Integration of Standard Myocardial and Epicardial Segmentation: Validation by Computed Tomography and Autopsy Studies

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Abstract

Background: The epicardial coronary segmentations have not established the relation between the epicardial branches and the supplied myocardial segments

Methods: The coronary angiograms of 37 patients were analyzed by a computer program called Holistic Coronary Care.

Results: The analysis of the coronary angiograms showed that out of the 17 left ventricular segments 9.5±1.9, 3.3±2.4 and 4.2±2.5 were supplied by the left anterior descending, the left circumflex and the right coronary artery, respectively. A highly significant correlation was found between the angiographic and both the CT and the autopsy determination of the number of left ventricular segments (r=0.97 and 0.94, p<0.001).

Conclusions: Coronary angiography from multiple projections can determine accurately the supplied left ventricular segments of the 3 main coronary branches.

1. Introduction

The standardized analysis of the LV segments has been accepted widespread since 2002 (1) recommending 17 myocardial segments can be assigned to the 3 major coronary arteries. It is quite strange that uniformly accepted epicardial segmentation has not been achieved for the time being. The ARTS I, II, the BARI and the Syntax studies proposed different classifications for the epicardial segments without relation the supplying epicardial branches with the standard myocardial segments (2). For evaluation of the functional significance of a lesion on the coronary angiography a reporting system relating directly to the standardized myocardial segments would be desirable. Obviously, the world cardiac community could not afford for himself for a long time to avoid the development of a clinically useful epicardial segmentation system.

2. Methods

Adopting the classic anatomic rules and assumptions of the epicardial surface of the left ventricle, the 3D characteristics of the coronary artery anatomy was translated on a 2D polar map display. For generation of this coronary polar map, two projections were taken into consideration: the 30 anterior oblique (RAO) and the 45 left anterior oblique (LAO) views (Figure 1.) (3).

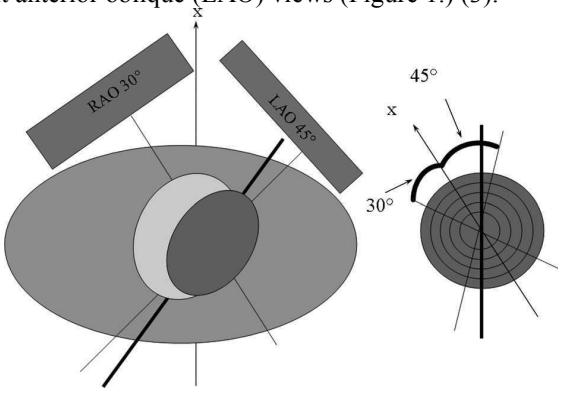

Fig. 1. The two main projections of coronary angiography and their relation to the left ventricular polar map: for comparison of the coronary artery tree with the polar map

The individual coronary artery circulation was typified from among 12 variations. First, the length of the left anterior descending (LAD) artery was assessed from the RAO projection as short (ending before the apex), up to the apex, or long (reaching beyond the apex). The LAO view allowed an evaluation of the right coronary artery (RCA) and the left circumflex branch (LCx) separation by comparing the left and right coronary angiograms; there are four possible scenarios: super right dominant, right dominant, balanced or left dominant coronary circulation. The individual coronary tree was generated by the combination of the two characterizations. In this way, the number of recordable circulation types was 12 (3×4).

The segments of the coronary branches were

determined in relation to side branches hallmarks. By slight modification of the Syntax segmentation [2] the coronary tree was divided into 23 segments (Figure 2.).

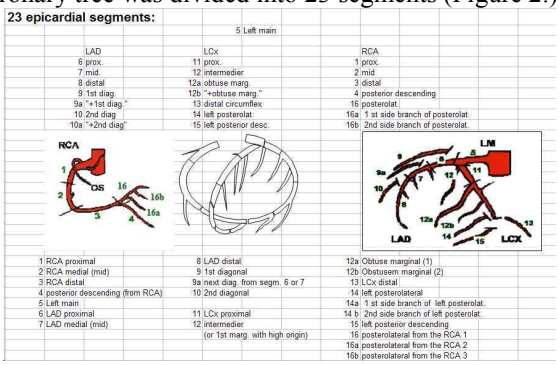

Figure 2.
The modified Syntax epicardial segmentation

The related left ventricular segments on the polar map were color coded by a dedicated Access (Microsoft Office) based software called Holistic Coronary Care developed by the authors.

This program can be downloaded from the http://delfin.unideb.hu/~balkay/HCC/ website. The software consist of two database files with different function; one is the „HCC_base.mdb" database file, this contains the real data, the other is the „HCC.mde" file, this includes the forms assuring the correct function, e.g. queries, macros and Visual Basic codes. The different results can be assessed and integrated. The system contains both contextual and graphical elements for a quick data entry.

The coronary angiograms of 37 patients were analyzed and registered on a polar map display by the HCC program. The data were compared with 16-slice computed tomography (CT) examination in 11 patients in vivo, and with 26 autopsy studies in cases that died because of cardiac cause 16.1±12.2 days after the cardiac catheterization.

Statistical analysis was performed by built-in programs. Significance level was considered at $P<0{\cdot}05$. The calculation of the positive predictive value and correlation analysis were performed by the routine procedure.

2.1. Invasive coronary angiography

Cardiac catheterization was performed by the Judkins technique. Coronary arteriograms were recorded in multiple projections with a Philips X-ray machine and archived on CDs in DICOM format. Coronary artery segments were identified and categorized by experienced reader in accordance with the modified Syntax classification.

2.2. CT examination

After intravenous administration of 100 ml iodine contrast material acquisition was performed by a GE LightSpeed16 CT scanner. 0.625mm slice thickness was achieved by a standard reconstruction algorithm.

The analysis software was GE Advantage Workstation Volume Viewer. A "short axis method" was used during the CT mapping to evaluate the presence of the epicardial arteries. In oblique view the four chambers were set at the first window of first monitor. By the batch film method planes were set in short axis according to basal-mid-apical-apex segments. By four chamber plane window was set oblique also. The orientation of the two planes was locked. The 3D cursor was moved into four segments (basal, mid, near apical, apical) tracking of the coronary arteries. The arteries were annotated on the image on the second window. (Figure 3.)

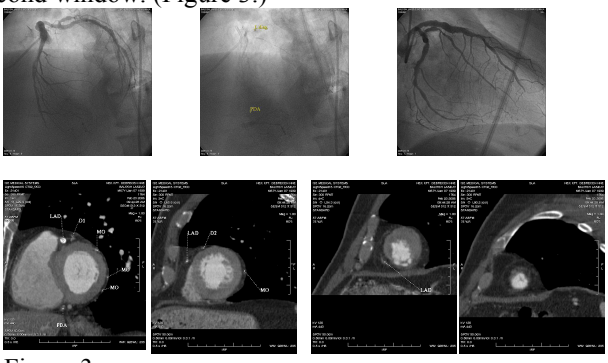

Figure 3.
Invasive coronary angiogram and CT scan of the same patient

2.3. Autopsy

Autopsy was performed lege artis forming 10-15 mm thick discs from the apex till basis perpendicular to the longitudinal axis of the heart. Presence of the epicardial arteries were observed in all disc. We used the principle that the presence of a coronary branch in a segment is responsible for the regional myocardial supply. (Figure 4.)

3. Results

The analysis of the coronary angiograms showed that out of the 17 left ventricular segments 9.5±1.9 (range:7-11), 3.3±2.4 (range:2-9) and 4.2±2.5 (range:0-7) were supplied by the left anterior descending, the left circumflex and the right coronary artery, respectively. In the 11 patients the numbers of the myocardial segments associated to the main coronary branches were 10.9±0.16,

2.6±1.6 and 2.7±1.2 on the CT, while in the 26 autopsy studies they were 9±1.9, 3.1±2.4 and 4.9±2.5, respectively. The myocardial segments predicted by the invasive coronary angiography overlapped the CT and the autopsy studies in 96%, 82%, 83% and in 93%, 91%, 84%, respectively. A highly significant correlation was found between the angiographic and both the CT and the autopsy determination of the number of left ventricular segments (r=0.97 and 0.94, p<0.001).

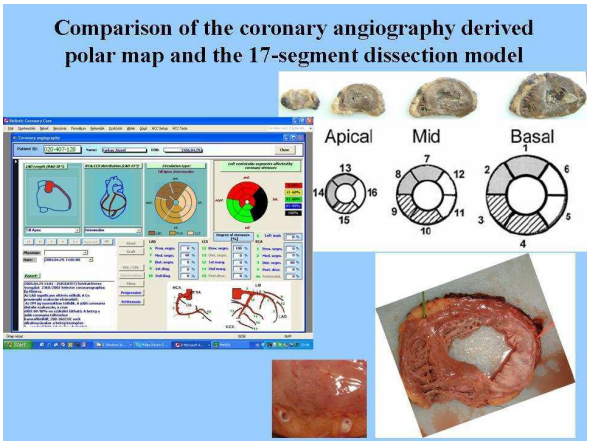

Figure 4.

4. Discussion and conclusions

The proposed method for the determination of the supplied left ventricular segments of a coronary branch on a polar map is hampered by the non-3D nature of the radiographic projections of opacified arteries. However, multiple views provide satisfactory information concerning the 3D coronary anatomy. The myocardial area at risk predicted by coronary angiograpy depends on the extent of myocardium distal to the coronary artery occlusion.

Usually the coronary angiogram serves as a gold standard for non-invasive diagnosis of coronary artery disease. Our approach was quite opposite during the calculation of predictive values of invasive coronary angiography for predicting the supplied left ventricle regions. The generated polar maps of the coronary artery tree were compared with the supplied segments detected by CT scan and autopsy study in order to test the accuracy of the localizing method. The overlap between the predicted left ventricular segments of a coronary branch derived from the angiogram and the associated segments detected by CT or the autopsy were considerable, and a highly significant correlation was found between the angiographic and both the CT and the autopsy determination of the number of left ventricular segments.

Coronary angiography from multiple projections can determine accurately the supplied left ventricular segments of the 3 main coronary branches.

Holistic Coronary Care program provides a polar map display appropriate for direct comparisons of the different imaging methods and findings. By this software the coronary angiography from multiple projections can be accurately analyzed for the supplied left ventricular segments of the coronary branches. Using this integration of different invasive and non-invasive cardiac imaging modalities may lead to a more precise evaluation of a coronary lesion indicating the required coronary interventions.

References

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