Integrating CT in minimally invasive treatment of the coronary arteries

e-Poster: C-200
Congress: ECR 2008
Type: Scientific Exhibit
Topic: Cardiac / Miscellaneous

MeSH: Coronary Vessels [A07.231.114.269]
Coronary Arteriosclerosis [C14.907.137.126.393]
Angioplasty, Transluminal, Percutaneous Coronary [E02.148.050.060.100]

Keywords: Coronary artery disease, Multi-modality guidance, Minimal foreshortening, Stent selection

1. Purpose

The development of Multi-Detector Computed Tomography (MDCT), together with ECG gating, has brought a reliable 3D reconstruction of the heart and the [CT coronary arteries] coronary arteries within reach. The cardiac CT reconstruction allows an evaluation of coronary artery disease, with respect to stenotic area and plaque. The CT reconstruction of the coronary arteries may indicate that percutaneous coronary interventional treatment (i.e. applying stents) is needed, which is being performed using C-arm [Coronary angiogram] fluoroscopy .

Here we discuss a novel method for the integration of cardiac CT in X-ray fluoroscopy procedures [1], enabling better decision making in the planning and guidance during the interventional treatment of coronary artery disease.

2. Methods and Materials

Our method offers the possibility of determining the C-arm incidence with the least foreshortening for a selected segment of the coronary vessels, segmented in a pre-operative cardiac CT dataset. In order to assist in stent length selection, the length of a vascular lesion can be measured in 3D along the centerline of the curved vessel. During the intervention the stored C-arm viewing incidence can be recalled, and the C-arm can be automatically steered to the corresponding angles.

Furthermore our method allows rendering of a curved Multi-Planar Reformating (MPR) and a 3D visualization of the coronary arteries, both following in real-time the direction of the viewing incidence of the C-arm. Based on this automatically registered reference image of the CT data, it is possible to steer the C-arm, without using additional contrast medium or X-ray radiation.

TrueView map

Spatial foreshortening is the distortion of geometrical structures (e.g. vessel) when depicted at an angle. Foreshortening of the vessel geometry in X-ray images makes it difficult to asses their true length, and therefore it is preferable to select X-ray projection views that have minimal foreshortening for the [A selected segment of a coronary artery] vessel segments of interest [2].
The [TrueView map] TrueView map [3,4] can be used to plan a C-arm position that provides a view with minimal foreshortening of the selected coronary artery segment.

Follow C-arc

The orientation of the coordinate systems of the CT dataset and the X-ray C-arm are registered, based on the DICOM information.
When the Follow C-arc mode is active, the viewing incidence of the CT dataset is matched in real time with the current rotation and angulation of the [X-ray C-arm system] C-arm geometry . This allows using the view on the CT dataset to predict an optimal working position for the C-arc without actually using X-ray.
The counterpart of this function is called 3D APC (Automatic Positioning Control), which allows the C-arc to be moved to a viewing incidence corresponding to the 3D rendering of the CT dataset. Desired working positions can be planned (e.g. using the TrueView map) and stored pre-interventionally and later recalled during the procedure when needed.

Curved MPR

A curved MPR [5] representation of the vessels is available, and helps the physician to find the best view on the stenosis and the surrounding calcified plaque. Since the curved MPR is coupled to the 3D view of the CT dataset, it will pursue the 3D orientation in the follow C-arc mode.
The curved MPR is complemented with a cross-sectional view and a measurement tool, providing true length along the 3D centerline as well as cross-sectional measurements.

Virtual X-ray

An X-ray angiography -like [X-ray -like visualization of the CT data] representation of the coronary arteries, based on the CT dataset, is provided, in order to assist the physician while planning the optimal views. This type of visualization allows a better impression of the X-ray angiographic view that will be generated from a particular viewing incidence.

Overlay

An overlay visualization of the CT dataset on the X-ray image can be presented for guidance during the procedure. This overlay application is preceded by a registration step, which correlates the C-arm coordinate system and the CT coordinate system.

3. Results

The proposed methods have been applied in the treatment of over 20 patients. The 3D visualization of the coronary arteries, which were segmented in the CT dataset, augment the sense of orientation and enhance navigation, especially when no contrast medium is visible in the fluoroscopy images. The CT integration especially helps in cases of Chronic Total Occlusions (CTO) where the vessel is no longer visible in angiography and CT may help to discern the original trajectory of the vessel lumen.

The methods have been used during live cases at the EuroPCR conference of 2006 and 2007 by Dr. Marie-Claude Morice, and the Transcatheter Cardiovascular Therapeutics (TCT) conference in 2006 by Dr. John D. Carroll.

4. Conclusions

The integration of cardiac CT data helps in improving planning and guidance of cardiovascular interventional therapies. The optimal system angles from true 3D datasets enable better stent length selection and in addition can lead to a reduction in the use of contrast medium.

5. Personal Information

We would like to acknowledge the Institut Cardiovasculaire Paris Sud, Massy, France, the Lenox Hill Hospital, New York, USA, and the Colorado University Hospital, Denver, USA, and especially Dr. Marie-Claude Morice, Dr. Harvey Hecht, and Dr. John D. Carroll for their feedback, help and provision of the clinical datasets.

6. References

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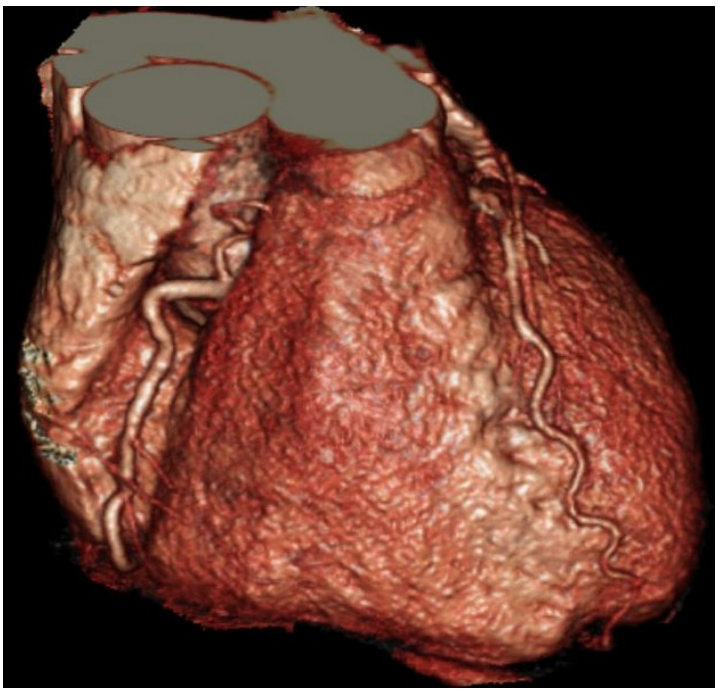
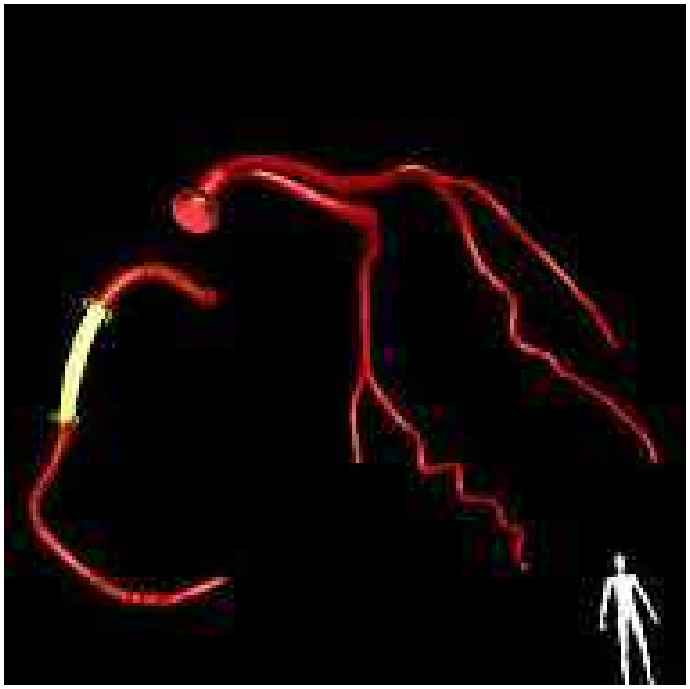
7. Mediafiles:

A cardiac CT reconstruction



A selected segment of a coronary artery



The yellow vessel segment has been selected. The TrueView map can be used to find the minimal foreshortening for the selected vessel segment.

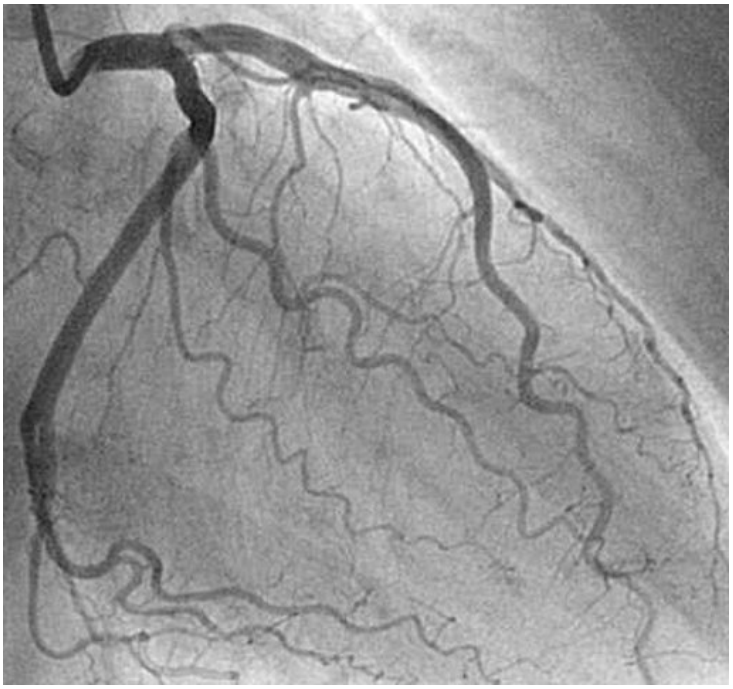
CT coronary arteries

Coronary arteries, segmented from a CT dataset

Coronary angiogram

Coronary angiogram, acquired with a C-arm X-ray system.

Coronary angiogram.



A coronary angiogram, acquired with an X-Ray C-arm system.

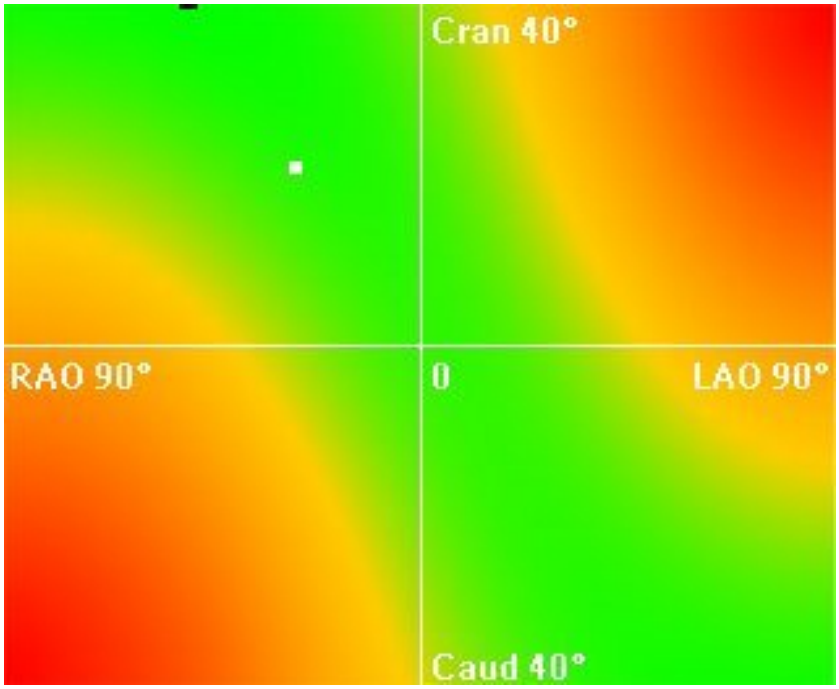
Fluoroscopy overlay

The 3D representation of the coronary tree in the CT data set has been registered to the coordinate system of the X-ray C-arm geometry. The fluoroscopy image is overlaid on the 3D representation in real-time.

MPR - 3D view coupling

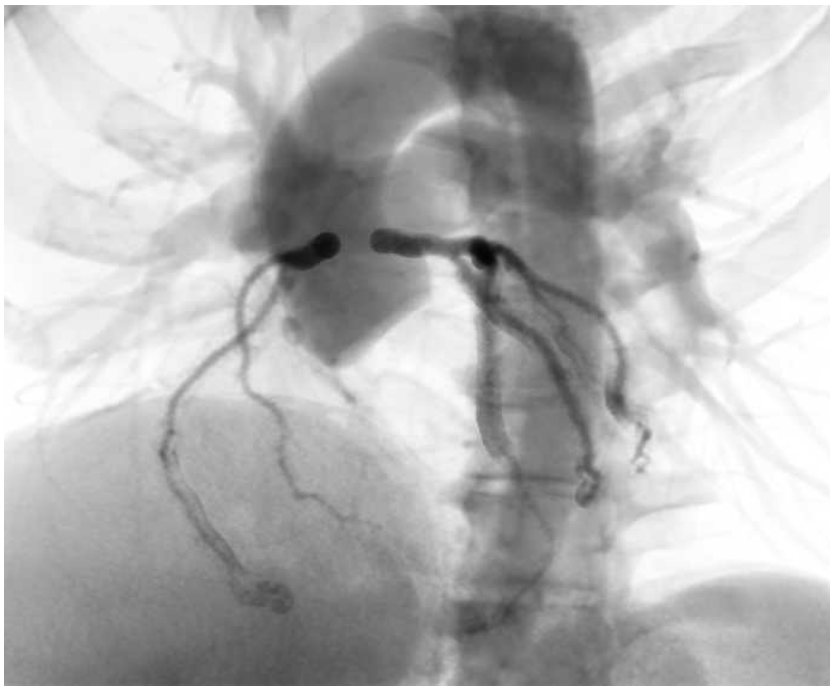
The curved MPR representation of the coronary arteries (right) follow the orientation of the 3D visualization (left) and vice-versa.

TrueView map



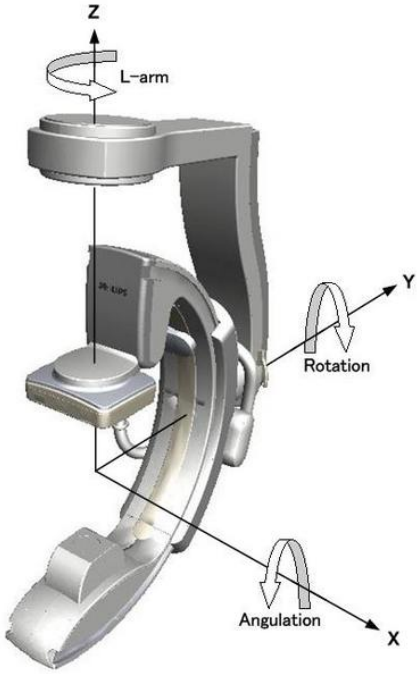
The vertical axis represents the angulation of the C-arm system, and the horizontal axis the rotation. The color of a point on the TrueView map represents the amount of foreshortening of the selected coronary segment.

X-ray -like visualization of the CT data



The X-ray –like visualization is based on the segmented CT data set. Since the intravenously injected contrast medium is also present in the heart structures for the CT data set, while this is not the case for the fluoroscopy images, segementation information is used to adjust the X-ray absorption levels for the different segments.

X-ray C-arm system



The C-arm geometry can rotate around three axis of freedom. The rotation and angulation angles can be automatically steered to match the viewing incidence on the CT data, using the 3D APC function.