scan field of view (SFOV) at 70 cm and the industry's largest extended field of view (EFOV) at a full 90 cm. A large SFOV prevents truncation of patient anatomy by keeping the entirety of the patient within the SFOV. CT simulators with a smaller 50 cm SFOV have been shown to lead to truncation of patient anatomy in almost 30% of cases.[17] Aquilion Exceed LB's 70 cm SFOV enables imaging of challenging positioning set-ups and a wide variety of patient sizes, including bariatric patients, without skin line or anatomical cutoff (Figure 3). This can be achieved without needing to laterally re-position the couch or patient, thereby optimizing workflow and treatment planning accuracy and reproducibility. Water phantom experiments demonstrate CT number accuracy of 0 ± 5 HU for a 32 cm phantom positioned at the isocenter of the 70 cm FOV and 0 ± 10 HU when positioned at the periphery of the 70 cm FOV.

To further prevent the need for patient re-positioning the Aquilion Exceed LB offers a 90 cm extended FOV that yields additional visualization, generated with Canon's proven eFOV reconstruction technology.

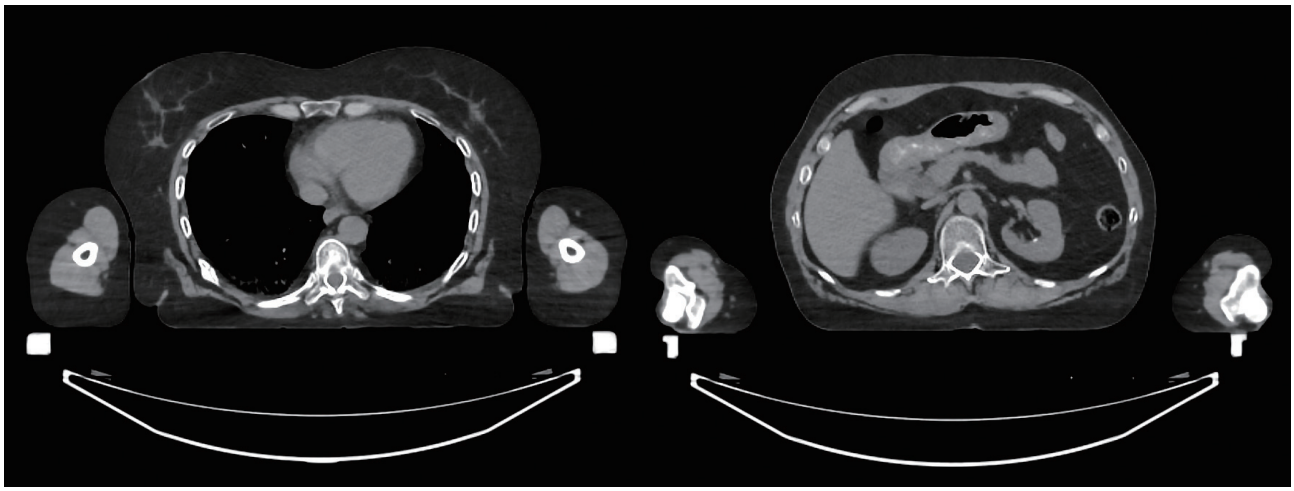

Figure 3 Large patient scanned with 70 cm FOV.

Deep Learning Artificial Intelligence for Image Quality

In 2018, Canon Medical introduced the first Deep Learning based reconstruction algorithm to CT. Canon's Advanced intelligent Clear-IQ Engine (AiCE) harnesses the power of Deep Convolutional Neural Networks (DCNN) to differentiate signal from noise.[4] The signal is then retained and enhanced, while the noise is suppressed to quickly reconstruct images with low noise, excellent high contrast spatial resolution, superb low contrast detectability, and a noise texture more similar to that of Filtered Back Projection (FBP) images*. AiCE DLR achieves this level of image quality via an extensive training process using target images acquired with high tube current and reconstructed with a highly sophisticated Model Based Iterative Reconstruction (MBIR) that incorporates modelling of the system optics, system physics, scanner statistical properties and human anatomy (Figure 4). AiCE is easy to use and fully integrated into the SUREExposure mA modulation system as well as applicable to all FOVs including the edge-to-edge extended FOV of 90 cm.

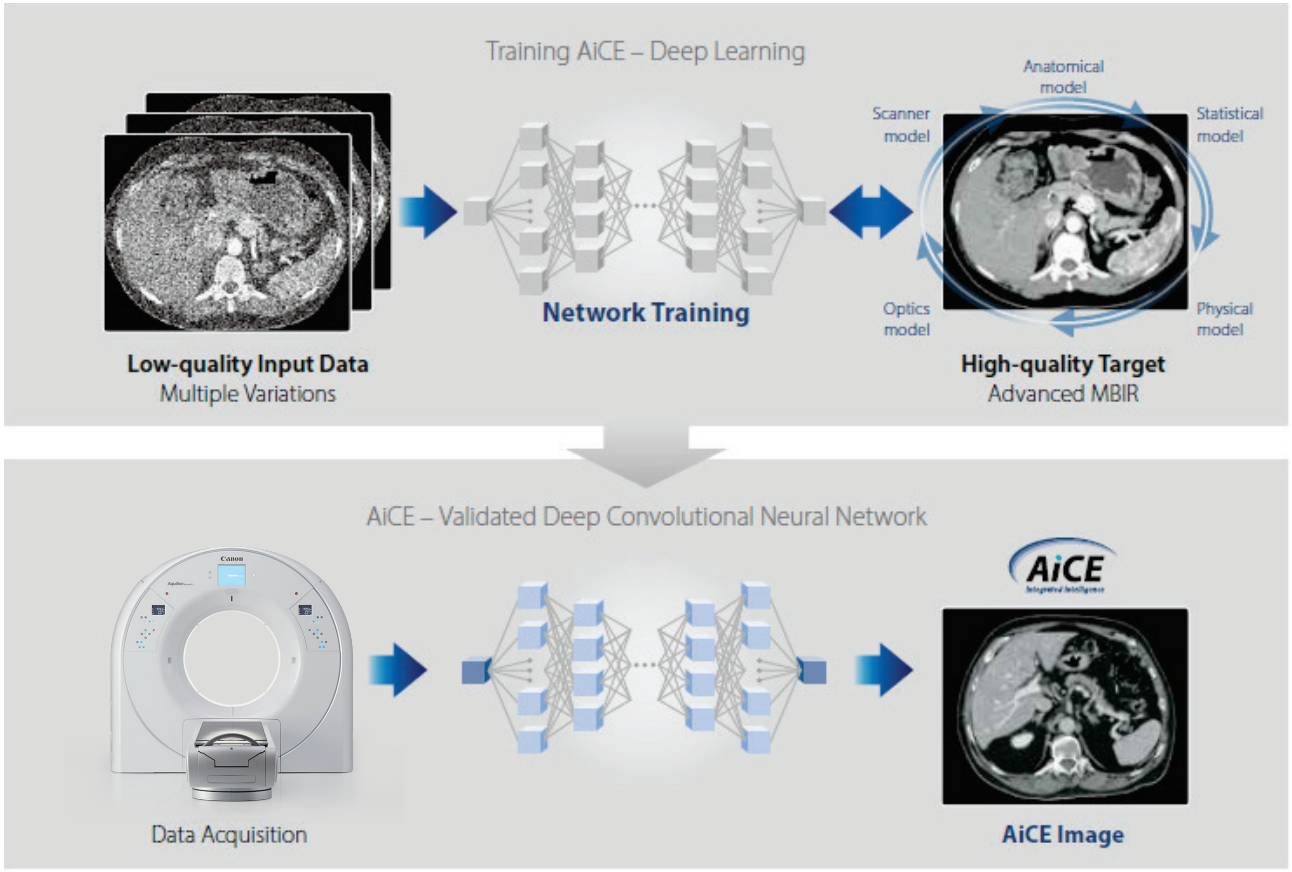

Figure 4 AiCE - Deep Learning Reconstruction utilizing a DCNN

* Compared to MBIR

Low Noise Magnitude and Excellent Low Contrast Detectability

Low noise images have the ability to aid in image segmentation and improve low contrast detectability (LCD). Improved LCD results in an increased ability to see small, low contrast objects such as hypo-attenuating lesions. At the same dose AiCE Body dramatically decreases the magnitude of noise by up to 67% versus FBP and up to 22% compared to AIDR 3D. Figure 5 shows the image noise magnitude (i.e. the standard deviation) in a water phantom for AiCE DLR, AIDR 3D and FBP as a function of CTDI.

Furthermore, at the same dose AiCE Body improves low contrast detectability by 87% relative to FBP and 14% relative to AIDR (Figure 6). Although radiation dose imparted during radiation therapy planning is a fraction of the overall radiation therapy dose, exposure to ionizing radiation should always be minimized while still accomplishing the tasks at hand such as contouring.[10,18]

Minimizing imaging CT dose is more important in pediatrics, 4D respiratory gated CT simulations, and re-planning during radiation therapy. AiCE DLR can help in the optimization of patient-specific CT protocols to reduce dose without compromising the radiation therapy clinical objectives. In addition, AiCE DLR reduces the magnitude of visually unappealing noise texture, found in low dose images reconstructed with iterative reconstruction algorithms, resulting in an appearance more similar to low noise filtered backprojection*. The AiCE DLR algorithm has also been shown to clinically outperform FBP and iterative reconstruction for lesion detection in Low Dose CT (LDCT) abdominal images.[19]

Contrast to Noise Ratio

By preserving CT number accuracy while reducing noise AiCE can improve the Contrast-to-Noise Ratio (CNR). In a phantom experiment, AiCE improved the CNR by 85% vs FBP and 30% vs AIDR at 120 kVp. Figure 7 demonstrates the CNR benefits of AiCE in a clinical chest image.

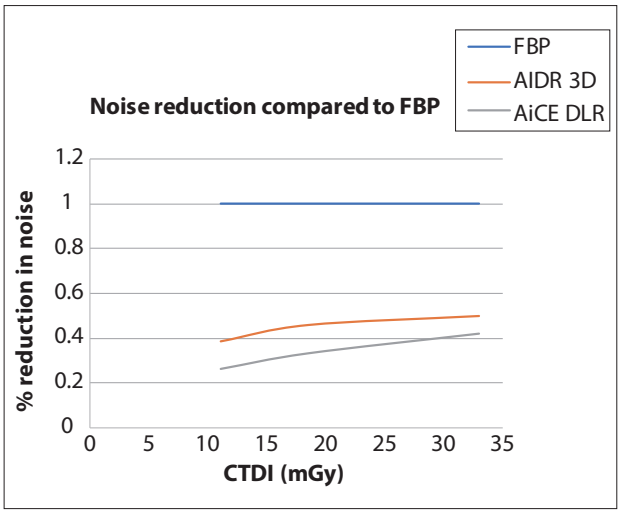

Figure 5 Noise magnitude (SD) for AiCE , FBP, and AIDR 3D as a function of CTDI.

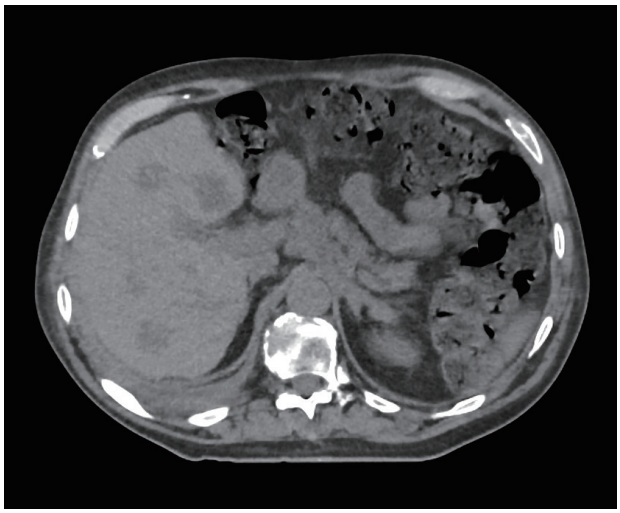

Figure 6 Excellent LCD clinical image quality with AiCE.

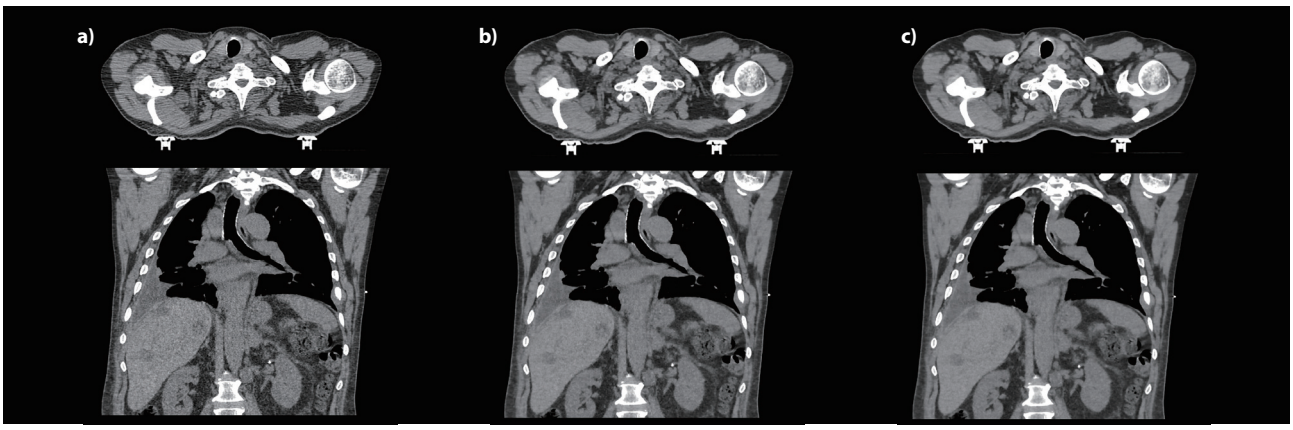

Figure 7 Chest and upper abdomen images demonstrating LCD and CNR. a) FBP, b) AIDR 3D, c) AiCE.

* Compared to MBIR

High Contrast Spatial Resolution

The term spatial resolution refers to the ability of a CT system to resolve small anatomical structures and objects such as implanted seeds. High spatial resolution can improve the precision of 3D structure delineation. Because it is trained on MBIR images, AiCE DLR learns to preserve high contrast spatial resolution, such as edge and small details, to a greater extent possible than with FBP. For routine abdominal scanning, AiCE increases the 10% of the MTF from 6.0 lp/cm with FBP to 13.4 lp/cm with AiCE Body Sharp (Figures 8 and 9). Notably, AiCE is able to improve high contrast spatial resolution while simultaneously reducing noise magnitude.

Figure 10 demonstrates the ability of AiCE to render fine detail images of the pelvis and lung while maintaining low noise, relative to both FBP and AIDR 3D.

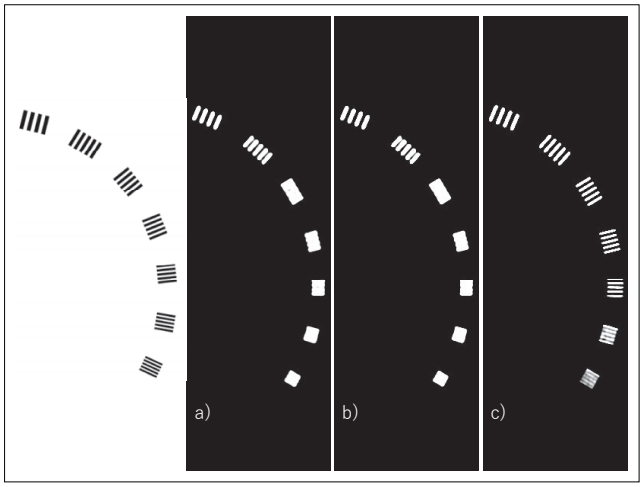

Figure 8 Line pair phantom images with a) FBP, b) AIDR 3D, and c) AiCE.

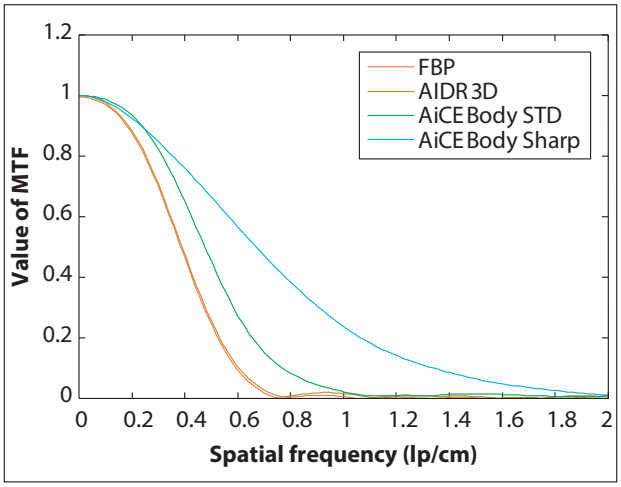

Figure 9 Respective Modulation Transfer Functions.

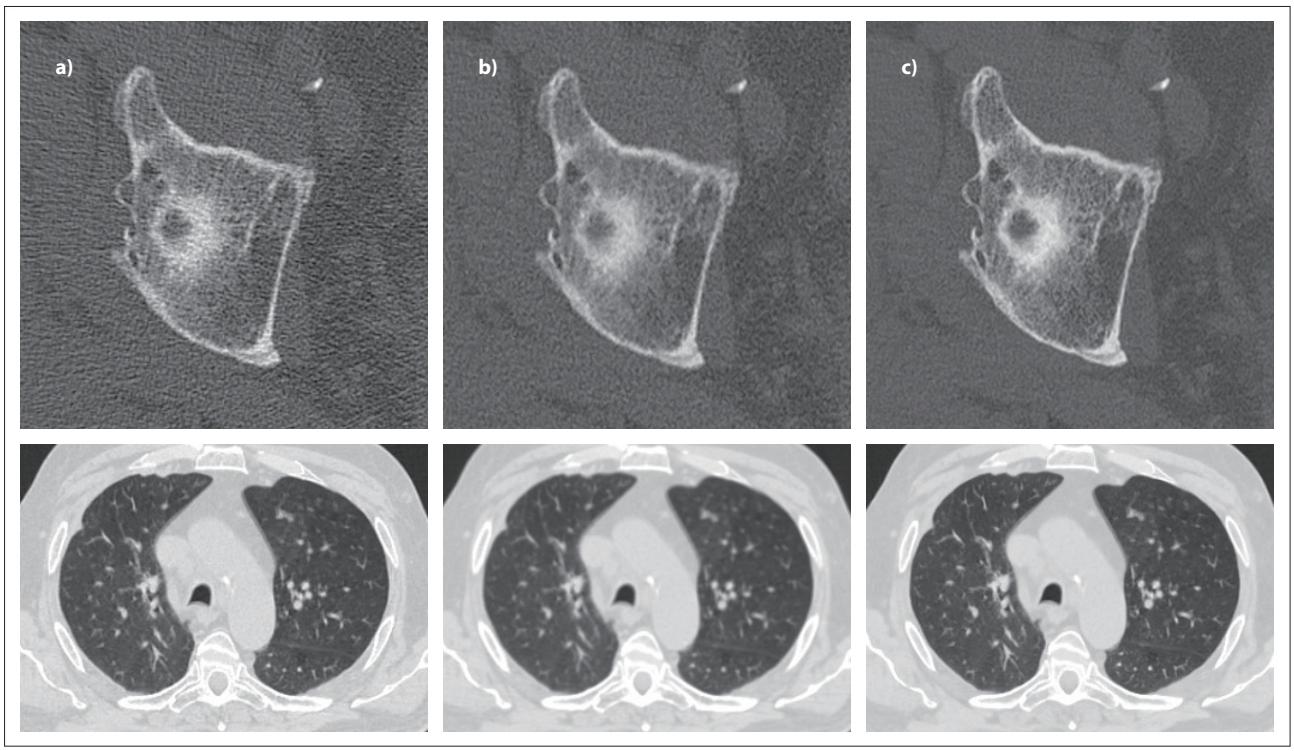

Figure 10 0.5 mm slice thickness pelvis and lung images demonstrating the ability of AiCE (c) to yield fine detail while maintaining low noise compared to both FBP (a) and AIDR 3D (b).

Respiratory Gating and 4-Dimensional CT

Thoracic and abdominal tumors are affected by respiratory motion that renders their accurate and reproducible irradiation during radiation therapy challenging. Motion management during CT simulation is particularly important for lung cancer due to both the prevalence of lung cancer and the wide adoption of lung radiation therapy as a treatment. The Aquilion Exceed LB offers a number of motion management options to reduce motion artifact and help ensure optimal patient care.

Acquisition Protocols

Both helical and axial protocols for respiratory motion management are available on the Aquilion Exceed LB with retrospective and prospective gating, respectively. The system is compatible with selected respiratory monitoring devices*.

Prospective and Retrospective Gating

Prospective gating is available with 4 cm axial volume mode during which data is acquired sequentially at any desired phase of the respiratory cycle. For helical scans, retrospective gating is available, which moves the table at low speed, ensuring sufficient data for reconstruction at each longitudinal position within the respiratory cycle. Before the acquisition begins, a breathing trial run is performed during which the breath rate is extracted from the respiratory waveform. An appropriate helical pitch is calculated for the recorded breath rate and the selected rotational speed. The default rotation time is 0.4 sec for optimal temporal resolution. Available helical pitches accommodate respiratory rates from 6 up to 50 breaths per minute (BPM). The Aquilion Exceed LB's Respiratory Gating Reconstruction (RGR) editor allows the user to reject a breath cycle, delete or add trigger points prior to image reconstruction from the raw data (Figure 11).

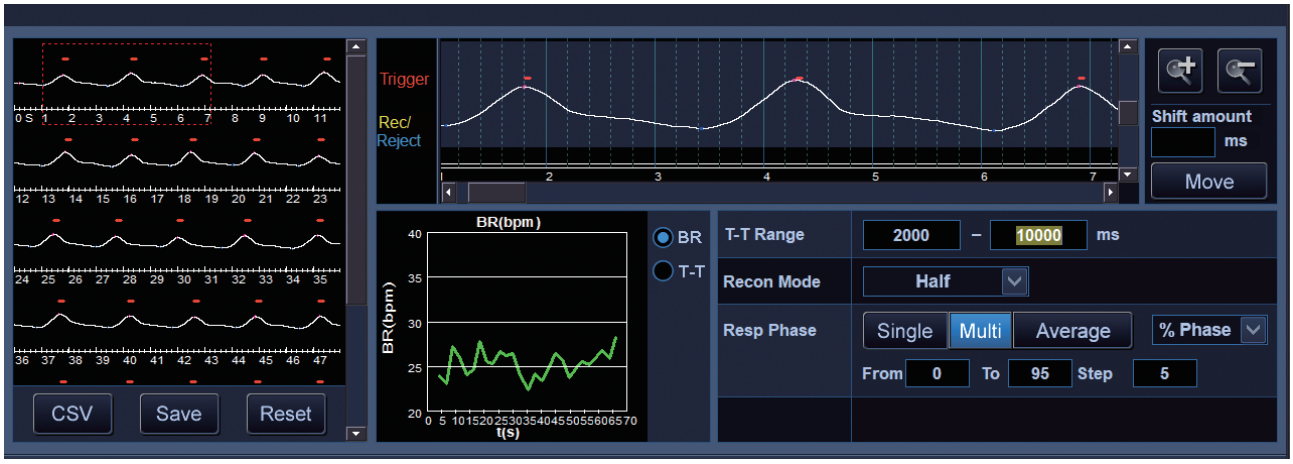

Figure 11 Respiratory signal from scanner console.

* Contact your Canon representative for more details

Phase and Amplitude Binning

Data acquired with 4-Dimensional (4D) CT low pitch helical acquisitions are correlated with the recorded respiratory waveform to perform retrospective reconstructions that are based on either phase or amplitude binning. In phase binning the imaged volume is reconstructed at multiple phases that correspond to equally spaced time points within the respiratory period, where 0% corresponds to the peak of the waveform and peak inspiration. In amplitude binning projection data are sorted based on the amplitude and direction of the breathing waveform. The range of respiratory amplitude over a complete breath cycle, is defined from -100% at peak inhalation to +99% just before the next peak inhalation point. The range of exhalation (descending) is -100% to -1% and the range of inhalation (ascending) is 0% to +99%. Reconstructions can be performed at single or multiple amplitude points. For multiple points, reconstructions are centered on equally spaced amplitude points of the waveform. To illustrate, if reconstructions are desired from end-inhalation to end-expiration at a spacing of 25%, the user can set the reconstructions as [-100, 0, 25] indicating reconstruction during the down-slope part of the respiration moving from end inhalation to end expiration at 25% intervals for a total of 5 reconstructed volumes (Figure 12).

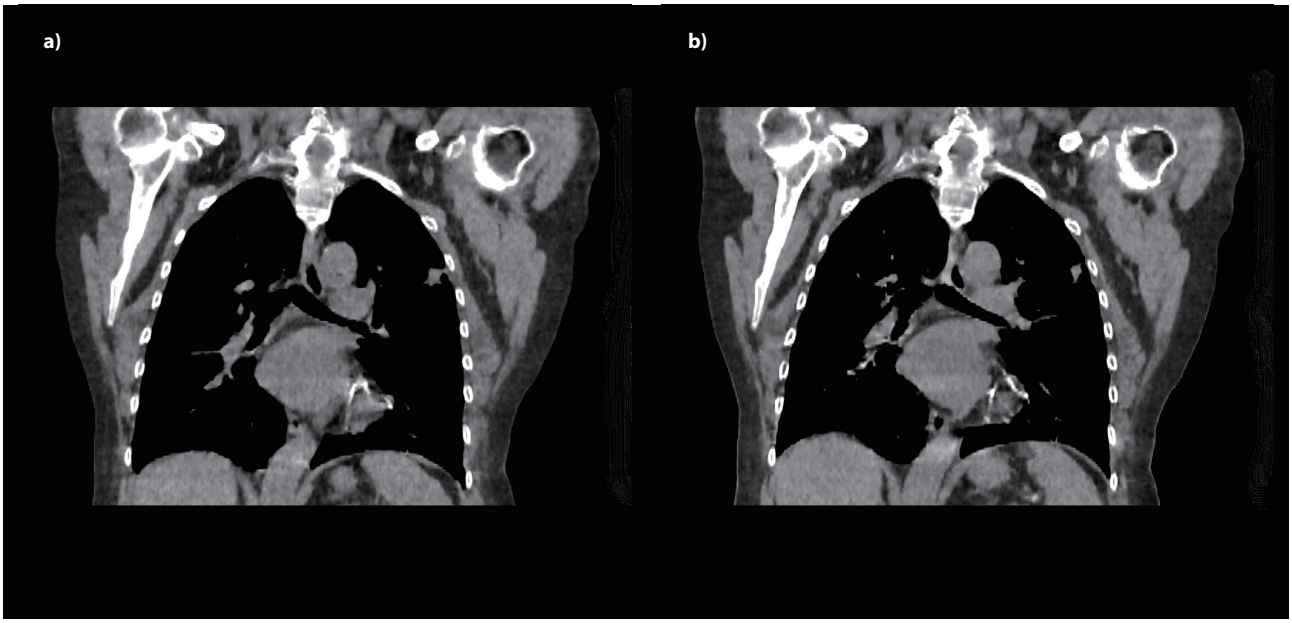

Figure 12 Chest scan performed with respiratory gating and reconstructed with a) phase binning and b) amplitude binning.

Other Premium Technologies: PUREViSION Optics, SEMAR, AIDR 3D

PUREViSION Optics[5] is Canon's latest optics assembly and detector combination, created to maximize performance at low flux due to increasing numbers of bariatric patients. PUREViSION Optics converts photons into light with 40% improved sensitivity, improved noise properties and low contrast detectability while reducing streak artifacts. The PUREViSION detector on the Aquilion Exceed LB utilizes a 0.5 mm detector channel and can produce the thinnest slice available in the industry for CT simulation. Thin slice thickness and small voxels reduce partial volume effects (PVE), improving organ delineation, volume determination of targets, accuracy of contouring, inter-observer variability, and quality of DRRs.[20, 21]

This becomes particularly important as treatment delivery methods evolve to precisely deliver high-dose irradiation to tumors, such as stereotactic radiosurgery (SRS).

PUREViSION Optics is coupled with AIDR 3D hybrid iterative reconstruction technology, both standard on the Aquilion Exceed LB. AIDR 3D helps to reduce dose and improve image quality at a reconstruction speed of up to 70 fps. Another reconstruction feature standard on the Aquilion Exceed LB is Single Energy Metal Artifact Reduction (SEMAR) for reducing metal artifacts and improving visualization of organs and tissues in proximity to metallic implants (Figure 13). Metal artifact reduction is particularly important in radiation therapy planning where metal artifacts can cause target and OAR delineation errors as well as HU value inaccuracies, potentially resulting in errors in dose distribution estimates.

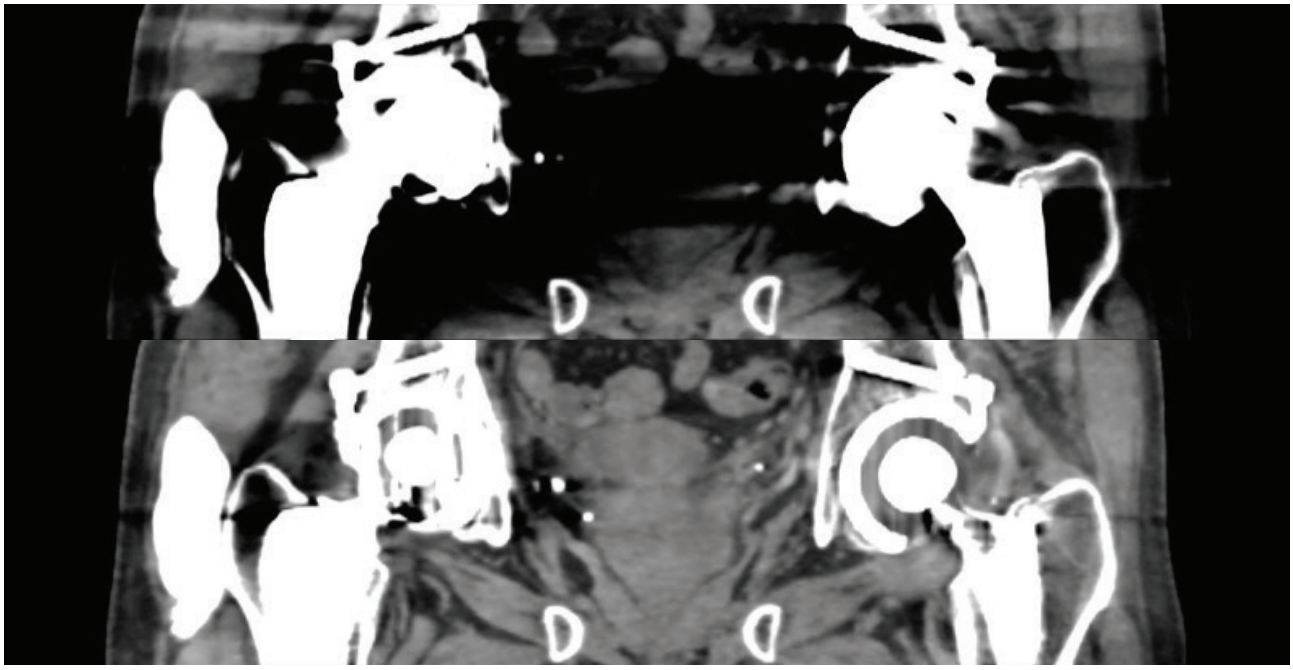

Figure 13 Reconstructions of pelvis with bilateral implants with SEMAR off (top) and on (bottom).

INTELLIGENT WORKFLOW

Quick and Automatic Patient Set-Up

Canon's SUREPosition technology remotely adjusts the patient's position to the gantry's isocenter for enhanced accuracy while obviating the need for repeat scanograms. In addition, the Tech-Assist Lateral Slide enables lateral couch movement of up to +/- 8.5 cm at the touch of a button, making patient set-up easy, accurate, and fast (Figure 14).

Faster Scans with 4 cm Detector coverage

The Aquilion Exceed LB offers up to 4 cm of detector coverage at isocenter for fast acquisitions with thin slices. The Aquilion Exceed LB can complete a scan twice as fast and with thinner acquired slices for the same rotation time and scan length relative to widely available systems that offer up to 2 cm of z-axis coverage. Faster scans can result in streamlined workflow, higher throughput, and improved patient comfort. Shorter scan times reduce the probability of patient motion or irregular breathing during the acquisition, reducing the potential for motion induced artifacts and the need to re-scan.

Seamless Integration

The Aquilion Exceed LB can be easily integrated with Canon's Vitrea™ solutions, third-party treatment planning systems, PACS, Oncology Information Systems, and devices such as respiratory gating solutions, patient alignment lasers, and virtual simulation solutions.

Virtual simulation solutions provide a range of capabilities to assist clinicians in contouring, determining the size and location of the tumor, planning the direction of radiotherapy beams and calculating appropriate isocenter locations.

Canon Medical in collaboration with RaySearch Laboratories AB (publ)* now offers an advanced, flexible, and more efficient workflow in the process of virtual simulation. RaySearch's RayStation virtual simulation** complements Canon's CT, PET/CT, and MRI scanners and can be expanded with deformable registration for maximum accuracy and consistency. This extraordinary oncology solution offers options for improved care and safety for patients—and smooth, efficient workflow for clinicians (Figure 15).

RayStation Simulation offers:

- Dedicated workspace for virtual simulation
- One-click creation of orthogonal beam pair
- Multiple tools for easy isocenter placement using DRR pair
- Export to patient marking systems
- A multitude of beam-design tools for field shaping
- RayDeformable: Deformable Registration

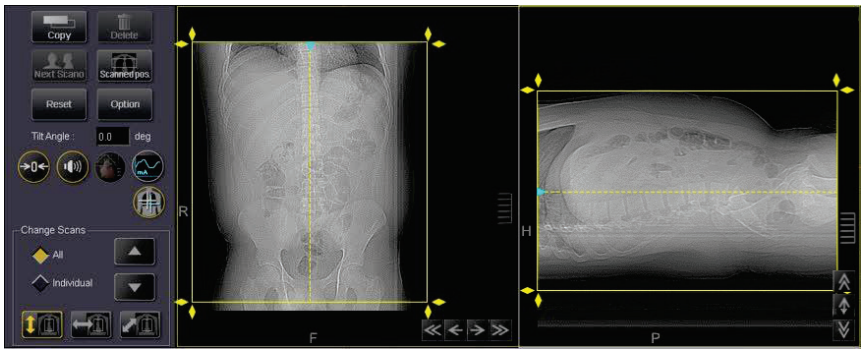

Figure 14 SUREPosition with lateral movement function

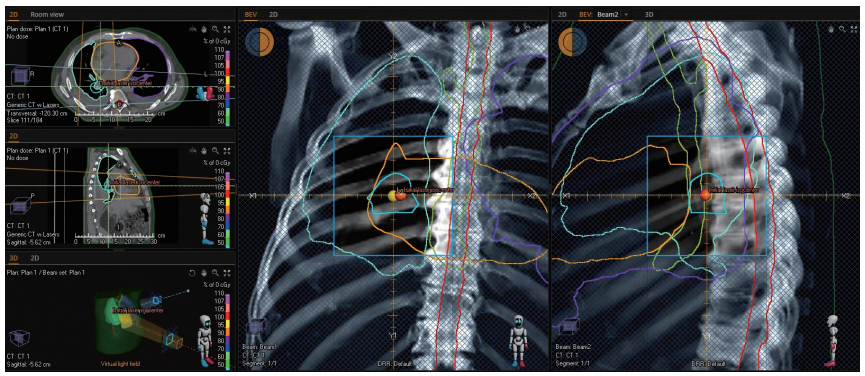

Figure 15 Contouring of the skin line, spine, right and left lung, and the GTV of the target lung tumor processed with RaySearch Virtual Simulation.

* Not available in all geographic regions
** Option

Conclusion

The Aquilion Exceed LB offers the industry's largest bore at 90 cm coupled with the largest SFOV and EFOV at 70 cm and 90 cm respectively. This premium 160 slice*, 0.5 mm x 80 detector row CT scanner is designed for fast, accurate, and reproducible CT simulation. With the inclusion of AiCE DLR, the system is the first CT simulation scanner to offer the power of Deep Learning based reconstruction. The Aquilion Exceed LB is designed to enhance radiation therapy planning with fast and flexible positioning, fast scanning, excellent image quality, and integration with third-party devices for virtual simulation, contouring, motion management, patient positioning and patient marking. Compatible with industry wide connectivity standards, the Aquilion Exceed LB can adapt to your department's equipment, therewith reducing costs and the burden of re-training required for additional simulation software, respiratory monitoring devices, and laser positioning systems.

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* With coneXact reconstruction

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