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Coronary Sinus to Mitral Valve Annulus Topography and Response to the Percutaneous Coronary Sinus-Based Mitral Valve Contour System

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Short running title: CT-angiography for CS Reconstruction

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Conflict of interest:

Hubertus Degen is a consultant for Biotronik and Cardiac dimensions. Michael Haude received institutional grants/research supports from Abbott, Biotronik and receipt of honoraria or consultation fees from Biotronik, Cardiac Dimensions, OrbusNeich and Philips. Martijn Chatrou is employee of Pie Medical Imaging. The other authors have no conflicts of interest to declare.

Key words

mitral regurgitation, mitral valve repair, MSCT

Abbreviations

CS	Coronary Sinus
CTA	CT-angiography
FMR	Functional Mitral Valve Regurgitation
GCV	Great Cardiac Vein
MSCT	Multislice Computed Tomography
3D	3-dimensional

Introduction

The Carillon Mitral Contour System (Cardiac Dimensions, Kirkland, WA, USA) for coronary sinus (CS) based percutaneous mitral valve repair demonstrated a reduction in functional mitral valve regurgitation (FMR) of heart failure patients (1-2). However acute reduction in FMR determined by echocardiography could not be achieved in all patients, since the AMADEUS trial reported 18.6% of the patients to have no acute effect on FMR (2). However percutaneous valve interventions has implemented three-dimensional (3D) imaging modalities in clinical routine. For example multisclice computed tomography (MSCT) is pivotal for procedural planning of transcatheter aortic valve implantation. This valuable technique may offer unique 3D CS / GCV and mitral annulus reconstructions to analyze their anatomical relation with latest technology. Based on the results of CT-based 3D CS/GCV and mitral annulus reconstructions, we aimed to analyze the rate of patients with sustained reduction of FMR three months after Carillon device implantation using echocardiographic assessment.

Methods

The study comprises 11 consecutive patients undergoing Carillon device implantation with prior MSCT and baseline, post-procedure and 3-month transthoracic echocardiography. Patients with symptomatic (> NYHA II) dilated ischemic or non-ischemic cardiomyopathy (left ventricular ejection fraction < 40%) on stable heart failure medication (medication prior to implantation: betablocker: n = 11, 100%; ACE-inhibitor/AT2-antagonists: n = 11, 100%;

spironolactone/eplerenone: n = 11, 68.5%; diuretics: n = 11, 100%) suffering at least from moderate FMR were eligible for percutaneous annuloplasty (3). Responders were defined as echocardiographic improvement of vena contracta, PISA, EROA and regurgitant volume at 3-months follow-up. We defined non-responders, when at least 3 parameters remained unchanged in follow-up. The 3-mensio Structural Heart (Pie Medical Imaging BV, Maastricht, Netherland) enables mitral valve annulus and CS reconstruction. Distance and angle of the mitral valve annulus (MVA) plane and a CS/GCV plane were calculated (Figure 1).

Results

A total of 11 patients with implantation of a Carillon device, prior CT-angiography (CTA) and 3-months follow-up transthoracic echocardiography were enrolled in this retrospective study. Figure 1 shows original reconstruction imaging from the 3-mensio structural heart software prototype and table 1 angulations and distances in responders and non-responders.

Figure 2 shows significant improvement of vena contracta, PISA, EROA and regurgitant volume in responders but not in non-responders over a period of 3-months. Comparison of the distance and angulation of the CS plane and the MVA plane showed a shorter distance and lower angulation in responders (distance: 5.1±1.7 mm responders versus 10.0±2.8 mm non-responders; angulation: responders 11.7±2.9° versus non-responders 19.8±4.7°). Our results suggest a CS plane and MVA plane with a distance of < 6.9 mm (sensitivity 100%, specificity 80%, AUC = 0,933) and an angulation of < 14.2° (sensitivity 83,3%, specificity 100%, AUC = 0,967) could be considered for predicting a reduction in FMR after mitral annuloplasty using a Carillon device.

Discussion

Clinical data for the Carillon Mitral Contour System showed an excellent safety profile. Furthermore clinical trials documented a reduction of echocardiographic FMR parameters and improved heart failure symptoms (1,2). However in an AMADEUS trial subanalysis, no

difference of the CS/GCV position relative to the MVA was found in patients with or without acute reduction of FMR based on multisclice CT (4). However, linear distances from the edge of the MVA to the center of the vein lumen were exclusively measured in long axis views. To determine the distance more precisely, we used 3-dimensional reconstructions generating a MVA and CS/GCV plane.

Our results suggest that shorter distance and lower angulation of the CS plane to the MVA plane might have an impact on procedure success up to 3-month follow-up. However coronary sinus anatomy is highly variable and other parameters might influence clinical success of CS-based mitral annuloplasty. Therefore further studies are needed to proof a potential benefit of a CT-angiographic screening to predict acute and long-term response of FMR after Carillon device implantation.

Study limitations

This is a retrospective, non-validated, single-center study and enrolls a small number of patients. Therefore, the results should be regarded as hypothesis generating and need to be verified by randomized, multi-center trials.

Conclusions

Distance and angulation of MVA and CS / GCV planes from 3D-reconstructions of MSCT have potential to predict the echocardiographic and clinical impact of percutaneous mitral valve repair using the Carillon Mitral Contour System, but further clinical studies are needed.

Impact on daily practice

Carillon device implantation into CS is effective at reducing FMR. Using the 3D-MSCT derived distance and angulation of CS/GCV to MVA planes have potential to predict echocardiographic and clinical non-responders after Carillon device implantation.

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Figure 1. Usage of CT-angiography reconstruction to determine coronary sinus anatomy and relation to mitral valve annulus.

A: Blue line: coronary sinus. Green line: left circumflex artery. Red line: mitral annulus (D-shape). Yellow line: aortic valve. B: variable distances of CS to MVA. C: MVA and CS plane as a 3D-model. D: calculation of angulation and distance of MVA and CS planes. Basically one plane for the MVA and one plane for the CS were calculated. To determine the distance a measurement from centroid to centroid of the 3D-planes is done. Therefore a perpendicular line is projected from the CS centroid toward the normal line of the mitral annulus. A straight distance is measured from the annulus centroid over the annulus normal towards the transection point of the projected CS line. For the angulation measurement centroids and normal (direction) are overlayed and an angle measurement between the CS and annulus normal is derived. E: CS (blue), MVA (red), left circumflex artery (green) and aortic valve (yellow). F: Responder. G: non-Responder.

Figure 2. Relationship of coronary sinus and mitral annulus in responders and non-responders following percutaneous coronary sinus based mitral valve repair.

A: Vena contracta, PISA, EROA and regurgitant volume at baseline, post implantation and 3-months follow-up (FU). B: NYHA classification at baseline and during follow-up. C: NYHA classification at baseline and during follow-up. C: dot plots of distance and angulation of coronary sinus and mitral annulus. D: ROC curve analysis of distance and angulation of coronary sinus plane and mitral annulus plane. R = responder, NR = non-responder.

	Carillon Device (mm)	CS Length (cm)	Tension Length (cm)	Distance (mm)	Angulation (°)
Responder-1	20x60x10	12	6	3.8	12.4
Responder-2	18x60x10	11	5	4	14.2
Responder-3	20x80x14	12	4	3.3	16
Responder-4	18x80x11	13	5	6.5	9
Responder-5	20x60x10	11	5	6.9	10.1
Responder-6	20x70x14	10	3	6.1	8.7
Mean±SD		11.5±0.93	4.7±0.73	5.1±1.67	11.7±2.87
Non-Responder-1	20x60x11	11	5	6.3	15.5
Non-Responder-2	20x60x10	11	5	8.7	16.6
Non-Responder-3	18x60x9	11	5	12.4	17.5
Non-Responder-4	18x80x11	14	6	13.2	26.7
Non-Responder-5	18x80x14	12	4	9.5	22.5
Mean±SD		11.8±1.06	5.0±0.58	10.0±2.81*	19.8±4.71*

Table 1. Carillon device selection and implantation parameters. Distance and angulation of CTA-derived MVA and CS/GCV planes in responders and non-responders. Carillon Device: proximal anchor x length x distal anchor. CS length = distance from distal anchor landing zone to the CS ostium measured with marker catheter during CS-Angio. Tension length = CS length - Carillon device length. * $p<0.05$.