Computed tomography

Using **spectral results** in CT imaging

Philips IQon Spectral CT

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In clinical practice, CT has become an essential tool with many applications in diagnosis and disease follow-up, and the assessment of response to therapy. Until now, CT with its conventional polyenergetic grayscale images based upon Hounsfield units has been limited by its inability to quantify contrast agents and to discriminate between various body materials. With conventional CT, beam-hardening artifacts and reconstruction algorithms produce interference that limits the accuracy of quantification.

Philips IQon Spectral CT is the first and only spectral-detector CT built from the ground up for spectral imaging so no upfront decision-making is necessary to obtain spectral information. Because use of IQon Spectral CT requires no pre-scan determination, if incidental abnormalities are encountered there is no need to call the patient back for additional imaging. On-demand spectral analysis of a region of interest allows the physician to further interrogate incidental findings.

How does spectral CT work?

Color quantification adds spectral resolution to image quality, delivering not just anatomical information but also the ability to identify and characterize structures based on material content.

Just as white light consists of an entire spectrum of colors, so the X-ray photon beam produced by CT scanners consists of a spectrum of photons with a range of X-ray energies from low to high.

The Philips IQon spectral detector has the ability to simultaneously distinguish between X-ray photons of high and low energies. This spectral analysis allows the discrimination of materials consisting of specific atomic numbers, such as iodine or calcium. Various elements are assigned individual colors, allowing them to be visually distinguished on CT scans.

Workflow considerations

Because the acquisition of spectral data is dependent on the detector rather than the X-ray tube, there is no need to decide to use a spectral protocol in advance of performing a scan. The patient is scanned using established workflows and a conventional anatomical image can be generated and interpreted. Data generated during scanning with the IQon Spectral CT are fully DICOM 3.0-compliant, and images can be sent to the PACS where they can be archived for retrospective spectral reconstruction and evaluation. Spectral image reconstruction can include image types such as monoenergetic (MonoE), iodine quantification, and images that map the effective atomic number of the tissues in question.

Spectral results

Spectral results include CT images reconstructed utilizing underlying spectral data which includes the contribution of photoelectric effect and Compton scatter. This spectral data is packaged into a spectral base image (SBI) from which spectral results can be derived. The spectral results can be displayed in the same way as conventional CT images (such as axial, MPR, MIP). The images may be displayed in gray or color scales. The image's pixel values can be expressed as HU, material concentration (mg/cc), or effective atomic number values.

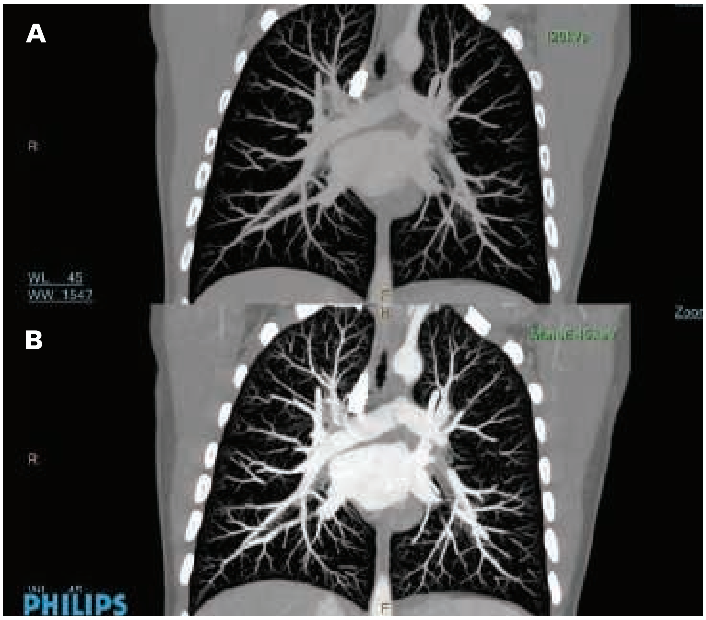


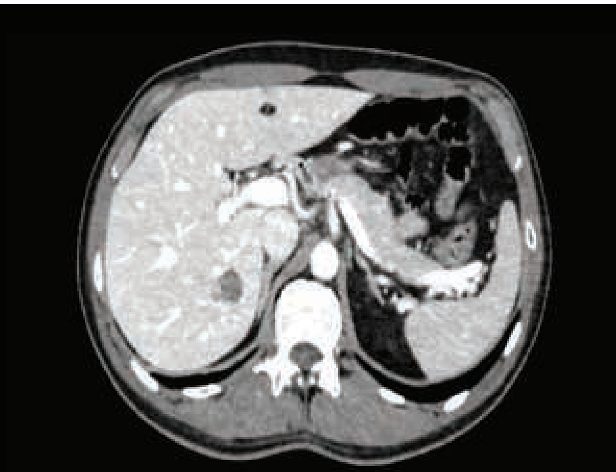
Figure 1 Chest image with contrast comparison. Enhanced image at 120 kVp (**A**). MonoE image at 45 keV (**B**).

The following is a description of various spectral results.

MonoE

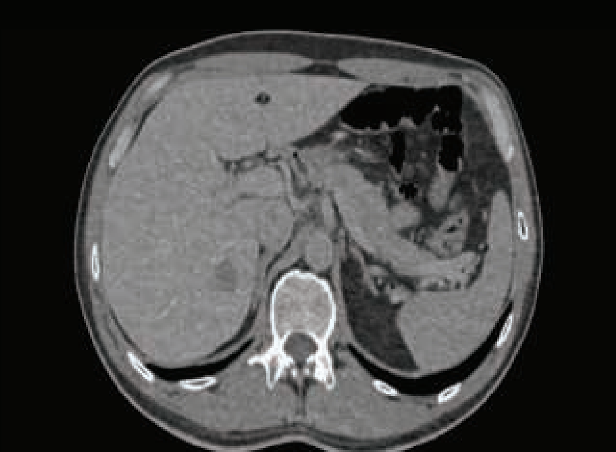
Each image series is at an energy level represented as a kilo-electron Volt value (keV), in the range of 40-200 keV. The pixels in these images represent Hounsfield values. In the software GUI, the series appears as MonoE“X”; for example, MonoE75, where 75 is the keV. MonoE images reduce image artifacts, such as beam hardening (high-range keV) and enhanced visualization (signal) of iodine-enhanced tissues (low-range keV).

Important note: When measuring HU values on MonoE images, note that keV values significantly affect HU values.



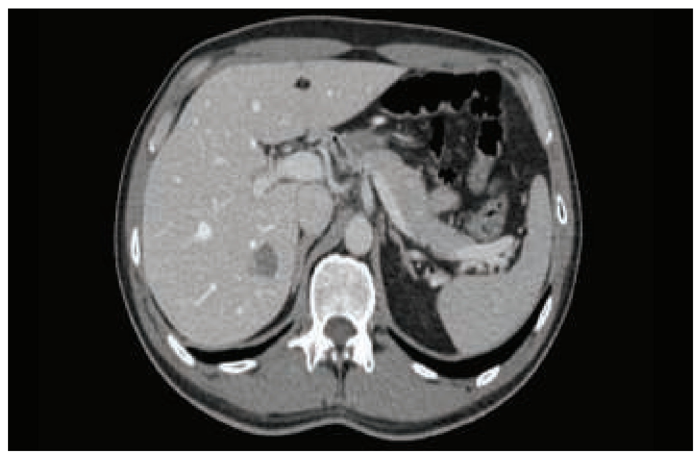
Low keV range can boost iodine signal.

Medium keV range can maintain HU values and reduce artifacts.



High keV range can reduce artifacts.

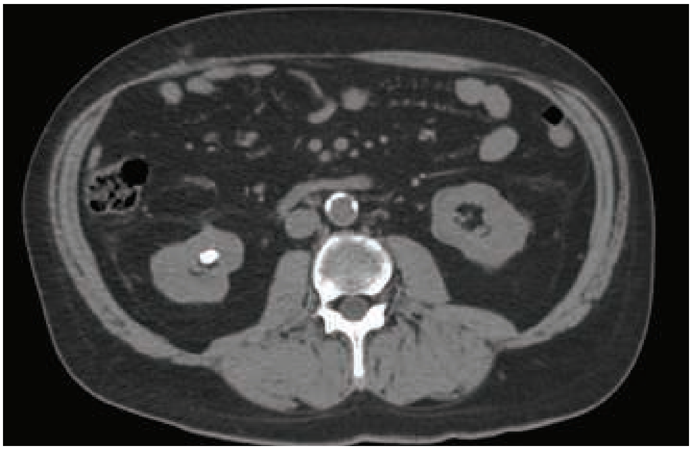
Monoenergetic kV equivalent



All tissues reproduce almost the same HU as in conventional.
The images can reduce artifacts.

This virtual monoenergetic image series is closest to the HU values of conventional CT. The spectral CT system can estimate the material content of the patient, and can estimate the mean detected spectra during imaging of the patient. In the software GUI, the series appears as MonoE“X” (“y” kV); for example, MonoE75 (120 kV) means that the virtual MonoE is at 75 keV, has almost the same HU as in the conventional 120 kV. This result has the benefit of closely matching the HU of conventional CT while improving image quality by reducing artifacts.

VNC (virtual non-contrast) [HU*}



Iodine is identified and replaced by HU value as if this material was not present. All other tissues are presented in their original HU value.

All tissues except Iodine are presented in their original HU values. Iodine pixels are identified and replaced by HU values as similar as possible to their HU without contrast enhancement.

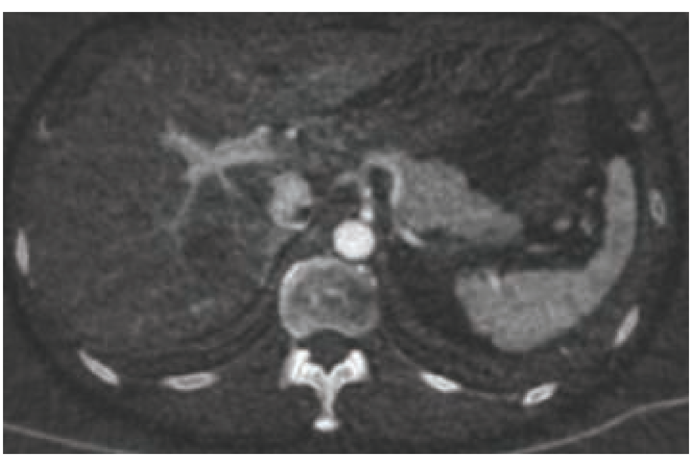
Why some units are marked with "*"

HU* or mg/ml*

These units are used in material-specific spectral results that are aimed at enhancing, suppressing, or removing certain materials.

For these spectral results – pixel values measurements (e.g., mean, SD) are only valid within the enhanced material (e.g., for the iodine-enhanced regions within Iodine_no_H_2O).

Iodine no H_2O [mg/cc*]

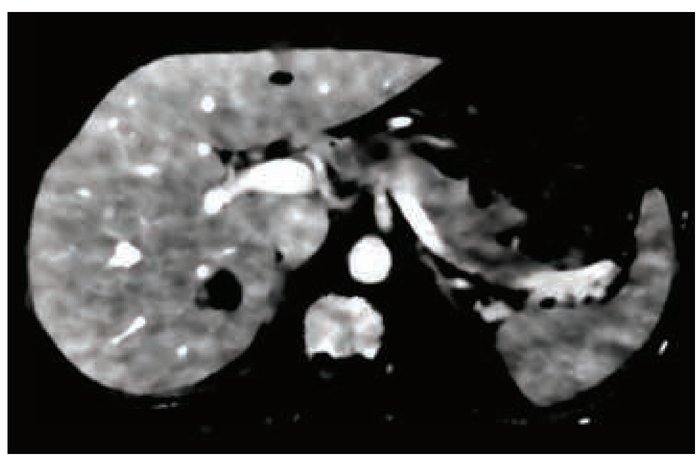


Water-like tissues are identified and suppressed (pixels are replaced by 0 mg/ml). Iodine is presented in concentration.

Pixel values represent the iodine concentration of the displayed tissue in mg/cc. Water-like tissues are identified and suppressed. The images enhance visualization and distribution of iodine-enhanced tissue.

Important note: ROI measurements are intended to be taken on areas which contain Iodine. ROI values on these images show mg/ml units.

Iodine only [mg/cc}

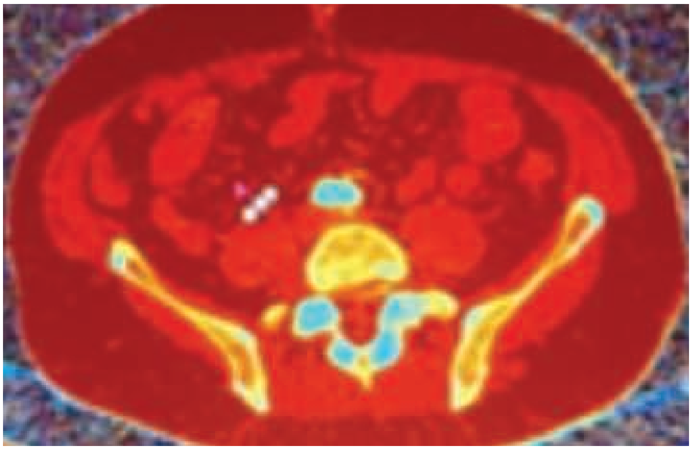
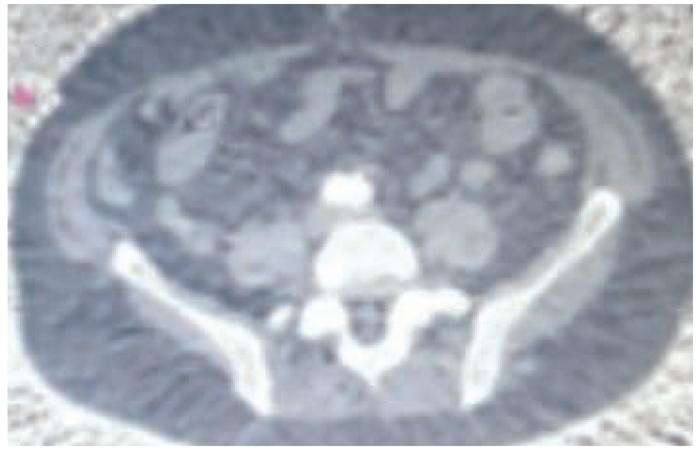


All tissue *except* iodine pixels are removed (replaced by black pixels like air). Iodine is presented in concentration.

Pixel values represent the iodine concentration in mg/cc. All tissues except iodine pixels are replaced by "black" pixels. The images quantify iodine enhancement, and improve iodine visualization and distribution within the enhanced tissue.

Important note: ROI measurements are intended to be taken on areas which contain Iodine. ROI values on these images show mg/ml units.

Effective atomic number (Effective Z)

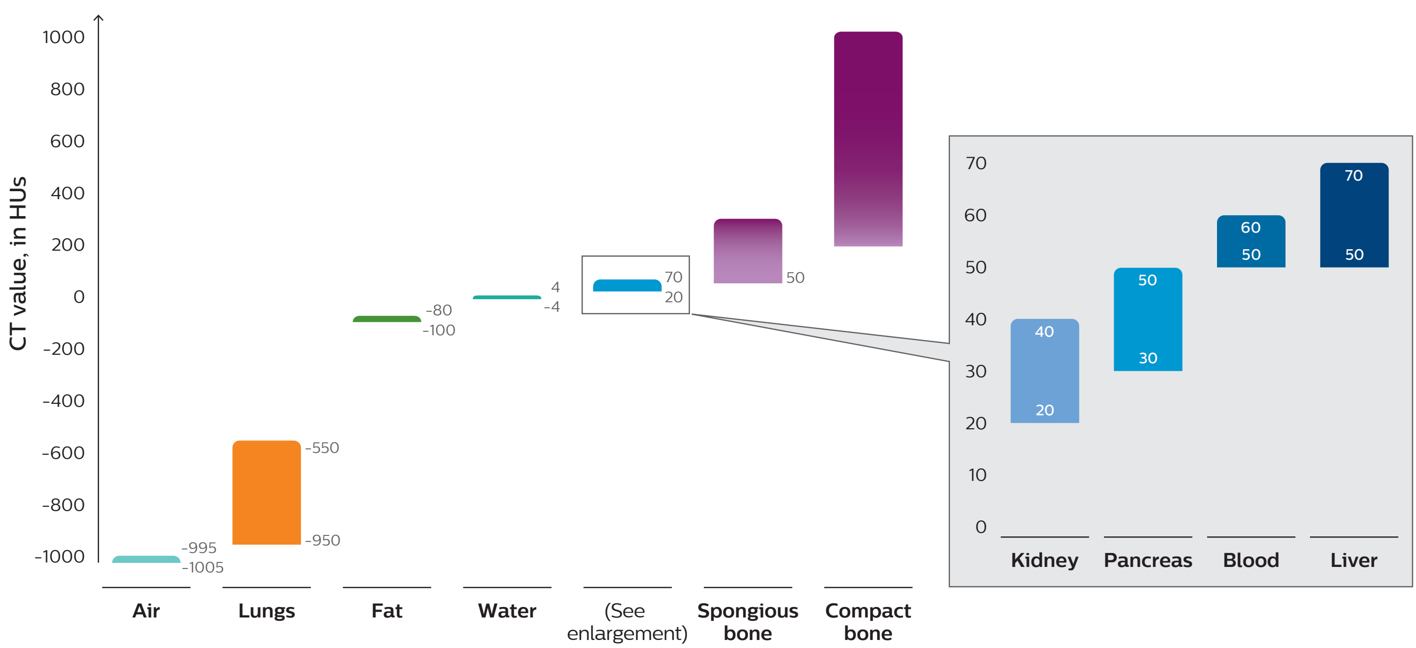



Color and grayscale display; tissues are represented by their effective atomic number value.

Pixel values represent the effective atomic number of the displayed tissue. Images can be displayed in color or grayscale. While imaging the body, the dynamic range is between 0 and 30. These types of images provide the ability to differentiate tissues based on these values (e.g., stone characterization).

> "Most important is therapy response in oncology. You want to know if a tumor is responding in the correct way. Is the patient getting an advantage from treatment?"
>
> *Zimam Romman, Clinical Scientist, Philips*

HU values of body materials



On-demand spectral analysis

If the clinician decides that spectral information would be of additional value in a particular Region of Interest, the spectral data acquired during the single scan can easily be accessed on the console from the PACS for retrospective on-demand spectral data analysis.

The Magic Glass enhanced visualization tool is superimposed on the conventional CT image, providing a spectral view of an area of special interest. **Figure 2** shows a conventional CT scan of the abdomen with the Magic Glass deployed to give a spectral view of the pancreas, revealing not only structural features but also providing information that can help in revealing the composition of the tissues.

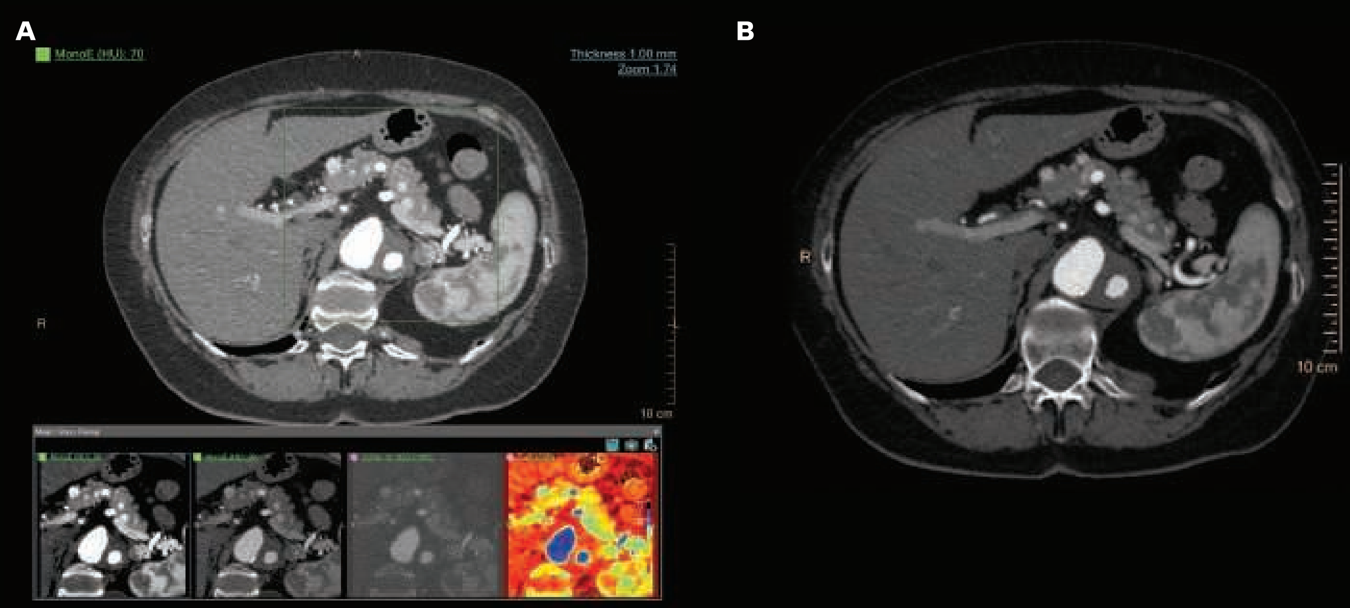


Figure 2 CT image of the abdomen of a patient with previously resected renal cell carcinoma, descending aortic dissection, and an infrarenal aneurysmal true lumen, with multiple enhancing pancreatic masses. The Spectral Magic Glass provides a spectral view of the pancreas. The user can assign different spectral results to further interrogate a Region of Interest (**A**) and compare to the 72 keV MonoE image (**B**).

Virtual non-contrast scans

Due to its ability to distinguish contrast materials such as iodine, spectral CT exams provide more efficient management of incidental findings in scans performed directly with contrast media.

Using traditional CT, a patient first undergoes a non-contrast scan and is then scanned after injection of contrast agent to acquire contrast-enhanced data for diagnostic purposes. Philips IQon Spectral CT requires only a single contrast scan. Because spectral CT can, for example, identify iodinated contrast agent, during image reconstruction iodine can be virtually removed from the image (**Figure 3**).

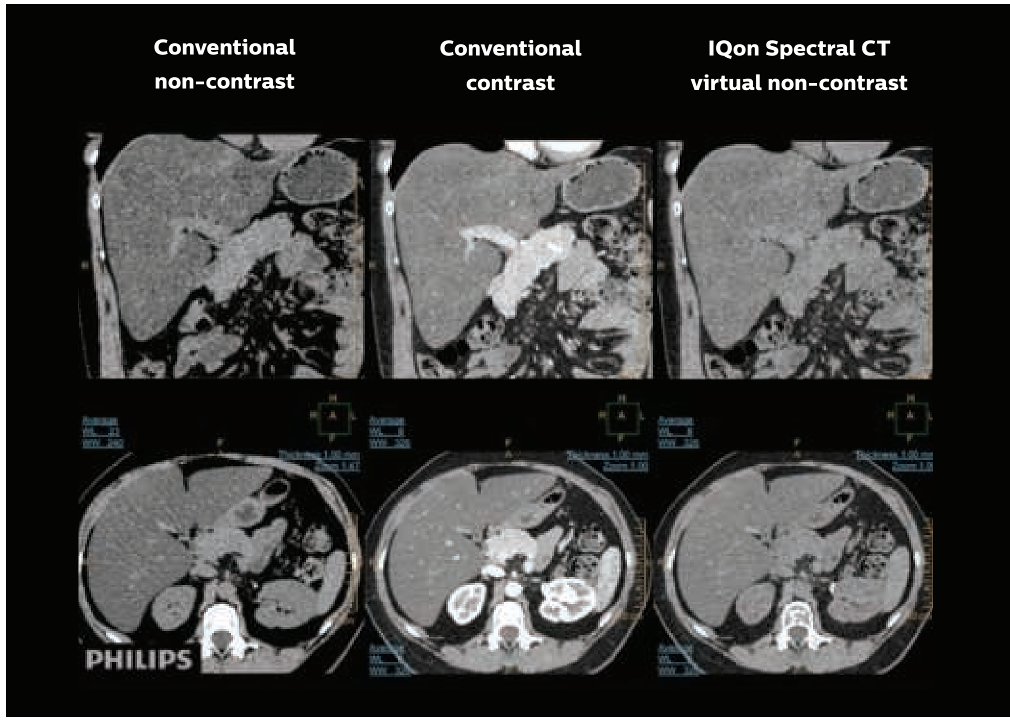


Figure 3 The figure demonstrates a comparison of conventional non-contrast image of the abdomen to virtual non-contrast using spectral data, allowing visualization of the contrast-enhanced tissues after removal of iodine.

Reducing artifacts

Beam-hardening artifacts

In conventional CT imaging, the polychromatic beam is a source of beam-hardening artifacts. By using the simultaneous detection of low- and high-energy signals it is possible to suppress beam-hardening artifacts. **Figure 4** shows beam-hardening improvement in the frontal brain using the Philips IQon Spectral CT.

A recent study using water-filled anthropomorphic phantoms of two sizes compared the stability of iodine density measurements in conventional scans and in virtual mono-energy images acquired using spectral CT.[1] Tubes of different diameters (11.1, 7.9, and 6.4 mm) filled with iodine solution (7 mg/mL) were located between 3 and 11 cm from the phantom center. It was shown that the quality of the virtual mono-energy images at 65 keV was improved and without beam-hardening artifacts. Independent of phantom size, tube location, or tube diameter, the virtual mono-energy images demonstrated stable iodine density.

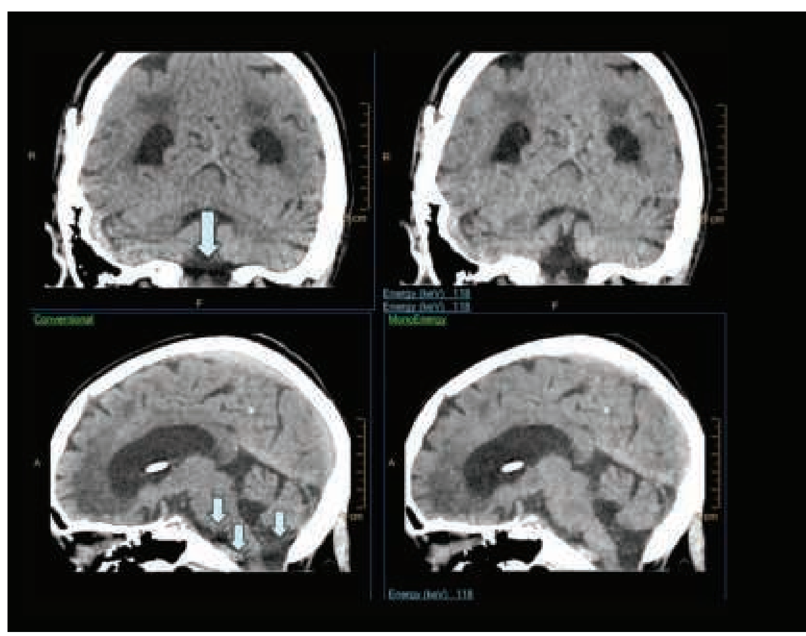


Figure 4 Beam hardening improvement in the frontal brain using the Philips IQon Spectral CT. Coronal view of a conventional CT and MonoE 118 keV that improves the beam-hardening artifacts in the posterior fossa (**A**). Sagittal views of a conventional CT and MonoE image that improve the beam hardening in the posterior fossa at the higher MonoE of 118 keV (**B**).

Metal implants

Metal implants are also a source of artifacts in conventional CT scans. Spectral CT reduces the streaking and banding that implants can cause, resulting in high quality images that enhance diagnostic confidence. **Figure 5** shows a non-contrast CT image of the lower extremities of a 31-year-old male following repair of fractured distal tibias using metal plates and screws. Conventional polyenergetic image (**A**) vs a high-energy mono-energetic image with reduced metal artifacts (**B**).

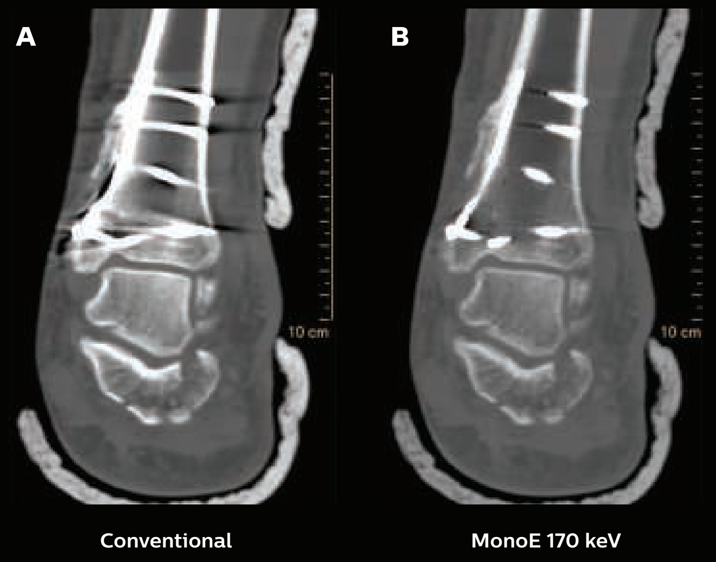


Figure 5 Non-contrast CT image of a 31-year-old male following repair of fractured distal tibias using metal plates and screws. Conventional polyenergetic image (**A**). High-energy monoenergetic image with reduced metal artifacts (**B**).

Conclusion

Previously mentioned features of Philips IQon Spectral CT, such as the capability to interrogate incidental findings using retrospective spectral data and the ability to generate virtual non-contrast images from a phase-1 scan with contrast injection, allowing visualization of the contrast-enhanced tissues after removal of iodine, are designed to have a positive impact on clinical practice without necessitating a change in workflow. Perhaps one of the areas where the application of spectral CT may have a major clinical impact is in the evaluation of tumor response to therapy.

Reference

1. Leichter I, et al. RSNA 2013. http://archive.rsna.org/2013/13021714.html. Accessed June 12, 2014.

Please visit www.philips.com/IQonSpectralCT

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