Aquilion ONE™

640 Multislice Reconstruction with Dynamic Volume CT

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Introduction

In computed tomography (CT) the number of detector rows has doubled annually over the last eight years. New image reconstruction algorithms have adapted to the requisite extended cone angles. An advanced 3D reconstruction algorithm called coneXact™ was developed for Aquilion ONE™ (Toshiba Medical Systems Corporation, Tokyo, Japan). This algorithm doubles the number of slice images combined with artefact suppression.

In order to improve spatial resolution and to reduce image artefacts other manufacturers have developed x-ray tubes with flying focal spot (FFS) in z-direction[1]. Cyclic focus alternation doubles the x-ray beam and the number of object data from both projection directions resulting in a 2:1 ratio increase of image slices to detector elements for computation. After data acquisition with the same detector elements, the resulting image series overlaps with half the detector width.

One drawback of the FFS technique is the increase in radiation exposure. Since the electron beam cycles between both focus spots, each slice reading receives only half the quantum intensity seen in conventional modalities using a solitary focal spot. The use of FFS technology, compared to conventional scanning, requires a wider tube collimation which increases patient exposure[2]. To the best of our knowledge, there are no dedicated study results in scientific publications regarding the use of dual-source FFS in cardiac imaging; the published 0.75 mm slice thickness with a reconstruction interval of 0.5 mm does not lead to a spatial z-resolution of less than 0.5 mm.

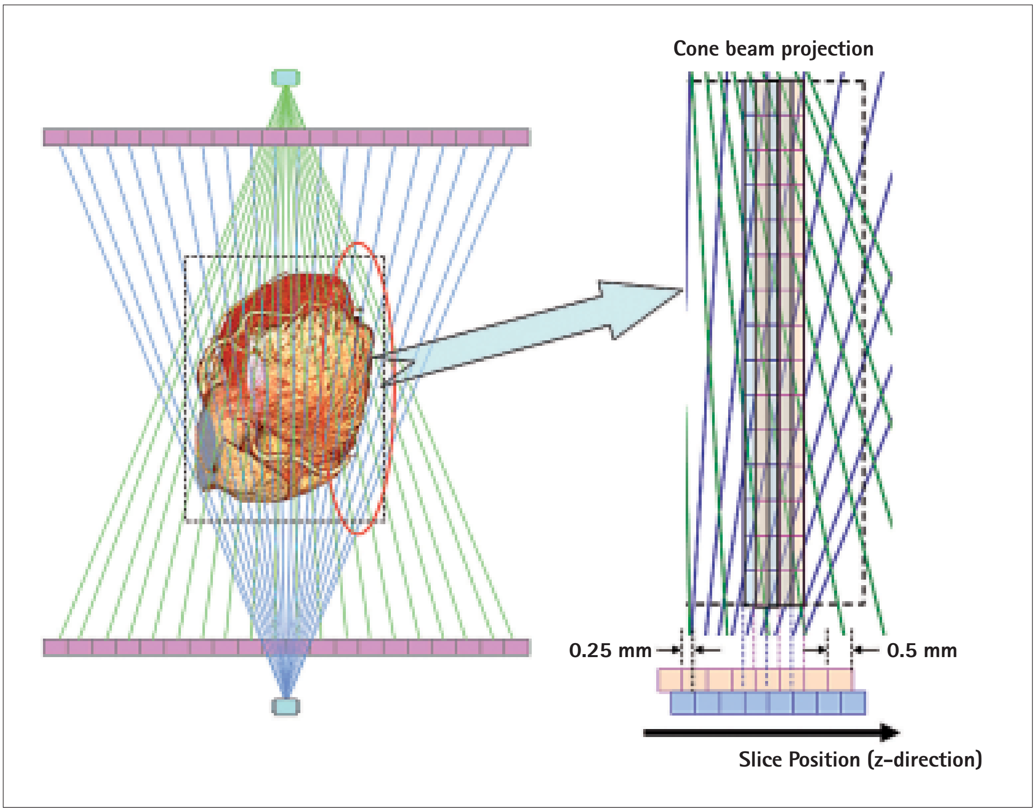


Fig. 1: Doubling the number of slice images (pink, blue) based on a three-dimensional reconstruction with Double Slice Mode

In order to avoid increased patient exposure the coneXact™ reconstruction algorithm is a viable alternative to FFS for improvement of spatial detectability with concurrent avoidance of structural artefacts. We performed phantom test validation to confirm the utility and clinical potential of this reconstruction algorithm in cardiac CTA.

640 slice reconstruction

The Aquilion ONE™ CT scanner generates a maximum volume coverage of 16 cm at the isocenter with 320 rows of detector elements with a thickness of 0.5 mm each. The reconstruction algorithm coneXact™ was developed for cone angles[3] of up to 15.2°, featuring double slice number with 640 slices of 0.5 mm thickness and 0.25 mm interval for improved detectability of fine structures (Fig. 1). Prior to image reconstruction from raw data, Standard Mode or Double Slice Mode can be selected, resulting in 320 or 640 slices, respectively.

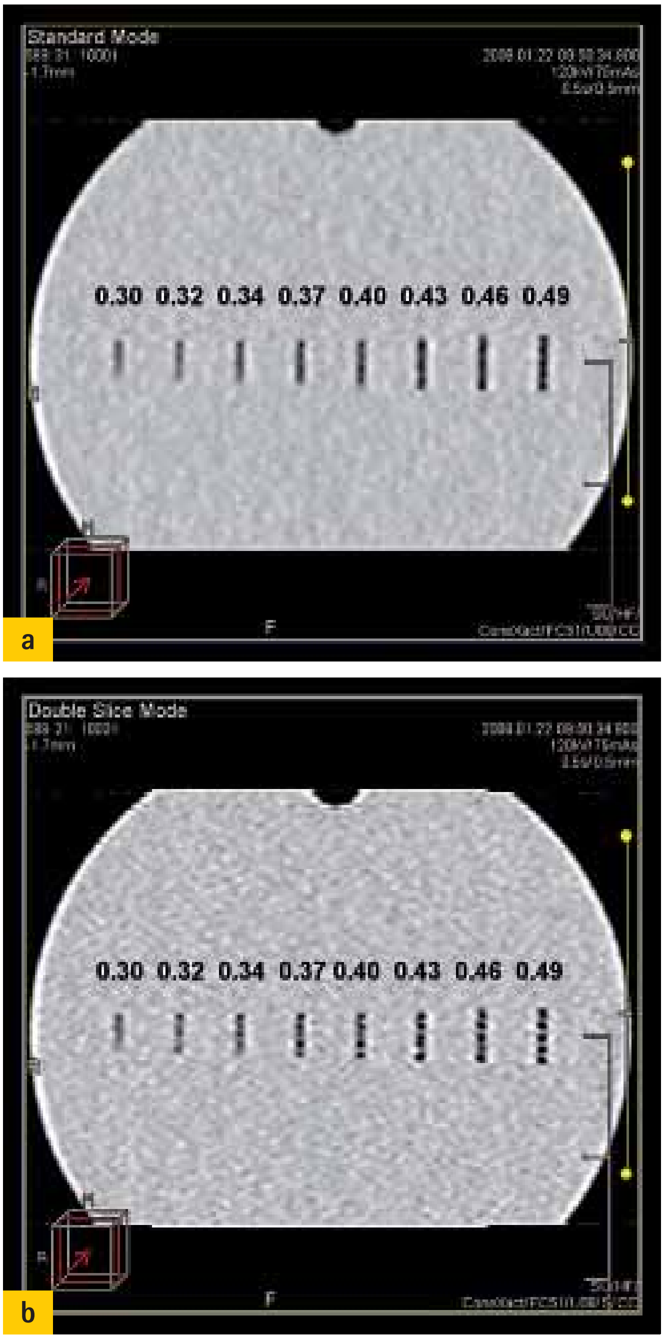
Using the raw data from all projection angles an infinite three-dimensional matrix of volume data is reconstructed as illustrated in fig.1. Because of the high density of the three-dimensional raw data in cone angle acquisitions the increased number of volume data (pink and blue for example in fig. 1) will be generated for 640 slices. The two-dimensional reconstruction is illustrated in fig. 1, however within coneXact™ the 3D data matrix for 640 slices is generated with a three dimensional reconstruction.

Results

Phantom testing

Phantom tests were performed on the Aquilion ONE™ at the Charité Berlin University Medical Center. A bore hole test pattern comprising eight rows of holes with a diameter of 0.31-0.50 mm and hole spacing of 0.30-0.48 mm was mapped microscopically. For each row of holes the hole diameter and hole spacing were averaged and the geometrically detectability assigned to each row (Fig. 2a-2b). The test phantom was positioned with a 5.5 cm y-offset of the hole center lines to the iso-center. After one gantry rotation using tube parameters of 120 kV and 75 mAs the same coronal slice image was reconstructed with Double Slice Mode (preset: 0.5 SR-0.25) at 640x0.5 mm slices and at a Standard Mode of 320x0.5 mm slices (preset: 0.5-0.5). The Hounsfield Unit (HU) windowing after reconstruction from these volume data sets was identical. Fig. 2 compares the lateral geometrically detectability based on Standard Mode and Double Slice Mode for the reconstruction filter FC51 commonly used in the chest volume scan protocol. The standard filter FC51 offer highest spatial detectability of 0.32 mm for Double Slice Mode and demonstrates in fig. 2b the separation of 5 holes over a range of 2.9 mm. The separation of the 0.32 mm diameter bore holes with Double Slice Mode in fig. 2b agrees with the 0.49 mm diameter bore holes of Standard Mode in fig. 2a. This corresponds with up to 35% improvement in bore hole detectability due to the used reconstruction modes. The result is also applicable to eccentric

Fig. 2: Coronal test phantom images down to 0.32 mm detectability with FC51 filter and
a) Standard Mode
b) Double Slice Mode



volume regions as the bore hole rows of the test phantom were offset from the iso-center by 5.5 cm.

Patient examples

It is much more difficult to demonstrate improved image quality by reconstruction of Double Slice Mode in cardiac studies due to cardiac motion and the interaction and superposition of spatial and temporal resolution. The patient images in this study were reconstructed using standard filters for diagnostic imaging of stent structures (Fig. 3) and for quantitative studies of calcificated and non-calcificated plaque (Fig. 4). The filters are combined with the noise reduction filter QDS+. Apart from these

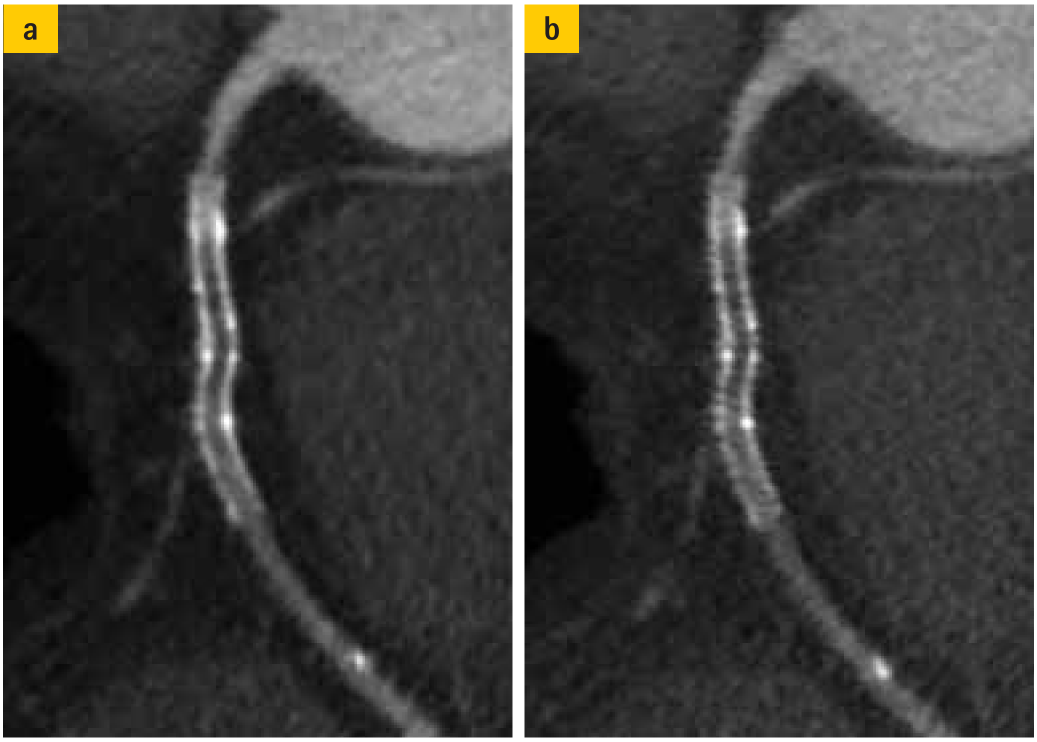


Fig. 3: Curved MPR of 2.5 mm stent in the RCA with a) Standard Mode and b) Double Slice Mode (Patient 1)

clinically relevant filters, no additional image post-processing was performed.

Fig. 3 compares MPR reconstruction with Standard Mode and Double Slice Mode of the first patient example (scan protocol: one heart beat, prospectively gated CTA in the 65%-R interval of the R-R cycle, DLP =277 mGy*cm, E = 3.9 mSv with conversion factor k=0.014 mSv/mGY/cm in thus study[7]), performed with the universal cardiac filter. All other parameters for both reconstructions from the same volume data set were identical. The more detailed Double Slice Mode image of the RCA stent with its

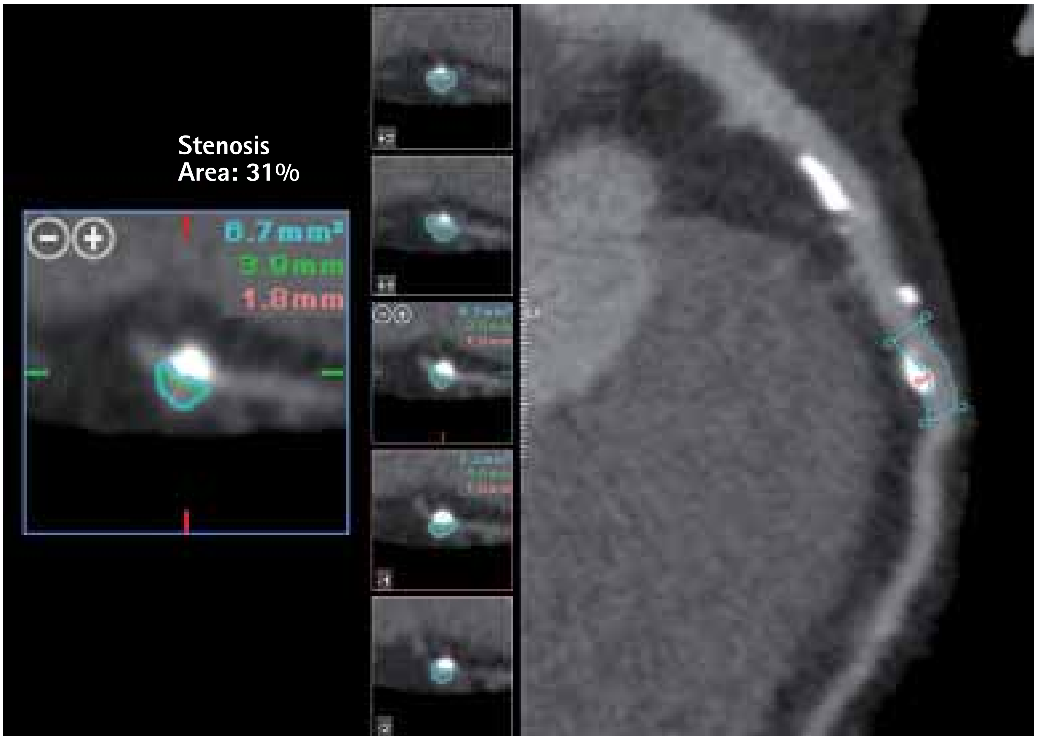


Fig. 4: Stenosis area of 31% computed with Double Slice Mode (Patient 2)

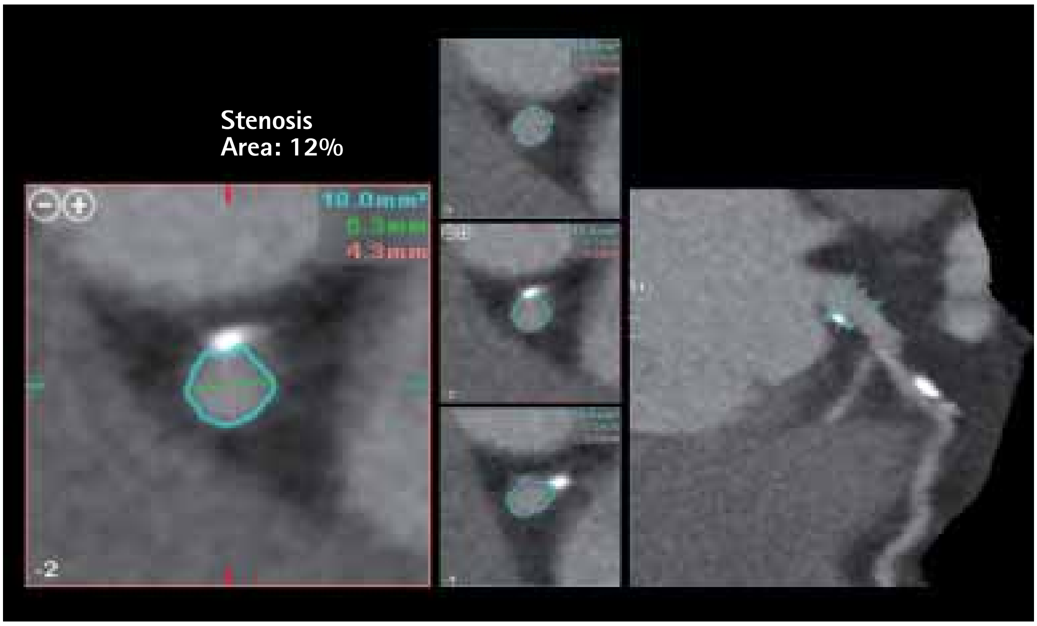


Fig. 5: Stenosis area of 12%, computed with Double Slice Mode (Patient 3)

diameter of 2.5 mm is shown in fig. 3b as compared with the Standard Mode image in fig.3a. The intersections of the stent lattice in fig. 3b with Double Slice Mode demonstrate the improvement of image quality in the beating heart. In clinical practice the application of Double Slice Mode does not require a higher patient exposure than Standard Mode since the superior detail definition will compensate for the slight difference in noise levels.

The improved spatial detectability with Double Slice Mode also helps minimize overestimation of the degree of stenosis. This overestimation has been described qualitatively[4,5], but rarely quantitatively[6]. In the multi-planar reconstruction of the LAD coronary artery studied in patient 1 (scan protocol: one heart beat, prospectively gated CTA in the 65%-R interval of the R-R cycle, DLP=271 mGy*cm, E= 3.8 mSv) the degree of stenosis was computed to be 31%, based on cross-sectional area analysis. Fig. 4 demonstrates three vascular plaques using Double Slice Mode with reduced overestimation of the degree of stenosis using a standard cardiac filter. In the second patient (scan protocol: one heart beat, prospectively gated CTA in the 65%-R interval of the R-R cycle, DLP = 271 mGy*cm, E= 3.8 mSv) the sharp demarcation of the 1 mm diameter plaque in the proximal LAD segment (fig. 4) leads to an accurate quantitative determination of less than 12% area stenosis due to the reduced over-blooming effect. A quantitative scientific comparison of Double Slice Mode with quantitative coronary angiography (QCA) is still lacking since this reconstruction modality has only become available within the last few weeks.

Summary

In phantom testing, image reconstruction with Double Slice Mode allows a bore hole detectability down to 0.32 mm in z-direction. The Double Slice Mode method improves the resolution of fine structures for various filter combinations by 35% compared with Standard Mode method. The phantom test demonstrate this increase in image quality with the FC51 filter used in routine clinical practice.

The patient examples confirm this improvement in image quality, particularly for high contrast objects such as plaque compositions and stent imaging in diagnostic cardiology. The over-blooming effect with its negative impact on stenosis evaluation is substantially reduced and the temporal resolution of 175 ms has no strong blurring influence. Patient exposure does not have to be increased in Double Slice Mode, compared with Standard Mode, in order to compensate for the slight difference in image noise.

Both patients were studied on the same day as the phantom testing at the Charité Berlin University Medical Center with the routine 640 slice image reconstruction technique described above. However, this algorithm is equally applicable to other body areas which have similar technical demands.

References

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