Spiral Breast CT: an innovative technology for high resolution real 3D breast imaging without compression

By E Bärnklau-Gooriah, V Ruth, Dr. C Steiding & Dr. D Kolditz.

Even when using images acquired by the latest high-tech breast imaging devices and read by experienced radiologists, the accurate diagnosis of early breast cancer remains challenging. The well-established conventional diagnostic breast imaging modalities all have well-known limitations. In contrast, 3D imaging of the breast at high isotropic resolution offers clear advantages. A dedicated breast CT system, nu:view developed by the German company AB-CT – Advanced Breast-CT, incorporates innovative technology that has the potential to take breast imaging to a new level. The new system provides high resolution 3D imaging of the breast at a very low radiation dose and without the need for any compression. To achieve this, nu:view uses state-of-the-art direct conversion photon-counting detector technology combined with a spiral CT acquisition concept. The CE-marked scanner is commercially available and is already in use with patients in Europe. This article gives an overview of the breakthrough technology as well as the clinical experience already obtained with the system in the University Hospital of Zurich, Switzerland.

SPIRAL CT WITH PHOTON-COUNTING DETECTOR

The design of the new nu:view scanner allows compression-free imaging of one breast at a time. To do this, the breast CT system uses a rotating gantry on which the X-ray tube and detector are mounted. During the image acquisition process, the gantry rotates around the breast in a downwards-oriented spiral trajectory. In the course of a single 360° rotation of the gantry around the breast, up to 2,000 projection images are acquired. A full spiral scan takes as little as 7 – 12 seconds. Exceptional image quality at a low radiation dose is possible, because the data acquisition is carried out by a dedicated, curved single photon-counting detector, which is the result of AB-CT's long-term technical collaboration with the Swedish company Direct Conversion. The nu:view scanner is the world's first CT in clinical use equipped with a direct converting detector. It features a pixel size of $(100\ \mu m)^2$ and a frame rate of up to 1 000 Hz.

Unlike traditional scintillation methods used in conventional CTs which convert X-rays into scattered light, in the nu:view photon detector, every single photon is directly converted into electrical energy, thus avoiding scattering effects and resulting in a much higher image quality. The unique combination of the detector's highly sensitive cadmium telluride (CdTe) material with its dedicated shape allows for highest image quality and dose efficiency.

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HIGH PATIENT COMFORT

The scanner is only 1.10m high which is easily accessible by the patient with the help of a step. The patient table is protected with lead foil sheeting, thus preventing any unintended radiation reaching the patient. For the examination procedure, the patient positions herself prone on the scanner table with the breast to be examined conveniently placed into the aperture. This non-compressive approach keeps the female breast in its natural shape – not only does this avoid the problem of superimposed tissue, but it also makes the examination procedure totally pain-free for the patients. Consequently the patients feel more reassured in a situation which, inevitably, is often highly stressful. A small supporting pillow and footrest may be used to help stabilize the position of the patient who can breath normally during image acquisition.

The entire examination process only takes between 3 – 5 minutes, from patient positioning on the scanner table; double-checking of the breast positioning by the radiographer; selection and confirmation of the scan parameters; the scan itself; right through to the final dismounting of the patient from the scanner table. The overall examination time may be slightly extended if contrast media is administered. The actual data-acquiring scan itself takes only 7– 12 seconds, depending on the length of the breast.

Scan parameters are adjustable to accommodate various clinical requirements and patient types.

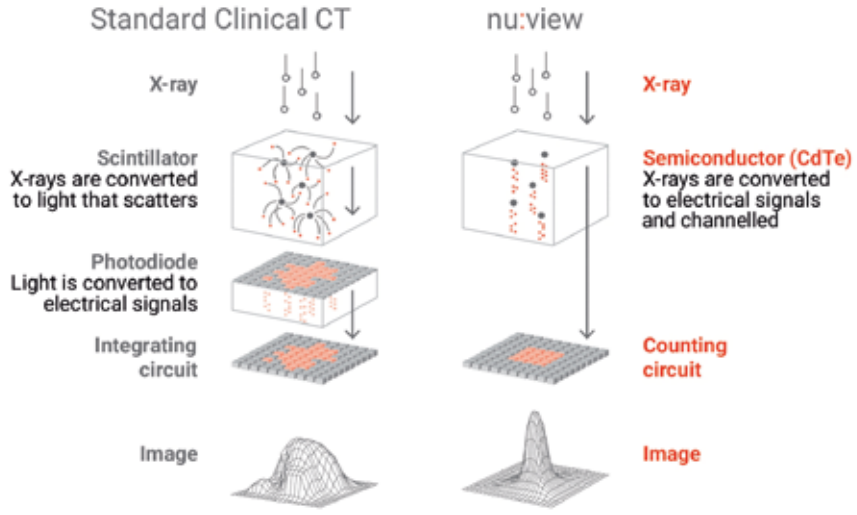
The nu:view dedicated breast CT scanner is highly appreciated by the patients because no breast compression is needed.

There are no restrictions regarding age or gender of the patient; the system is also suitable for patients with small breasts, dense breasts, mastodynia or implants. Advanced visualization techniques such as 3D volume rendering make the 3D high isotropic spatial resolution images a highly useful option for surgery planning.

Likewise, the gentle, pain-free examination procedure also makes it suitable for post-operative follow-ups. As the images are acquired with the breast in its natural shape and without any "squeezing" of tissue, the three-dimensional images provide precise information about the exact location of the depicted lesion.

FLEXIBLE SUPPORT OF CLINICAL WORKFLOWS

Following image acquisition, the image data are transferred to nu:view's reconstruction workstation which is the platform where highly sophisticated algorithms operate on image reconstruction before sending the images in DICOM format to the Picture Archiving and Communication System (PACS). The nu:view system does not require any custom viewing software, so radiologists can continue working in their familiar reading environment. Radiologists used to reading 3D images (e.g. from standard clinical CT or MRI), have confirmed that they find the 3D multiplanar reconstructions of the female breast easy and intuitive to read.



Comparison of the principle of standard clinical CT with that of single photon-counting detection. The single photon-counting detector provides excellent image quality at low dose

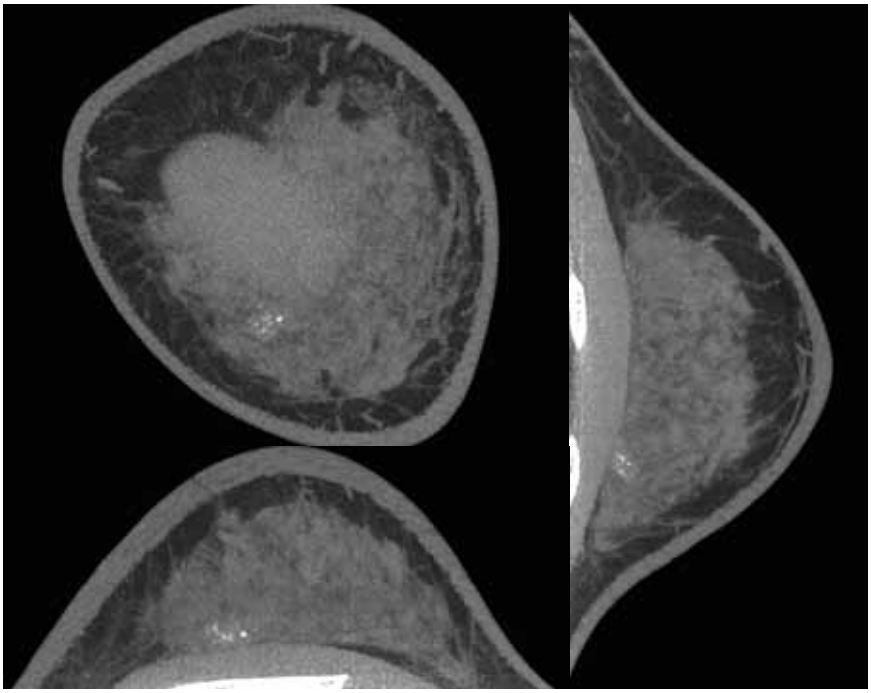
nu:view offers two out-of-the-box protocols for acquisition and reconstruction: a Standard mode with a voxel size of $(300\ \mu m)^3$ and a HighRes mode with $(150\ \mu m)^3$ voxel size. Although the choice of these protocols always depends on individual circumstances, with the ultimate decision being made by the radiologist, the Standard mode is typically the preferred method for scrolling through soft tissue, before switching to HighRes mode e.g. for a more granular analysis of microcalcifications.

CLINICAL RESULTS - INCREASED DETECTION OF EARLY CANCERS

Clinical experience from the University Hospital Zurich (USZ), where the nu:view was first installed, confirms that breast CT provides high quality images and is a viable alternative to mammography or tomosynthesis, especially in those patients reluctant to undergo mammography because of the issue of breast compression. In the absence of an organized national screening programme in the canton of Zurich, breast CT is now being offered to women as an alternative to screening mammography at the USZ. Since the availability of the new system, breast cancer detection rates have notably increased. The senior consultant responsible for breast imaging at USZ, Prof. Andreas Boss has expressed himself to be very pleased with nu:view's image quality. He attributes the increase in detected lesions primarily to the fact that women who had previously refused routine check-ups are now much more willing to undergo the potentially life-saving examination of their breasts.

In a recently published study [1] of the first 300 consecutive women who were examined using spiral breast CT at the University Hospital of Zurich (August 2018 to March 2019, age range: 35 to 84 years (mean age, 56.8 +/- 9.9 years)), a total of 591 acquisitions were performed.

The main reason cited by the women for their preference of the breast CT system over mammography was the lack of breast compression. Out of the 300 women in the trial, 254 (84.7%) explained that they preferred the breast CT for personal reasons or



Suspicious microcalcifications BI-RADS 4. Histology: sclerosing adenosis. Top Left: coronal view. Bottom Left: transverse view Right: sagittal view. Clinical images courtesy of Prof. Andreas Boss, University Hospital Zurich

mastodynia, while 10 patients (0.3%) had implants hampering conventional mammography.

The scans were performed with an initial tube current of 25 mA which later was routinely increased to 32mA for better image quality (at a fixed X-ray tube voltage: 60 kV).

The breast CT system detected 102 possible lesions, including 4 cases of breast cancer (1.3% of all patients). Additional ultrasound was performed in 226 patients (102 due to detected lesions and 124 due to dense breast tissue). Three malignant lesions were detected resulting in seven confirmed malignancies (2.3% of the examined patients). Four of the lesions were seen in breast CT (1.3%), 36 lesions were rated BI-RADS 3 (12%). Those numbers are much higher than the number of malignant lesions typically found in breast screening mammography programs, which detect about three to four cancers in 1000 patients (0.3%-0.4%) [4, 1].

These findings are in line with Prof. Boss' personal observation who noted that the modality proved to be particularly beneficial for women who did not want to undergo breast compression, in an additional ultrasound (1% of all patients). None of the examinations showed any movement artifacts. In 99% of all women, the examination was carried out without any problems, demonstrating the "*already high degree of technical maturity of this new breast imaging modality* "[1]. Out of the 300 patients, nine suspicious lesions were biopsied, for reasons ranging from inconvenience or personal dislike to deep-rooted fear: "*I cannot emphasize enough the importance of this method being completely compression-free. Some women had missed their breast checks for years because they feared compression. Breast CT really solves their dilemma.*"

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Prof. A Boss

Besides the enhanced patient comfort, the fact that the levels of radiation dose are comparable to those of mammography and the clear potential of reaching a larger cohort of women, Prof. Boss also highlighted the decrease in the number of recalls that would otherwise have been caused in mammography because of superimposed structures, These are avoided in breast CT, thanks to the multiplanar, real 3D pictures.

CONCLUSION

Around 97,000 people, the vast majority of whom are women (almost 99%), die from breast cancer each year in the EU [2]. Breast cancer is often diagnosed at an advanced state but is generally much more likely to respond to effective (and less expensive) treatment if the cancer is detected early. It has been shown that early detection can result in a greater probability of survival [3].

Combining high resolution images with high dose efficiency, the nu:view system was developed to support radiologists to reliably diagnose breast cancer at the earliest possible stage. With high resolution, non-superimposing isotropic 3D images and excellent soft tissue differentiation, the innovative spiral breast CT integrates the strengths of mammography/tomosynthesis and MRI technologies in one system, providing a valuable tool for diagnostic breast imaging.

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FURTHER READING

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