Latest Technical Advances in the Cathlab through 3D Arteriography and 3D Coronary Angiography

T Hilbel[1,2], D Lossnitzer[1], R Becker[1], F Voss[1],
W Rottbauer[1], H Kuecherer[1], HA Katus[1]

[1]Division of Cardiology, University of Heidelberg, Heidelberg, Germany
[2]University of Applied Sciences Gelsenkirchen, Gelsenkirchen, Germany

Abstract

For a long time, the switch from analog to digital X-ray imaging seemed to be the only technical progress of X-ray fluoroscopy in the cardiac cathlab. But recently, two major 3D fluoroscopy imaging technologies for coronary angiography and electrophysiology were developed and brought into the clinical practice of coronary angiography and electrophysiology laboratories. 3D coronary angiography (3DCA) and the 3D arteriography (3DATG) methods take advantage of a new high speed C-arc X-ray gantry that acquires the image data while swinging over the patient's body. With 3D coronary angiography a 3D model of the coronary artery tree is calculated. The calculated 3DCA model is used to plan an optimal viewing angle for an interventional procedure with minimal foreshortening. 3DATG is useful for guiding anatomically determined left atrial ablation such as pulmonary vein isolation for atrial fibrillation. It is advantageous for electrophysiological therapy to see the true positions of the EP mapping and ablation catheters in the live X-ray fluoroscopy merged with the true anatomical walls of the left atrium.

1. Introduction

For a long time, the switch from analog to digital X-ray imaging seemed to be the only technical progress of X-ray fluoroscopy in the cardiac cathlab. But recently, two major 3D fluoroscopy imaging technologies for coronary angiography and electrophysiology were developed and brought into the clinical practice of coronary angiography and electrophysiology laboratories. 3D coronary angiography and the 3D arteriography methods take advantage of a new high speed C-arc X-ray gantry that acquires the image data while swinging over the patient's body (approx. 30° degrees/second, figure 1a, b, c, and d). High speed personal computers with high performance graphic cards are then able to reconstruct 3D cardiac anatomy images from the rotational angiography acquisition almost in real time.

2. Methods

At Heidelberg University Medical Center, one cathlab modality (XPER FD 10, Philips, Best, Netherlands) is equipped with the software and hardware to perform 3D coronary angiography, and the EP cathlab modality (XPER FD 10/10) is able to do 3D arteriography.

a) Angles approx. LAO 45 b) approx. LAO 30 c) approx. RAO 20 d) approx. RAO 40

Figure 1. For rotational angiography the C-arc X-ray gantry rotates with 30° degrees/second over the patient table (Fig. 1a to 1d)). High speed personal computers linked to the X-ray modality reconstruct 3D cardiac anatomy images from the rotational angiography X-ray acquisition.

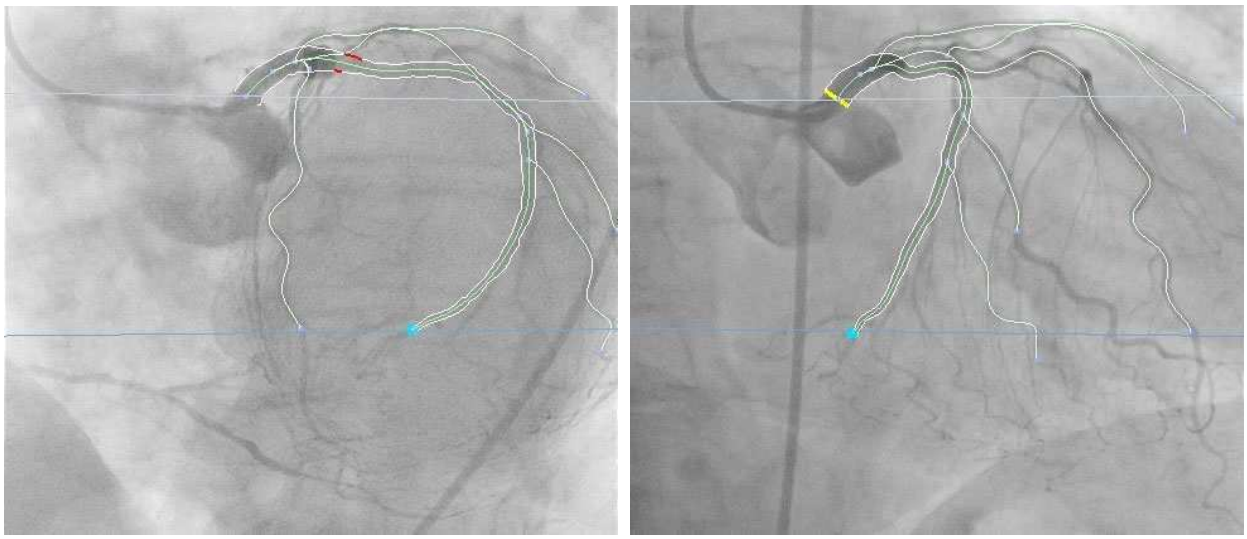

Figure 2. Manual marking of the coronary tree with a mouse in two different projections (LAO26°/CAU1° left, RAO22°/CAU1° right) is mandatory for the computation of the 3D Coronary Angiography tree model.

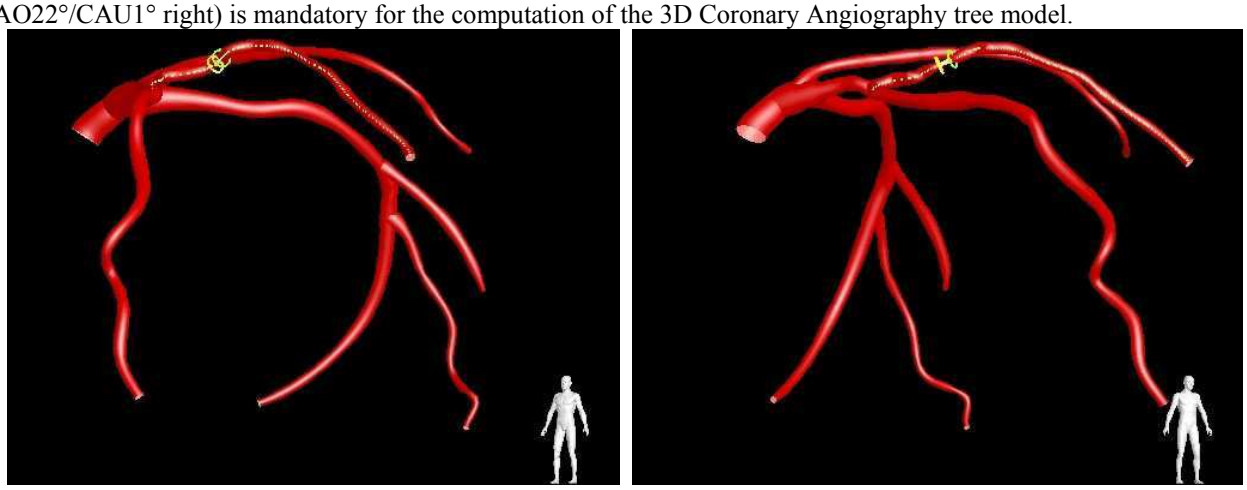

Figure 3. The reconstructed 3D Coronary Angiography tree model computed from the marked trees of above Fig. 2.

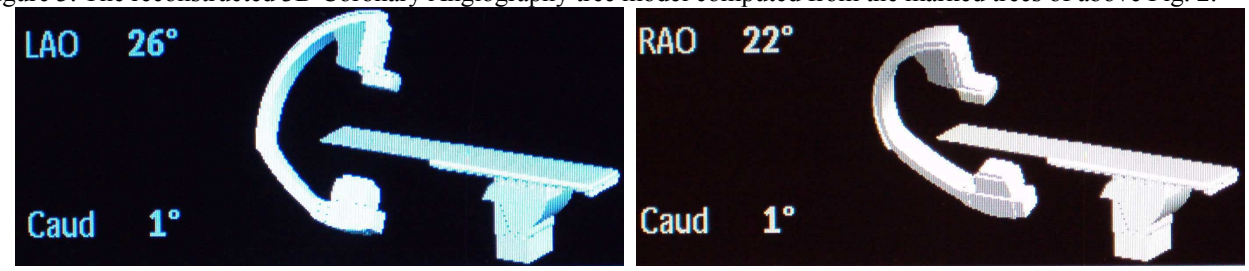

Figure 4. Corresponding C-arc position for the fluoroscopic images and the 3D Coronary Angiography images above.

3. Results

Advantage of 3D Coronary Angiography

Rotational angiography was first developed for therapeutic strategy planning in neuroradiology and neurosurgery before the accelerated calculation power of PCs and Open GL graphic cards allowed to use it in the interventional cardiac cathlab for the coronary vessels of the beating heart. 3D coronary angiography is acquired through a high speed C-arc sweeping motion over the patient's body while injecting contrast media into a coronary vessel. With the acquired dataset a 3D coronary angiography model of the coronary artery tree is calculated. The calculated 3D coronary angiography model is used to plan an optimal viewing angle for an interventional procedure with minimal foreshortening. The planning is done without the application of additional X-rays or contrast medium (Fig. 2 -7) [1 - 3].

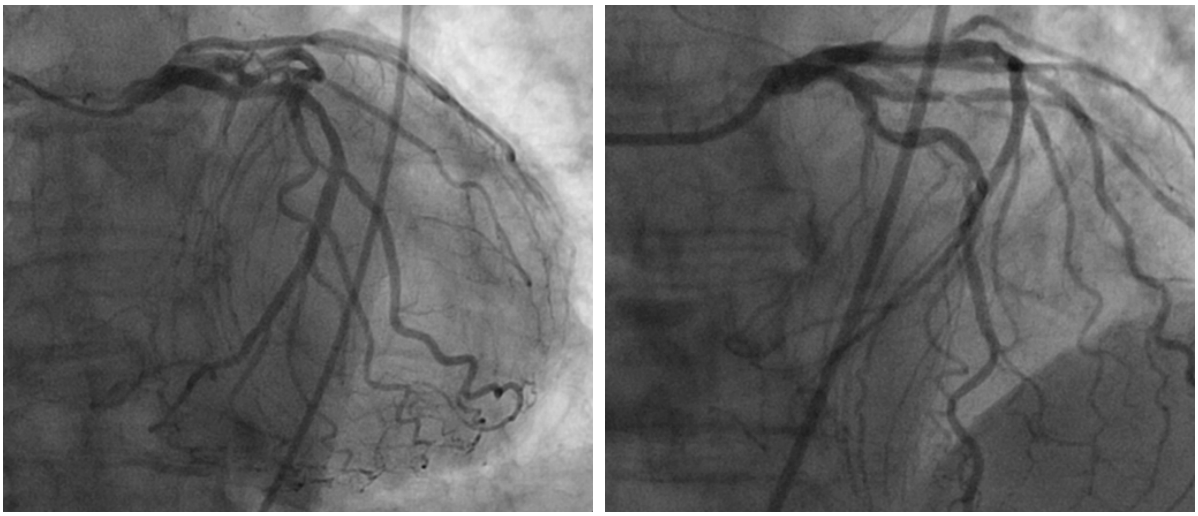

Figure 5. Due to overlap by the contrast agent of other vessels the coronary stenosis of a diagonal vessel is difficult to see on the left fluoroscopic image. With a gantry position of LAO 2° / CRAN 2° an optimal view is achieved as shown on the right image. This optimal view of the right image is predicted by the calculated tree model of figure 6 without the application of additional X-rays or contrast medium.

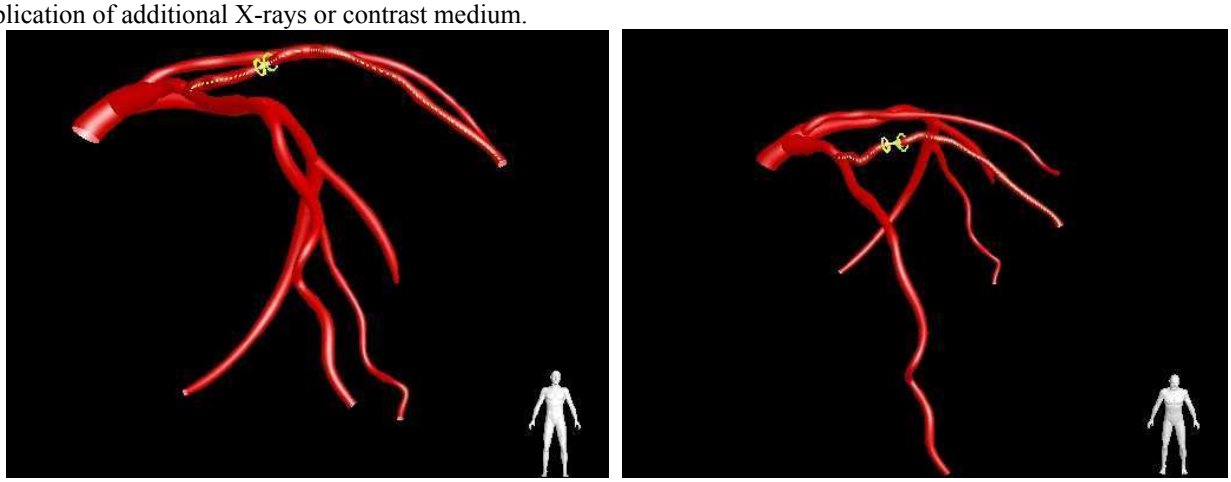

Figure 6. The reconstructed 3D Coronary Angiography tree depicts an optimal view of the stenosis (between yellow circles) for an interventional therapy on the right image, while the image on the left has overlap by another vessel.

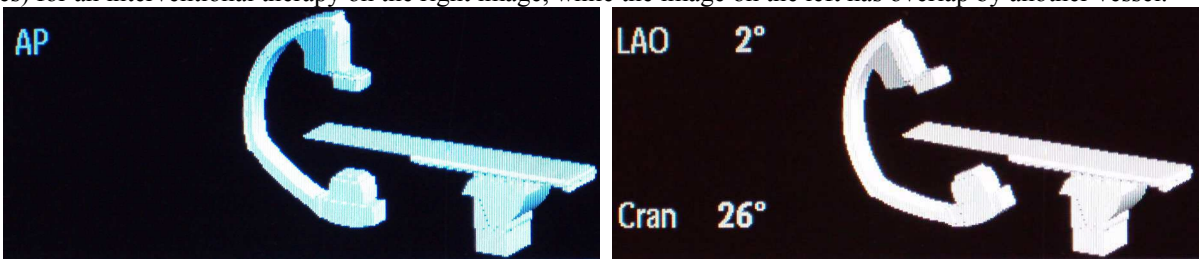

Figure 7. Corresponding C-arc position for the fluoroscopic images and the 3D coronary angiography images above.

A clinical trial has shown 31% reduction of radiation and 33% reduction in the amount of contrast agent [4]. Once the best viewing angle is found the computer is able to move the C-arc gantry automatically to the position with the optimal viewing angle. The rotational acquisition is done in a calibrated fashion so that the calculated 3D coronary angiography model is good to measure absolute values, like the right length for a coronary stent, before implantation.

Advantage of 3D Arteriography

3D arteriography is useful for guiding anatomically determined left atrial ablation such as pulmonary vein

isolation for atrial fibrillation. It is advantageous for electrophysiological (EP) therapy to see the true positions of the EP mapping and ablation catheters in the live X-ray fluoroscopy merged with the true anatomical walls of the left atrium. With rotational angiography acquisition during right atrial contrast media injection and following automatic computerized segmentation, the 3D anatomies of the left atrium and of the pulmonary veins are obtained (Fig. 8, 9).

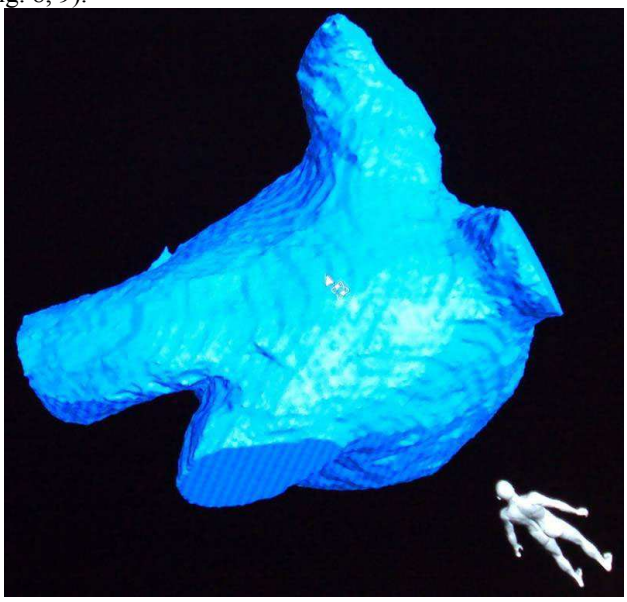

Figure 8. Computed 3D arteriography images of the left atrium and the pulmonary veins.

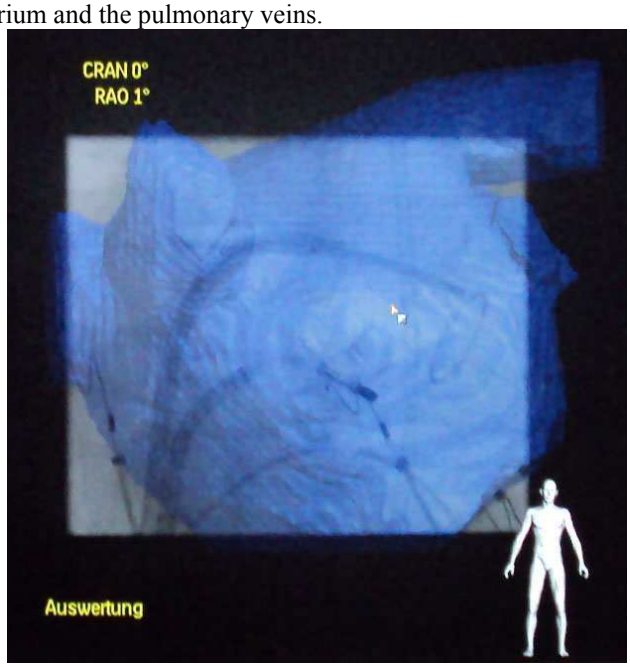

Figure 9. 3D arteriography image of the left atrium and the pulmonary veins combined with the true, real-time fluoroscopic EP catheter positions.

The 3D anatomy of the atrium and the pulmonary veins can then be merged with live fluoroscopy images so that an optimized image guided electrical ablation within the atrium can be performed. The anatomical position and movement of the catheters can be seen in real-time within the heart.

4. Discussion and conclusions

The new 3D cardiac image guided X-ray developments are intended to perform an optimal cardiac vessel intervention or an optimal electrophysiological ablation intervention with a reduced amount of X-ray exposure for both the patients and the clinical investigators. The collaboration of clinicians and image scientists together with the ability of present personal computers capable of fast 3D segmentation and reconstruction brought real world anatomical 3D information into the 2D world of the interventional cardiac X-ray catheter laboratories. Still both methods do need user interactions. The manual drawing of the coronary tree can be time consuming. The adjustment of the calculated 3D Arteriography may be also time consuming but not of much consequence for a general long-standing EP therapy.

References

[1] Chen JSY, Carroll JD. Computer Assisted Coronary Intervention by Use of On-line 3D Reconstruction and Optimal View Strategy. In: Wells WM, Colchester ACF, Delp S. Medical image computing and computer-assisted intervention MICCAI'98. Springer Verlag, 1998: 377–385.

[2] Messenger JCM, Chen JSY, Carroll JD, Burchenal JEB, Kioussopoulos K, Groves BM. 3D coronary reconstruction from routine single-plane coronary angiograms: Clinical validation and quantitative analysis of the right coronary artery in 100 patients. The International Journal of Cardiac Imaging 2000;Vol. 16, No. 6: 413-427.

[3] Carroll JD. Allura 3D-CA with true view. Coronary intervention live case, during the annual transcatheter cardiovascular therapeutics scientific symposium (TCT) October 17, 2005.

[4] Maddux JT, Wink O, Messenger JC, Groves BM, Liao R, Strzelczyk J, Chen SYJ, Carroll JD. Randomized study of the safety and clinical utility of rotational angiography versus standard angiography in the diagnosis of coronary artery disease. Cathet Cardiovasc Intervent 204;62:167-174.

Address for correspondence

Thomas Hilbel MD
University of Heidelberg, Division of Cardiology
Im Neuenheimer Feld 410
69120 Heidelberg, Germany
thomas.hilbel@med.uni-heidelberg.de