Journal of Cardiovascular Computed Tomography xxx (2017) 1–7

Contents lists available at ScienceDirect

Journal of Cardiovascular Computed Tomography

journal homepage: www.JournalofCardiovascularCT.com

Research paper

Left ventricular access point determination for a coaxial approach to the mitral annular landing zone in transcatheter mitral valve replacement

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A R T I C L E I N F O

Article history:
Received 25 October 2016
Received in revised form
22 March 2017
Accepted 5 April 2017
Available online xxx

Keywords:
Transapical access
Transcatheter mitral valve implantation
Transcatheter mitral valve replacement
TMVR

A B S T R A C T

Introduction: To facilitate coaxial device deployment in transcatheter mitral valve replacement (TMVR), a coaxial approach to the mitral annular plane is needed. We sought to establish a method to determine an 'orthogonal' left ventricular (LV) access point for transapical TMVR and to quantitatively characterize its location in patients with severe mitral regurgitation using cardiac computed tomography.

Methods: Cardiac CT data sets of 54 patients with moderate-severe mitral regurgitation evaluated for potential TMVR were analyzed. The D-shaped mitral annular contour was segmented and a 2-dimensional annular plane was derived, allowing for subsequent definition of the perpendicularly oriented mitral annular trajectory. The 'orthogonal' LV access point was defined as the transection point of mitral trajectory with the LV epicardial surface. The location of the access point was quantified by its epicardial distance from the true apex and by the rotational offset from a 3-chamber view.

Results: LV access points orthogonal to the mitral annular plane were most frequently located in the anterolateral (n = 22, 40.7%) and anterior (n = 16, 29.6%), less frequently anteroseptal (n = 6, 11.1%) and inferolateral (n = 5, 9.3%) ventricular segment; none inferior or inferoseptal. The mean distance to the LV apex was 17.6 ± 7.7 mm. The mean forward rotational offset from the 3-chamber view was 96.4 ± 43.4°, relating to a mean forward rotational offset of 6.4 ± 43.4° in regard to a hypothetical, secondary 90° x-plane view. No significant difference between patients with degenerative mitral valve disease or functional mitral regurgitation was observed.

Conclusion: The location of the LV access point that provides an orthogonal trajectory to the mitral annular plane exhibits relevant inter-individual variability. It is commonly not identical with the true apex, and frequently localized in the anterolateral or anterior ventricular segments.

1. Introduction

Transcatheter mitral valve replacement (TMVR) is an evolving treatment approach for patients with advanced mitral valve disease deemed at high or prohibitive risk for surgery. The majority of devices currently under investigation in human trials have used

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http://dx.doi.org/10.1016/j.jcct.2017.04.002
1934-5925/

List of abbreviations

CT	computed tomography
DMVD	degenerative mitral valve disease
FMR	functional mitral regurgitation
LV	left ventricle
TAVR	transcatheter aortic valve replacement
TEE	transesophageal echocardiography
TMVR	transcatheter mitral valve replacement

transapical access.[1–4] Ideally, for a transapical approach the delivery system should be inserted coaxial to the mitral landing zone in order to facilitate successful device deployment.[5] For pre-procedural annular assessment prior to TMVR, a D-shaped segmentation method has recently been proposed and is currently used for device sizing.[6] Advanced post-processing of cardiac computed tomography (CT) allows for computation of a 2-dimensional mitral annular plane with subsequent definition of a perpendicular trajectory through the geometrical centroid of the annular contour,[5,6] which can be extended past the epicardial surface in order to identify a mechanistically 'orthogonal' left ventricular (LV) access point. We hypothesize that an access route following this trajectory facilitates coaxial delivery of the transcatheter heart valve, and that access points are patient specific. The distribution of these 'orthogonal' LV access points has not yet been investigated, as this concept has been of rather limited relevance for historical transapical aortic valve replacement (TAVR). Furthermore, clinical implementation will require standardized nomenclature, in particular for conveying the derived information to the echocardiographer to facilitate peri-procedural identification of the predetermined access point on x-plane 3D transesophageal echocardiography.

The aim of this investigation was to establish a method to determine the LV access point that provides an orthogonal trajectory to the mitral annular plane and to quantitatively characterize its location in patients with severe mitral regurgitation using cardiac computed tomography.

2. Material and method

2.1. Study population

The study population was comprised of patients evaluated between November 2014 and November 2015 for enrollment in the Early Feasibility Study of the Tendyne Mitral Valve System (NCT02321514).[7] All patients had moderate-severe or severe mitral regurgitation (degenerative mitral valve disease, DMVD,[8] or functional mitral regurgitation, FMR[9]) and had undergone ECG-gated cardiac CT for work-up of potential TMVR. Exclusion criteria were existing aortic or mitral valve prostheses. All patients provided written informed consent for study enrollment.

2.2. CT data sets

CT examinations were performed according to site specific institutional CT protocols, comprising ECG-assisted, multiphasic, contrast enhanced cardiac CT using contemporary CT systems. Anonymized CT data sets, including thin-sliced axial reconstructions throughout multiple time points in the cardiac cycle (multiphase data) were provided to the CT core lab at St. Paul's Hospital, Vancouver. For this analysis all data sets were transferred to a dedicated post-processing workstation equipped with Circle CVI42 (Version 5.2, Circle Imaging, Calgary, AB).

2.3. Mitral annular segmentation

The method for segmentation and assessment of the D-shaped mitral annulus with cardiac CT has been recently described[6,10] (Fig. 1). In brief, mid-to-late diastolic image reconstructions with the least artifact identified by visual assessment were utilized for mitral annular segmentation. Using short- and long-axis views, the mitral annulus was tracked by manually placing 16 seeding points for cubic-spline interpolation along the insertion of the posterior mitral valve leaflet and along the contour of the anterior peak comprising the fibrous aorto-mitral continuity by step-wise rotation of the long axis view aligned to the left ventricular long axis. The lateral and medial fibrous trigones were then manually identified. The initially segmented saddle-shaped annulus was truncated along a virtual line connecting both trigones, referred to as TT-distance. A 2-dimensional annular plane was computed using the method of least-squares plane fitted to the 3D annular contour as described previously.[11,12] The SL distance was defined as the projected distance from the TT line to the posterior peak; and the IC distance as the diameter perpendicular to the SL distance and parallel to the TT-distance transecting the geometric centroid of the mitral annulus.[13]

3. Determination of 'orthogonal' LV access point

The 'orthogonal' LV access point was defined as the transection point of mitral trajectory with the LV epicardial surface. The mitral trajectory was defined as an axis oriented perpendicular to the 2-dimensional mitral annular plane while transecting through the geometrical centroid of the D-shaped annular contour (Fig. 2). This trajectory is thought to represent the ideal delivery path of a transapical delivery system to facilitate coaxial device deployment by being both, perpendicular to the annular plane and also being centered within the annulus. The trajectory was automatically calculated and displayed by the post-processing software and extended beyond the epicardial surface (Fig. 3). The transection point of the trajectory with the epicardial surface was visually identified. In addition to the annular trajectory a rotational axis (LV long axis) was created, defined by the mitral annular centroid and the LV apex.

4. Quantification of the 'orthogonal' LV access point location

Using the rotational axis, a 3-chamber view was identified and optimized by ensuring the selected plane transected the LVOT through its maximal dimension while simultaneously depicting the LV apex (Fig. 3). Using the short axis view, the position of the transection point was then quantified by 1) the degree offset from the 3-chamber view, resulting in a positive value for a forward rotation and a negative value for backward rotation as per ASE definitions for forward and backward rotation[14] (Fig. 4), and 2) the absolute distance along the epicardial surface from the LV apex on a long axis view cutting through the transection point (Fig. 4). The LV apex was therefore visually identified, including image review in cine mode throughout the cardiac cycle. To semi-quantitatively describe the location of the transection point, the apical myocardium was divided into anterior, antero-lateral, infero-lateral, inferior, infero-septal, antero-septal segments (Fig. 4). Finally, the relative angulation between the LV long axis and the mitral annular trajectory was determined (Fig. 2/3).

Please cite this article in press as: Blanke P, et al., Left ventricular access point determination for a coaxial approach to the mitral annular landing zone in transcatheter mitral valve replacement, Journal of Cardiovascular Computed Tomography (2017), http://dx.doi.org/10.1016/j.jcct.2017.04.002