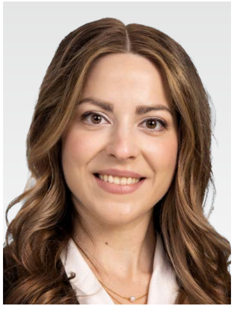
CT / White paper

The power of SilverBeam with DLR for high quality lung cancer screening exams



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Introduction

Canon Medical's SilverBeam Filter is a novel X-ray filtration system specifically developed for computed tomography (CT) imaging. This innovative solution capitalizes on the physical properties of silver to optimally filter low-energy X-rays for low dose lung CT, which is crucial for lung cancer screening exams. Combined with Advanced intelligent Clear-IQ Engine (AiCE), a pioneering Deep Learning Reconstruction (DLR) algorithm for CT, SilverBeam provides the penetration needed for larger patients and through the shoulder region while preserving low contrast detectability. SilverBeam with AiCE is a robust solution to the increasing need for low dose, high quality lung cancer screening exams.

CT in Lung Cancer Screening

Lung cancer remains the leading cause of cancer-related deaths worldwide, responsible for 1.8 million deaths annually. The ability of computed tomography to offer three-dimensional anatomical information gives it a significant advantage over chest X-ray for visualizing cancer. Because of lung cancer's high mortality rate, imaging-based screening for early detection of lung cancer has been the subject of extensive research. Several large-scale, multi-center studies have demonstrated the ability of CT lung cancer screening to significantly reduce lung cancer mortality and improve patient outcomes [(1-8)].

The U.S.-based National Lung Screening Trial (NLST) found that low dose CT screening lead to a 20% reduction in lung cancer mortality compared to chest X-ray screening among over 50,000 current or former heavy smokers aged between 55 and 74 years after a median follow-up of 6.5 years [(1)]. Based on these findings, the U.S. Preventive Services Task Force recommended annual low dose CT screening for individuals aged 55 to 80 years with a smoking history of 30 or more pack-years, who currently smoke or quit smoking within the past 15 years.

Similarly, the European Randomized Controlled Trial (NELSON) demonstrated a 26% reduction in lung cancer mortality for current and former smokers with CT screening [(2,8)].

CT lung cancer screening protocols are designed to use a fraction of the dose of diagnostic chest exams. CT hardware and software are evolving to minimize radiation exposure while maximizing image quality for diagnostic accuracy [(9,10)]. Because lower radiation dose can lead to increased image noise, decreased image quality, and reduced sensitivity to pulmonary pathologies, Canon Medical has optimized the imaging chain to ensure high quality exams at low screening radiation doses. **With SilverBeam, Canon Medical offers a hardware-based solution for scanning large patients and high attenuation regions in the chest while optimizing low contrast detectability with DLR.**

These images are used to detect, measure, classify and follow up nodules. The accuracy and speed of workflow is affected by image quality, therefore having the best possible image quality has the potential to result in a more accurate and efficient lung cancer screening program.

SilverBeam Filter with Advanced intelligent Clear-IQ Engine (AiCE)

Physical filtration of the X-ray beam is a standard design feature on CT Systems. The composition of the physical filter determines the average energy of the beam coming out of the collimators. In addition to removing undesirable X-rays with energies too low to penetrate the patient, the physical filter determines trade-offs in low contrast detectability vs patient penetration. Historically, higher effective energies offer greater penetration but at the cost of low contrast resolution.

Figure 1 (a) provides a visual representation of pre-patient spectra after basic tube filtration and Figure 1 (b) demonstrates the impact of adding a thin sheet of copper filtration.

To exploit the power of hard X-ray beams without unacceptable tradeoffs in image quality, it must be combined with a software solution.

Silver filtration is a novel technique for filtering X-rays in CT scans and hardening the X-ray spectrum. Silver's X-ray attenuation properties, including a K-edge of 25.5 keV, high atomic number (Z=47), high atomic weight (107.87 u), and high density (10.49 g/cm^3), harden the beam more than other commonly used materials like aluminum (Z=13, 26.98 u, 2.7 g/cm^3) and copper (Z=29, 63.54 u, 8.96 g/cm^3).

Additionally, as demonstrated in Figure 2 silver has a higher linear attenuation coefficient (µ) than other metals such as tin in the diagnostic X-ray keV range, meaning it more effectively attenuates these X-rays.

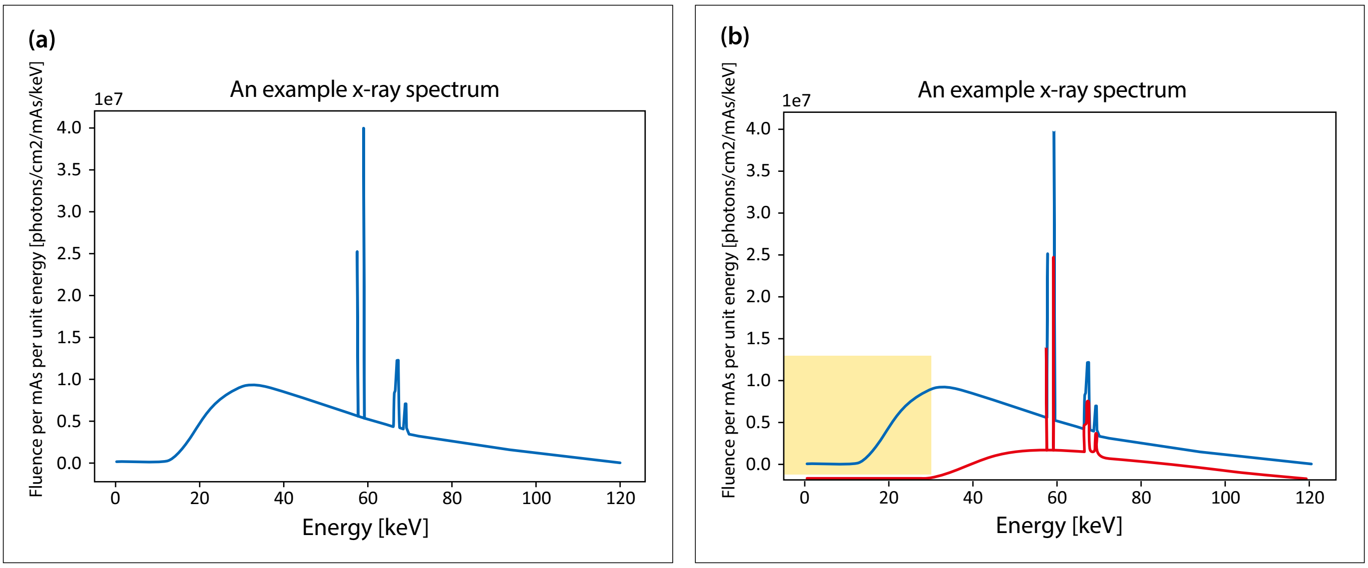


Figure 1: (a) A generic example of pre-patient spectra after the basic tube filtration and (b) after adding copper filtration. The yellow box highlights the low-energy X-rays, which are undesirable in imaging. (Figures are illustrative, and there might be slight differences from actual clinical system spectra.)

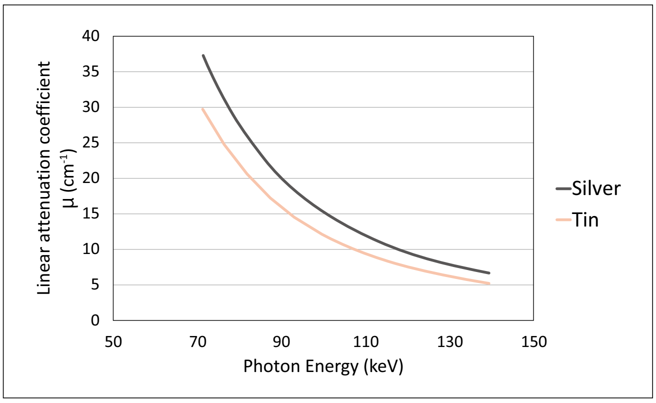


Figure 2: Comparison of the linear attenuation coefficients (µ) of silver and tin (Data from https://physics.nist.gov/PhysRefData/XrayMassCoef/tab3.html)

SilverBeam generates an energy spectrum that exhibits a significant shift towards higher energies, as depicted in Figure 3, compared to traditional filtration materials. This energy increase can help improve signal-to-noise ratio (SNR) in challenging, high-attenuation scenarios such as with larger patients or the shoulder region and is therefore especially useful for examinations like reduced-dose lung cancer screening.

The use of AiCE DLR in combination with SilverBeam ensures that low contrast detectability is not sacrificed. AiCE is a fast, DLR algorithm that includes both raw data and image domain components to reduce artifacts and improve the SNR. Research has shown that AiCE provides a better high-resolution CT image with improved quality compared to Hybrid Iterative Reconstruction (HIR) for evaluating lung nodules, with significantly reduced objective image noise and subjective improvements in noise, artifacts, depiction of small structures and nodules, and overall image quality [12, 13].

To illustrate the benefits of SilverBeam filtration in combination with AiCE reconstruction, an anthropomorphic phantom (CTU-41, Kyoto Kagaku CT) was scanned with a lung cancer screening protocol using CTDIs ranging from 0.1 to 1.5 mGy. The phantom was then also scanned with conventional filtration and reconstructed with conventional hybrid iterative reconstruction across the same dose range. Circular regions of interest (ROIs) with a 32.5-pixel diameter were placed to calculate SNR values for each dataset.

$SNR = ROI_{(soft\ tissue)}/SD_{(noise)}$,

Where $ROI_{(soft\ tissue)}$ is the mean CT number of the ROI in the heart-like structure of the phantom, and SD(noise) is the SD of the CT number in an ROI placed in the air part inside the phantom (Figure 4 and Figure 5).

The combination of SilverBeam and AiCE resulted in superior SNR values, by up to 70%, compared to conventional filtration and reconstruction, as shown in figure 6.

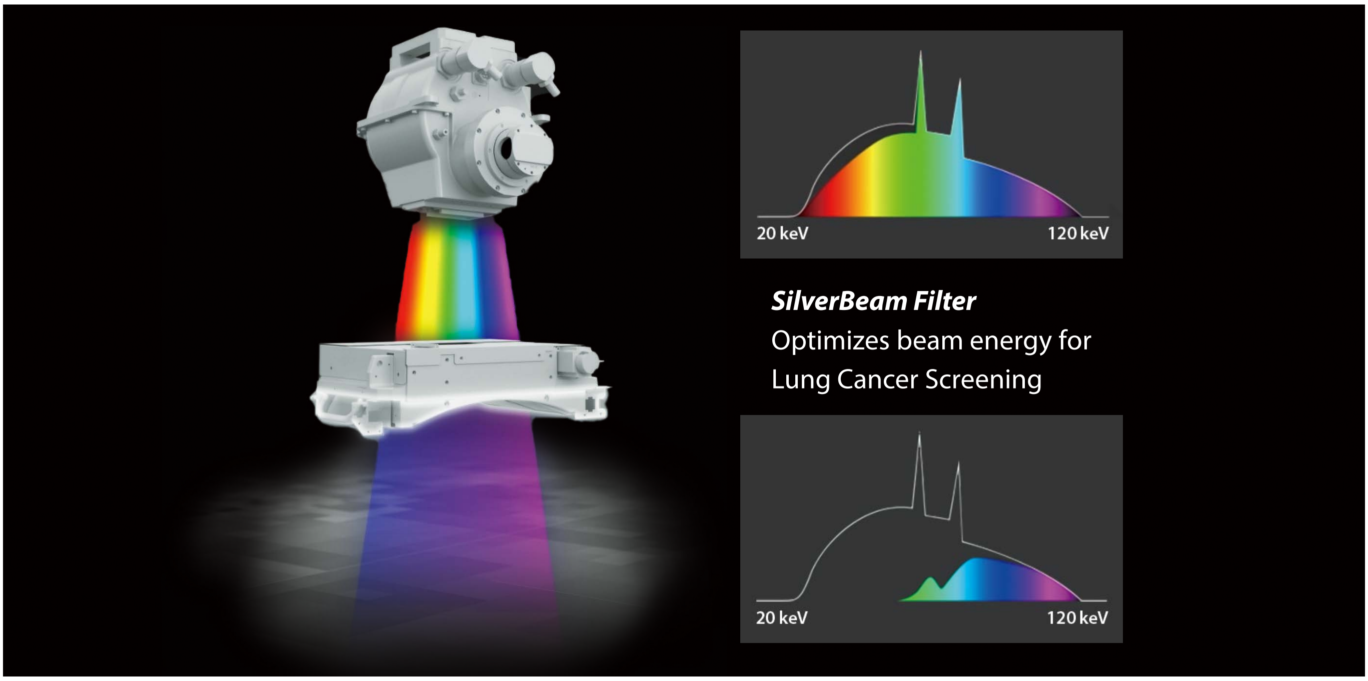


Figure 3: SilverBeam Filter is an energy filter that utilizes the photo-attenuation characteristics of silver to selectively eliminate low-energy photons from a polychromatic X-ray beam. This process results in the formation of an energy spectrum shifted toward higher energies.

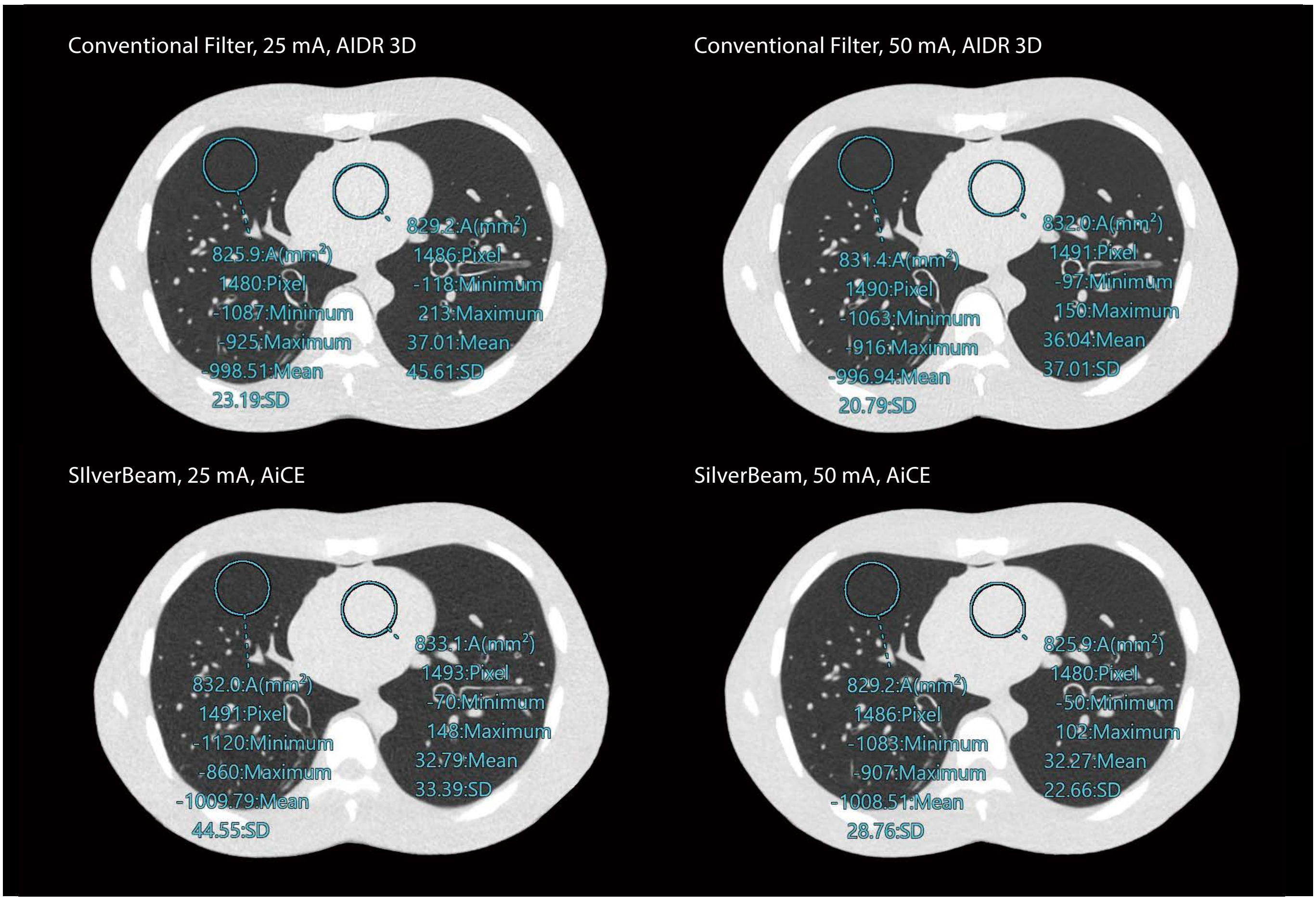


Figure 4: Example of the ROIs placed in the phantom to measure, mean HU, SD, and SNR. Top: Images were acquired with conventional filter and fixed mA of 25 and 50 and reconstructed with HIR (AIDR 3D*). Bottom: Images were acquired with SilverBeam Filter and fixed mA of 25 and 50 and reconstructed with AiCE.

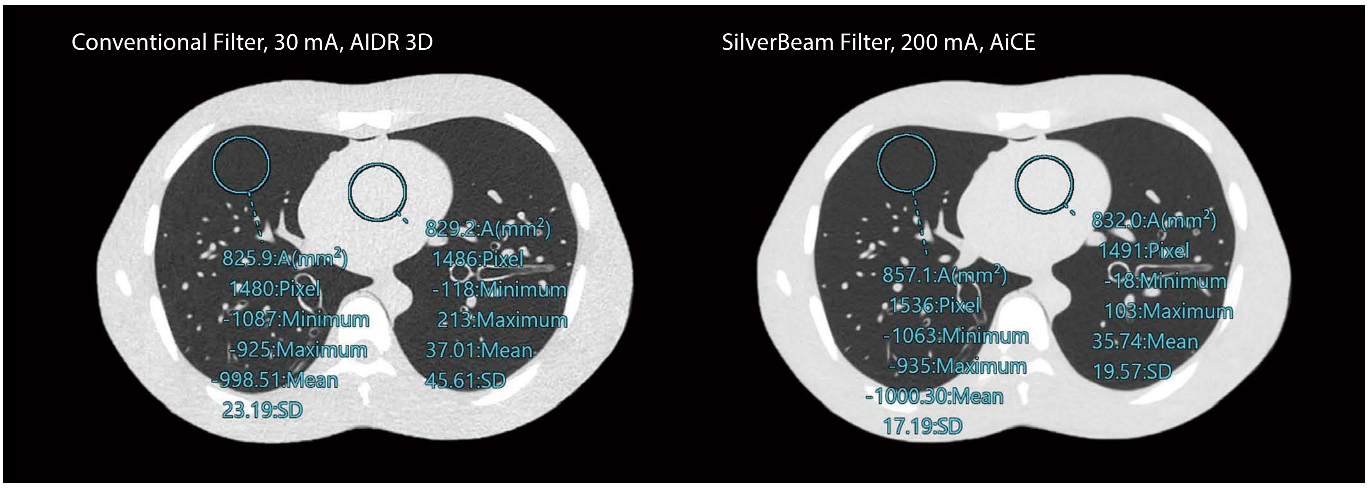


Figure 5: Example of the ROIs placed in the phantom to measure, mean HU, SD, and SNR at matched CTDI=0.9 mGy. Left: The image was acquired with conventional filtration, fixed mA of 30 and reconstructed with AIDR 3D (SNR= 1.6). Right: The image was acquired with SilverBeam, fixed mA of 200 and reconstructed with AiCE (SNR= 2.1).

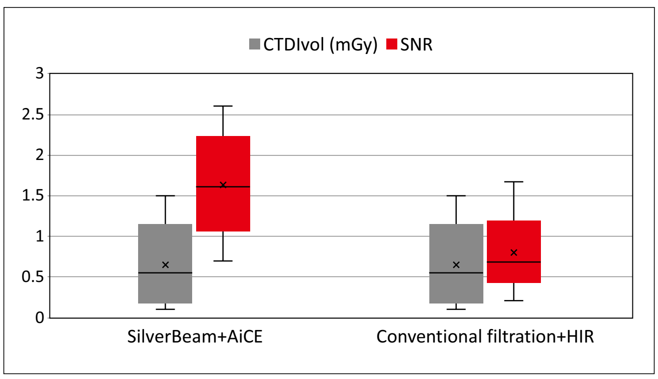


Figure 6: Results of evaluation of SNR on anthropomorphic phantom comparing SilverBeam and conventional filtration with the AEC and different scanograms. Black lines = median. The use of Silver filtration (SilverBeam) results in a 13-70% increase in SNR at matched dose.

* Adaptive Iterative Dose Reduction 3D

Clinical Examples

These clinical cases demonstrate that lung screening scans performed with SilverBeam Filter result in effective doses that are up to 22 and up to 33 times lower than the standard European (~5.5 mSv) [14] and U.S. (~8 mSv) effective doses [15].

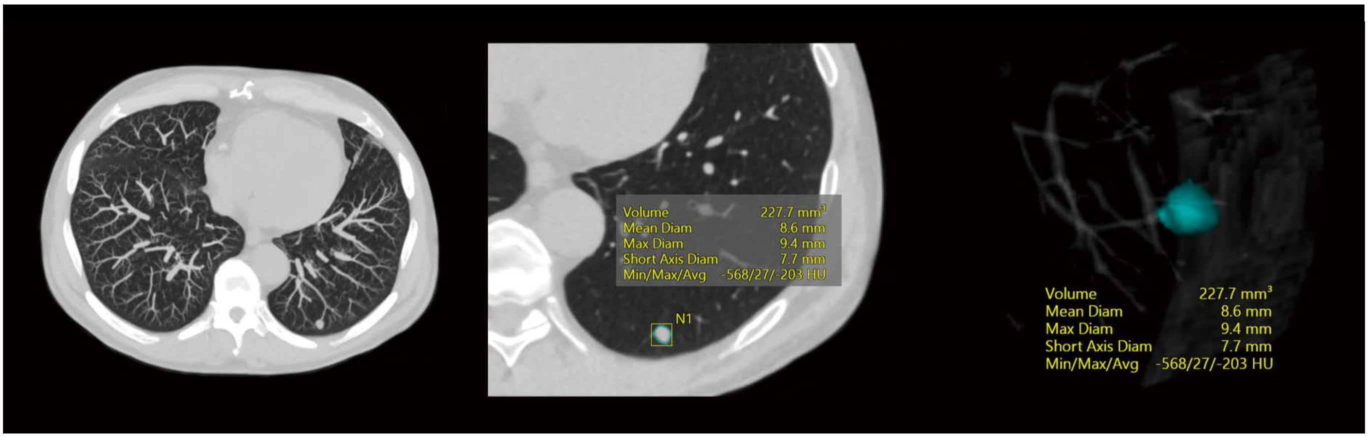
Case 1 - nodule

In this lung screening scan performed with SilverBeam Filter and AiCE a small nodule can be seen in the upper lobe of the right lung (yellow circle). CTDI 0.9 mGy, DLP 38.7 mGy·cm, effective dose 0.54 mSv (k=0.014)*. Courtesy Fujita Health University, Japan.

* American Association of Physicists in Medicine (AAPM) Report 96, 2008.

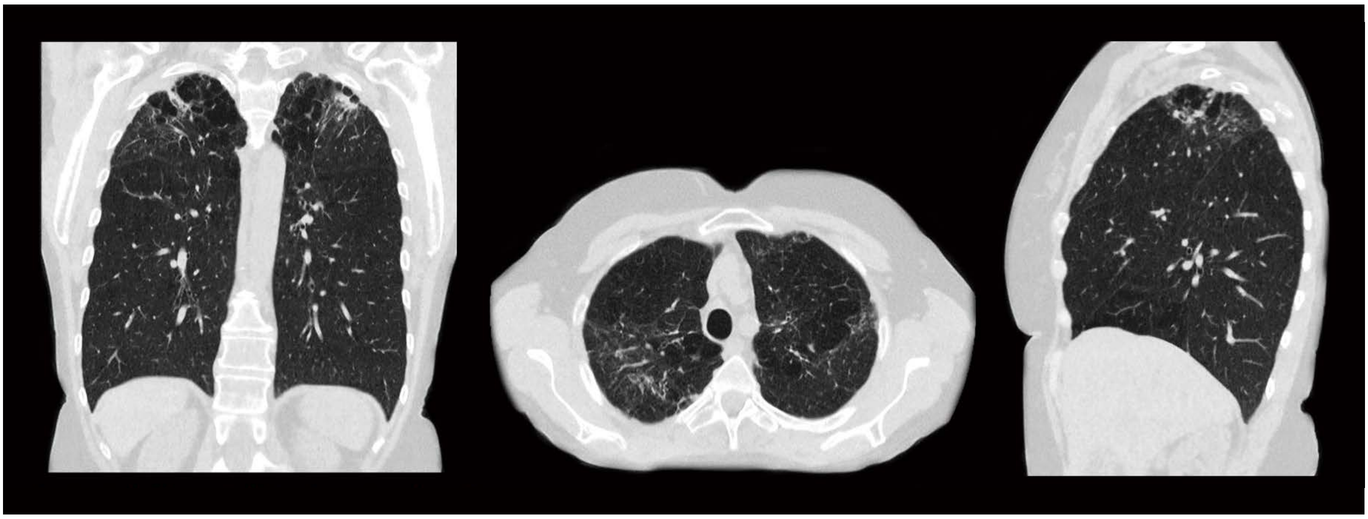
Case 2 - nodule

A 7.7 mm nodule is seen in this screening chest CT performed with SilverBeam Filter and AiCE. CTDI 0.7 mGy, DLP 27.1 mGy·cm, effective dose 0.38 mSv (k=0.014)*. Courtesy Radboud University Medical Center, the Netherlands.



Case 3 - fibrosis

In this lung screening scan performed with SilverBeam and AiCE fibrosis is seen in the lung apices, but no nodules were detected. CTDI 0.5 mGy, DLP 17.7 mGy·cm, effective dose 0.24 mSv (k=0.014)*. Courtesy Radboud University Medical Center, the Netherlands.



* American Association of Physicists in Medicine (AAPM) Report 96, 2008.

Conclusion

SilverBeam, Canon Medical's novel silver-based filtration for CT, selectively eliminates low-energy photons from a polychromatic X-ray beam, thus offering numerous advantages that position it as the preferred approach over other filtration materials for specific applications, like reduced-dose lung screening. When combined with AiCE technology, SilverBeam demonstrates the ability to produce CT images of high quality while minimizing patient radiation exposure.

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