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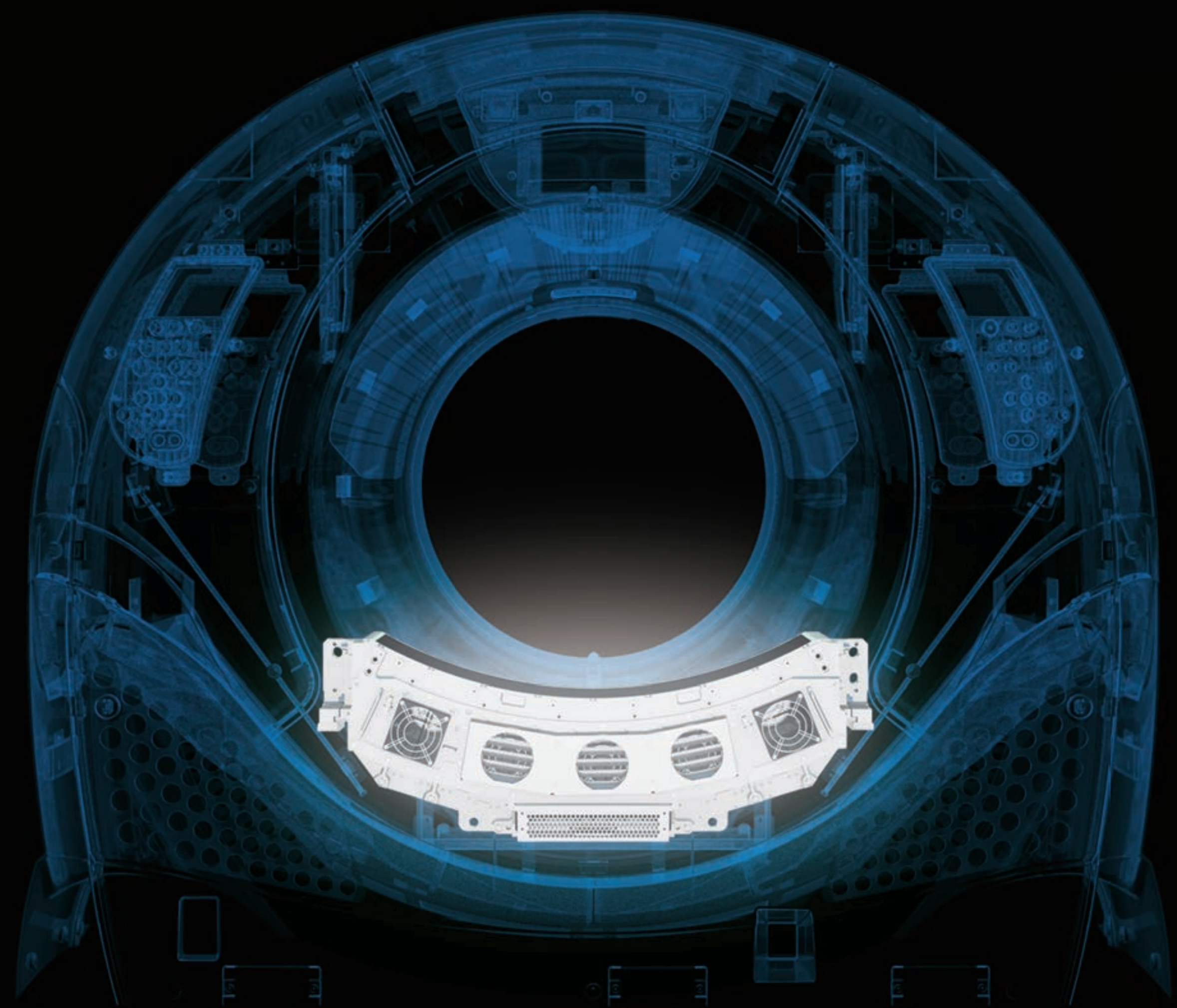
The PURE ViSION CT Detector in Clinical Practice

Dr. Russell Bull



Introduction

In November 2013, the 3rd generation Aquilion ONE™ CT system was installed at our institution, being the first of its kind to be installed outside of Japan. This third iteration of Toshiba's dynamic volume CT system came with many new enhancements, most significantly a uniquely manufactured detector that became known as the PUREViSION detector (Figure 1) when launched a year later at the RSNA meeting in 2014.

Through innovative advancements in manufacturing technology, the PUREViSION detector was shown to provide a **40% increase in light output** compared to conventionally manufactured detectors, as evidenced by engineering measurements in the Toshiba factory. In addition, through miniaturization in the Data Acquisition System (DAS) integrated circuit board, metrics indicated a 28% decrease in electronic noise.[1] Combined, these statistics were predicted to translate to significant radiation dose savings of up to 40%. Having already seen doses more than halve with the introduction of iterative reconstruction (AIDR 3D), I was initially skeptical that when put into clinical use, these claims would become a reality.

As it turns out, this breakthrough in detector manufacturing technology provided even more benefits to our patients and has actually saved us money.

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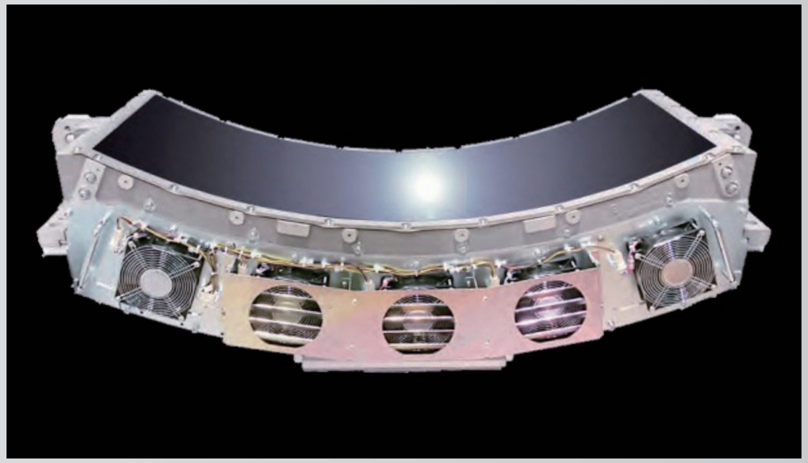

Figure 1: The PUREViSION detector for the Aquilion ONE and Aquilion ONE /ViSION Edition features 16 cm of anatomical coverage in a single gantry rotation.

Initial Results

Two independent audits were performed at our institution in July/August 2013 and March 2014 as part of national British Society of Cardiovascular Imaging (BSCI) cardiac CT dose audits. Our scanners involved in these dose audits were the Aquilion ONE and the Aquilion ONE with the PUREViSION Detector, respectively. All consecutive patients were included for both audits with no exclusions. Rotation time (0.35 s), median BMI (27), median acquisition heart rate (56 bpm) and image noise were identical in both groups. Automatic exposure control (SUREExposure™ 3D) was used in all patients and image reconstruction was performed with AIDR 3D*.

*Adaptive Iterative Dose Reduction 3D

The median DLP on the Aquilion ONE with PUREViSION was 77.5 mGy·cm (1.08 mSv), compared with a median DLP of 139 mGy·cm (1.9 mSv) on our previous Aquilion ONE (**Figure 2**). This represents an impressive 44% radiation dose reduction that can only be attributed to the improved efficiency of the PUREViSION detector.

Remarkably we had not changed any aspect of our scanning protocol between the two systems. The dose reduction was automatically assured by the sophisticated automatic exposure control system that ensures our desired diagnostic image quality which had been calibrated to the new levels of detector efficiency.[2,3]

Taking a Closer Look

The results of this independent audit not only laid any skepticism to rest but rekindled an excitement of possessing truly ground-breaking technology providing possibilities to change patient care.

We reviewed the average radiation dose levels and image quality for a wide variety of examinations and observed similar dose reduction for standard examinations and improved image quality for ultra-low-dose cases performed on young patients. This led to a project focused on fine-tuning patient protocols in order to push the limits of the new technology.

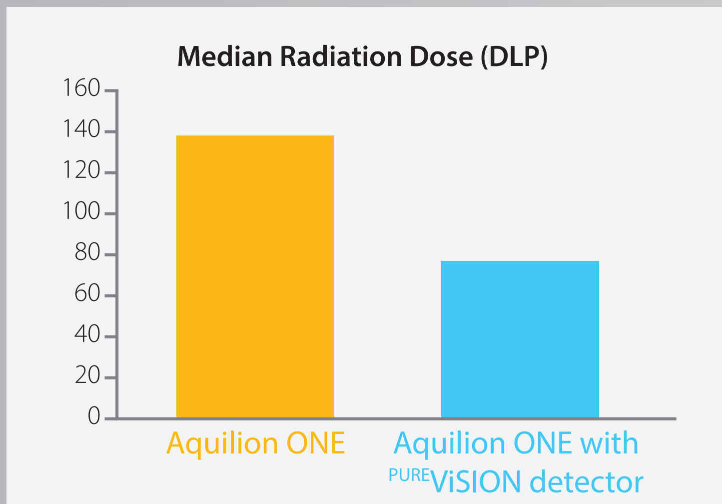

Figure 2: Direct comparison of the photon output of the PUREViSION scintillator and a conventionally manufactured scintillator demonstrating a 40% increase in light output.

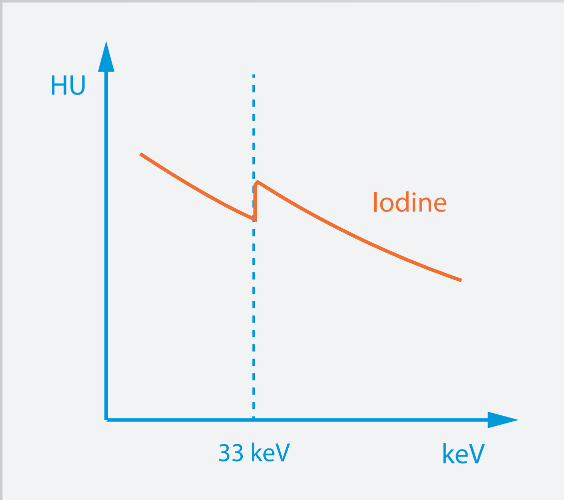

Figure 3: This graph shows the sudden increase in the HU density of iodine at (and above) 33 keV due to the K-edge effect.

There were three avenues we wanted to explore. Firstly, the PUREViSION detector allowed use of lower tube current, thus expanding the patient population that could be imaged with low-kVp settings. This would in turn permit us to reduce iodinated contrast dose through the well known K-edge effect (**Figure 3**). Secondly, the improved image quality at new low dose standards meant we would be able to further drive down radiation exposure dose for all examinations, but in particular for young patients, who are more radiation sensitive. Lastly, and perhaps controversially, we wanted the ability to offer extremely low-dose CT examinations as an alternative to plain x-ray where the clinical indication was appropriate.

Reducing Contrast Dose

Low-kVp scanning generates a higher proportion of lower energy photons at an energy level just above the binding energy of the K shell electrons of iodine at 33.2 keV. Photons of this effective energy and slightly above are more likely to be absorbed by iodine, which results in an increased HU density of contrast-enhanced tissue in the resultant images. This allows equivalent enhancement to be obtained using much lower doses of iodinated contrast compared with conventional 120-kVp scanning.

Low-kVp scanning generates fewer photons for a given tube current and has been traditionally limited to patients with low BMI due to poor signal-to-noise ratios in larger patients with conventional detector systems.

Our investigation resulted in the ability to use 80-kVp scanning in a much wider group of patients, and it is now our standard technique for CT angiography examinations in patients with BMIs of up to approx. 35. As a result, we have been able to reduce contrast volumes by approximately 40% in these patients, significantly reducing the risk of contrast-induced nephropathy (CIN). Additionally, we are now able to perform ultra-low-dose contrast examinations in patients with impaired renal function much more safely (**Figure 4-6**).

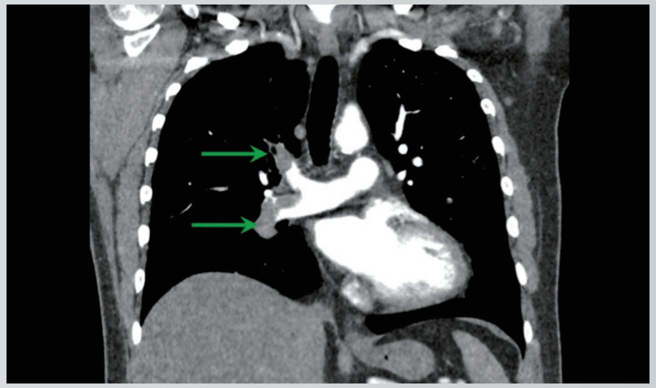

Figure 4: Routine helical CTPA – BMI 26. 80 kVp. 45 ml Niopam 370 @ 3 ml/s. Dose 1.3 mSv. Multiple right-sided pulmonary emboli (arrows).

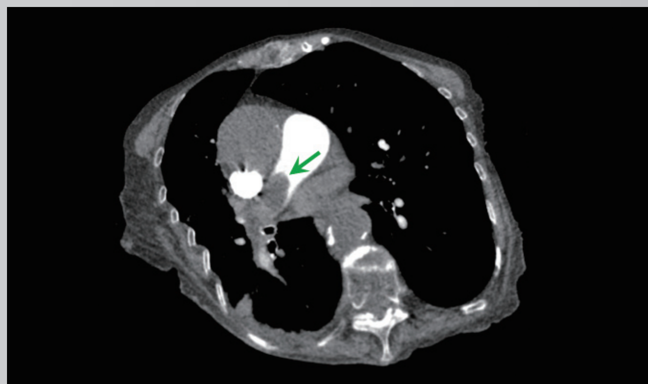

Figure 5: Free-breathing single-rotation CTPA – 80 kVp. 30 ml Niopam 370 @ 3 ml/s. Dose 0.5 mSv. Large pulmonary embolus obstructing the right pulmonary artery (arrow).

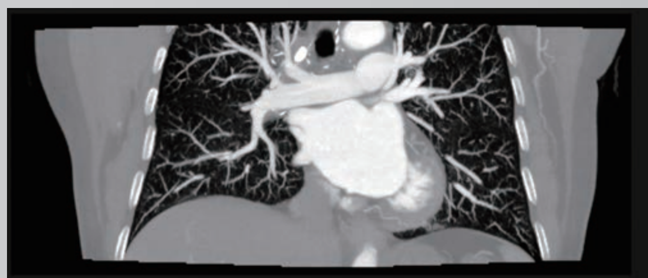

Figure 6: PE and aortic dissection can be excluded in the same rotation routinely at <1 mSv. 30 ml Niopam 370 @ 3 ml/s.

PUREViSION Detector Reduces Costs

The efficiency of the PUREViSION detector has enabled us to reduce contrast doses for all body parts, including for all cancer staging studies. Almost all patients can now be scanned at 80-100 kVp, resulting in substantial contrast dose reduction whilst maintaining or increasing organ enhancement. This has resulted in an overall 25% reduction in contrast usage, with estimated savings of approx. £15,000 ($23,500 USD approx.) per year.

Further Reducing Radiation Dose

"As Low As Reasonably Achievable" (ALARA) is a mantra that all prescribers of ionizing radiation for diagnostic imaging should live by. With truly disruptive new technology such as the PUREViSION detector, one must not be complacent and must thoroughly explore new possibilities.

Traditionally with low dose imaging, areas that are prone to photon starvation, for example through the shoulders, are often poorly visualized. With the PUREViSION detector, we found that we could drive down dose for routine chest examinations and still maintain adequate signal to noise permitting unobstructed imaging through the lung apices. The decrease in DAS noise in these low-photon areas compensated to maintain the overall signal-to-noise ratio (Figure 7).

Our typical patients for coronary CTA examinations now receive sub-millisievert doses of radiation with excellent image quality (Figure 8,9). In young radiosensitive patients, we are now able to perform scans well below 0.5 mSv to answer the clinical question (Figure 10). Such an example is in the investigation of anomalous coronary arteries, where a survey of the anatomy is really all that is required.

Replacing Traditional Radiographs

With the dose reduction technology at hand, including AIDR 3D iterative reconstruction, combined with the new standards in detector efficiency, it is well and truly possible to produce diagnostic-quality CT examinations with the equivalent dose of a standard x-ray examination. Of course these extremely low-dose CT scans are not currently suitable for low-contrast imaging, but they are perfectly adequate and far superior to a set of radiographs for many clinical indications involving high contrast delineation. The previous limitations of extreme photon starvation simply no longer apply (Figure 11,12).

As an ongoing area of investigation in our institution, we have started to slowly replace x-ray where appropriate. For example, lung nodule CT screening examinations can be acquired with x-ray equivalent doses and offer superior diagnostic accuracy.

I believe, in the future, x-ray radiographs will be replaced by a CT scan for the majority of examinations. While this view is controversial, we need to consider the current reality, where many patients with equivocal results from x-ray examinations progress to a CT scan anyway, resulting in unnecessary radiation and needless delays. In the future, we may actually be able to improve patient care, reduce the cost of care and increase throughput simultaneously by replacing routine x-ray examinations.

Conclusion

As a radiologist practicing for 20 years, I have seen great advancements in CT technology. Starting back in the late 1990's, the race for multi-detector row scanners with an ever increasing number of slices heralded an explosion in the utilization of CT. This growth would not have been sustainable or even tolerated without dramatic advancements in dose reduction strategies.

Today we have a 3rd generation Aquilion ONE with the PUREViSION detector that has reduced dose by more than 40% overnight. Thanks to this breakthrough technology, we can image all patients more safely with less radiation and reduced iodinated contrast volumes and we are even able to perform CT examinations with dose levels equivalent to an x-ray examination, leading to new possibilities in patient care.

Figure 7: Routine helical HRCT 0.5 mm. Total DLP 46 (0.8 mSv).

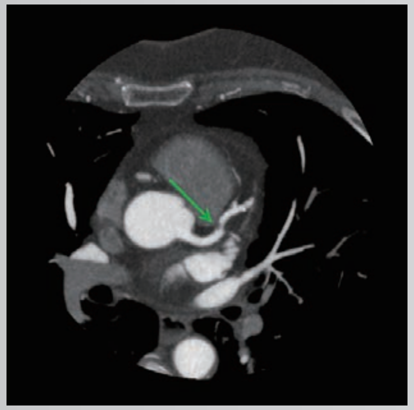

Figure 8: CT coronary angiogram. BMI 26. Critical LAD stenosis (arrow). Dose 0.8 mSv.

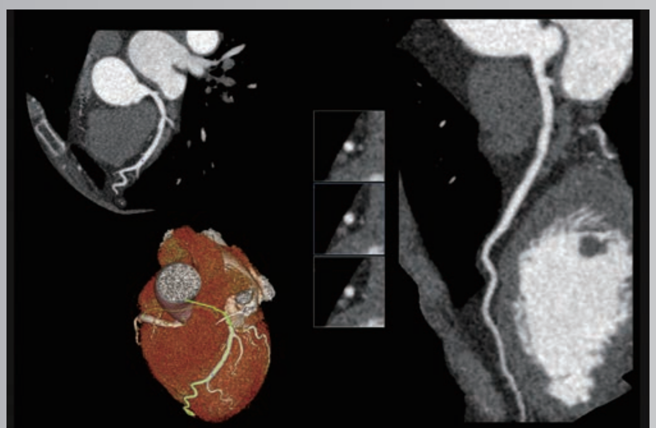

Figure 9: Minor LAD plaque. DLP 30 (0.4 mSv).

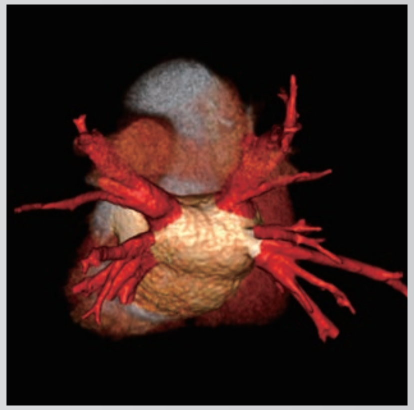

Figure 10: Left atrial planning pre ablation. DLP 7 (0.1 mSv).

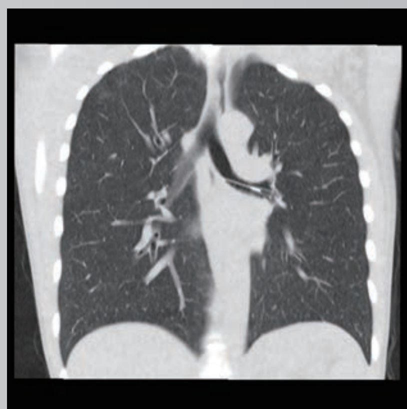

Figure 11: Ultra-low-dose chest CT. 0.1 mSv - 35-year-old woman IVDU. Needle in LM bronchus. DLP 6.

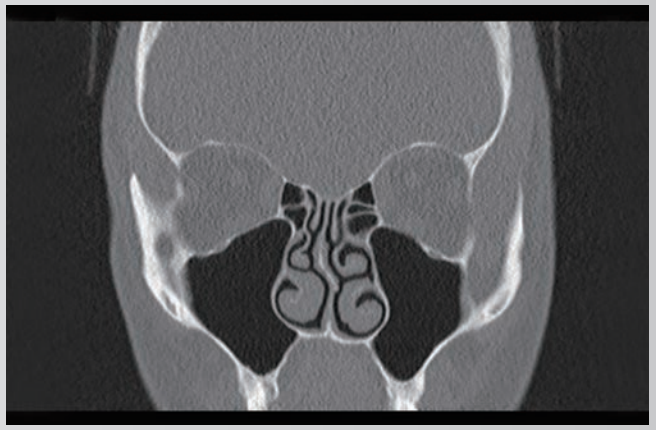

Figure 12: CT sinus. 0.02 mSv - 60-year-old woman. Dose: DLP 8.9 mGy·cm.