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IMAGING VIGNETTE

CT for the Transapical Off-Pump Mitral Valve Repair With Neochord Implantation Procedure

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THE ADVENT OF TRANSAPICAL ECHOCARDIOGRAPHY-GUIDED MITRAL VALVE (MV) REPAIR WITH implantation of polytetrafluoroethylene neochordae (NeoChord, St. Louis Park, Minnesota) has identified some critical aspects of the procedure that require accurate understanding of cardiac anatomy (1,2). In particular, transapical access, used for transcatheter aortic valve replacement, does not provide direct alignment with the MV, which is more posterior with respect to the aortic valve (**Figure 1**). Thus, posterolateral ventricular access provides a better approach to the MV, reducing the risk of the device interfering with the native subvalvular apparatus and enabling a more physiological axis orientation of implanted neochordae (**Figure 2**) (1,2). Cardiac computed tomography has recently been used as an additional tool for pre-operative procedure planning (**Figure 3**, Online Video 1) and for post-operative assessment of implanted neochordae (**Figures 4 and 5**, Online Videos 2, 3, 4, and 5). Ideal access can be identified by projecting the desired neochordae trajectory inside the left ventricle, starting from the diseased MV leaflet toward the left ventricular epicardial surface between the papillary muscles.

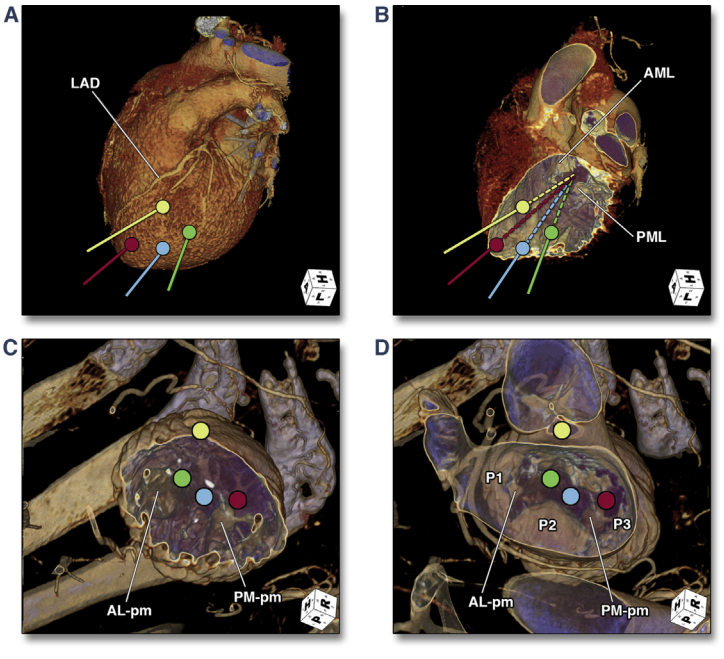
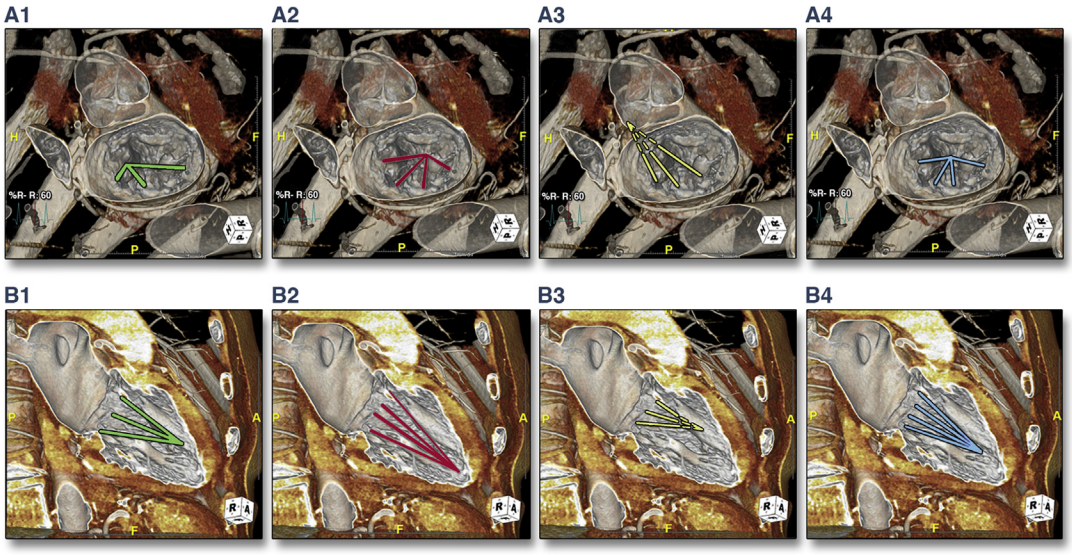


FIGURE 1 Prospective Ventricular Access Sites for Transapical Neochord Repair

Volume-rendered, cardiac computed tomography reconstruction (TeraRecon, Foster City, California) reveals 4 different prospective neochordae trajectories with respect to different ventricular access sites. **(A)** Epicardial LV entry **(dots)** with trajectory lines identify anterior access (corresponding at 5th intercostal space, **yellow**), anteroseptal access (corresponding to the 6th intercostal space, **red**), posterolateral access (corresponding to the 5th intercostal space, **blue**), and lateral access (corresponding to the 4th intercostal space, **green**). **(B)** Intraventricular continuation of the trajectory lines with the apical myocardium removed shows their convergence on the central MV plane coaptation line. Each entry site is discussed separately in **Figure 2**. **(C)** Surgical view of mid-ventricular and apical portions of the LV. Respective **dots** identify endocardial position of each entry site relative to the papillary muscles. **Red and green** access points approximate the papillary muscles bases, **blue** represents the midpoint between the two, and **yellow** is directed more anterior and superior. **(D)** Surgical view of the MV. The MV leaflets relative to each access site can be identified. AL-pm = anterolateral papillary muscle; AML = anterior mitral leaflet; LAD = left anterior descending coronary artery; LV = left ventricle/ventricular; MV = mitral valve; P1/2/3 = posterior leaflet scallops; PML = posterior mitral leaflet; PM-pm = posteromedial papillary muscle.

FIGURE 2 Ventricular Access Simulations



Volume-rendered, computed tomography reconstructions in diastole of the MV can be analyzed from a standard surgical view **(A1 to A4)**, intercommissural view with cutplane through the anterior LV wall **(B1 to B4)**. Trajectories of implanted neochordae from ventricular access (VA) are drawn to different MV segments are simulated. The neochordae orientations are represented from VA sites: lateral **(A1 and B1)**, anteroseptal **(A2 and B2)**, anterior **(A3 and B3)**. These orientations have the potential risk of damaging the AL-pm (lateral and anterior) or PM-pm (anteroseptal), as well as interfering with the subvalvular apparatus. Moreover, the working angle is not favorable to reach the medial and lateral segments of the MV; when neochordae are implanted, there is asymmetrical alignment with respect to the posterior mitral leaflet, causing unequal tension. Posterolateral access **(A4 and B4)** is considered the ideal VA site located between lateral and anteroseptal sites. Trajectories arise between the papillary muscles with the safest and symmetrical working angle. Abbreviations as in Figure 1.

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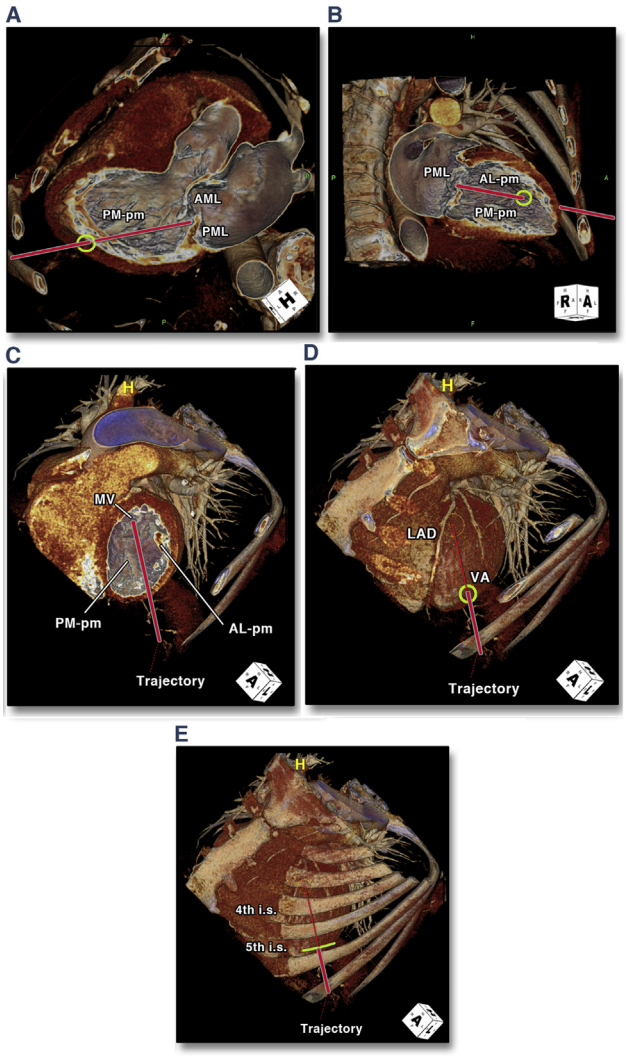
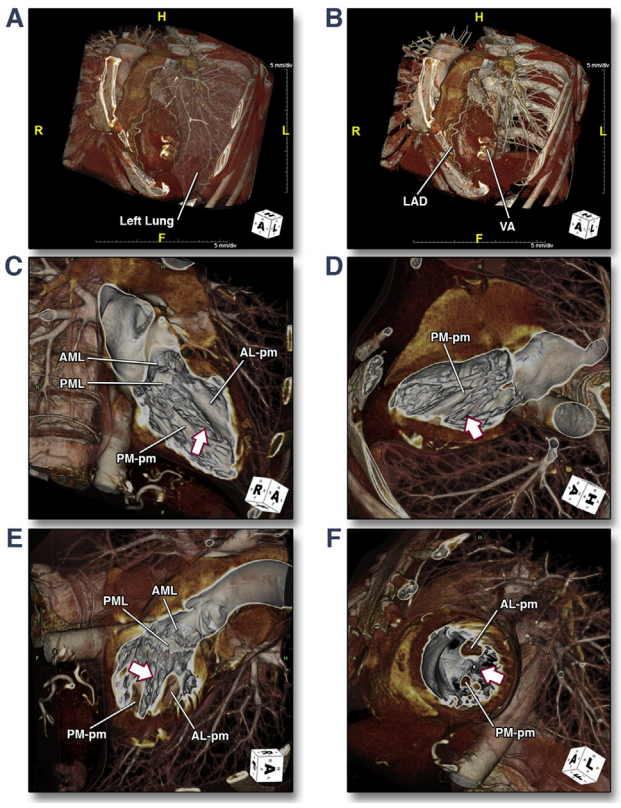
FIGURE 3 Intercostal Access Site Simulation



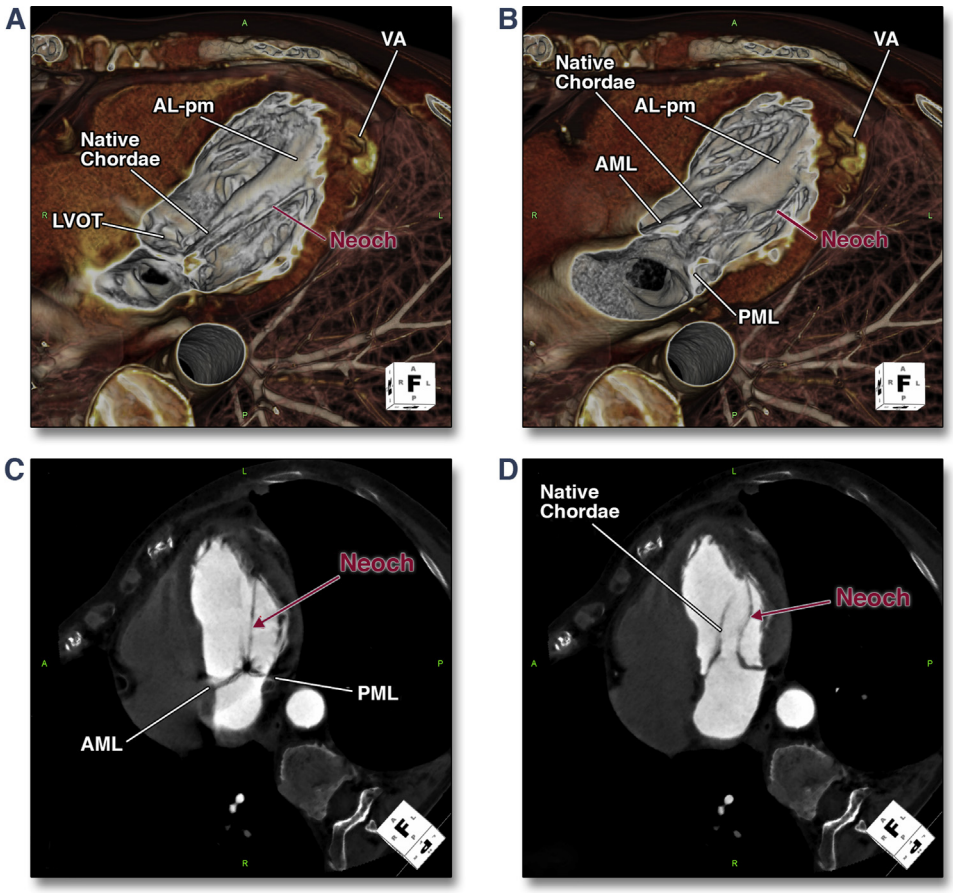
Volume-rendered computed tomography images (TeraRecon) with different cutplanes to highlight the working trajectory alignment from the MV to the chest wall. The ideal trajectory of the device and neochordae **(red line)** is projected from the valvular plane where the target MV segment abnormality exists. **(A)** Three-chamber view in systole, **(B)** intercommisural view in systole, **(C)** subvalvular intraventricular view in diastole showing the MV leaflets opened into the LV, **(D)** epicardial projection (**green circle**, VA), and **(E)** extension to the skin surface identifying the rib cage. The neochordae occupy the inflow portion of the LV, between the papillary muscles, arising from the lateral wall of the LV to the edge of the prolapsing MV segment. Such simulation allows the surgeon to identify the most appropriate intercostal space (i.s.) to be used for a mini-thoracotomy approach **(green line)** (Online Video 1). Abbreviations as in **Figures 1 and 2**.

FIGURE 4 Post-Operative Neochordae Visualization



Volume-rendered, computed tomography (CT) reconstructions of a patient who underwent successful transapical neochord repair with details of VA and visualization of implanted neochordae are shown **(white arrows)** (pre-operative CT, Online Video 2). **(A)** Rib cage is removed, and VA is highlighted by the presence of epicardial pledgets used to secure the apical purse strings and neochordae, partially covered by the left lung. **(B)** Rib cage and left lung are removed, and VA is highlighted by the presence of epicardial pledgets used to secure the apical purse strings and neochordae. **(C)** Intercommissural view shows the position of the neochordae among the papillary muscles. **(D)** Two-chamber view illustrates the neochordae arising from the apical VA to the PML. **(E)** Off-axis view displays the neochordae between the papillary muscles with both PML and AML visible underneath the aortic valve. **(F)** Short-axis view shows the neochordae within the LV inflow tract and in the middle of the papillary muscles (Online Videos 3, 4, and 5). Abbreviations as in **Figures 1 and 2**.

FIGURE 5 Neochordal Behavior During Cardiac Cycle



Post-operative 2-chamber view in systole **(A and C)** and diastole **(B and D)**. Volume-rendered, 3-dimensional computed tomography reconstruction **(A and B)** and maximum intensity projection visualization **(C and D)**. Both tensioning and relaxation of the implanted neochordae (Neoch) on the PML is evident. Native chordae on the AML equally relax during diastole. The transapical neochordae do not interfere with this mechanism. The correct procedural neochordal tensioning not only allows achievement of mitral leaflet coaptation but also enables the neochordae to behave almost as a native chordae during the cardiac cycle (Online Videos 3, 4, and 5). Abbreviations as in **Figures 1 and 2**.

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KEY WORDS computed tomography, degenerative mitral valve, mitral valve, mitral valve regurgitation, mitral valve repair, neochord

APPENDIX For supplemental videos and their legends, please see the online version of this article.