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CASE REPORT

ADVANCED

CLINICAL CASE

Incremental Utility of 3D Printing to Guide the Surgical Management of Apical Aneurysm

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ABSTRACT

A 24-year-old man presented with a nonischemic cardiomyopathy of unknown etiology, apical aneurysm, and a secondary mitral regurgitation. Computer tomography–derived 3-dimensional model of the patient's heart was an essential step in guiding the surgical management for an optimal outcome. (**Level of Difficulty: Advanced.**)
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HISTORY OF PRESENTATION

A previously healthy 24-year-old man presented to the emergency department with 5 weeks of worsening dyspnea on exertion and orthopnea. Vital signs were within normal limits, and a 3/6 holosystolic murmur was found on physical exam, with clear lungs and no pedal edema. He was admitted for further evaluation. On transthoracic echocardiography (TTE), he was found to have left ventricular (LV) and atrial dilation, severely reduced systolic function, and significant secondary mitral regurgitation (Videos 1 and 2).

LEARNING OBJECTIVES

- To show the effectiveness of 3D printing in guiding the decision and management in cardiac surgery.
- To discuss the etiology and management of apical aneurysms.

PAST MEDICAL HISTORY

The patient had no significant past medical history.

DIFFERENTIAL DIAGNOSIS

Coronary cardiac computed tomography angiography did not reveal any significant coronary atherosclerotic disease.[1] However, an LV apical/anterolateral pouch was noted. Differential diagnosis was consistent with ventricular aneurysm vs ventricular diverticulum (Video 3, **Figure 1**). The patient was then referred to our institution for further assessment.

INVESTIGATIONS

He underwent cardiac magnetic resonance imaging which corroborated the computed tomography (CT)

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finding of a ventricular aneurysm (Video 4). In addition, there was thinning of the apical walls with near-transmural delayed enhancement suggestive of an ischemic etiology (**Figure 2**). The multidisciplinary consensus opinion was that open-heart surgery was required for aneurysmal repair and mitral valve repair to improve LV function and enhance its remodeling. In this case, the geometry of the aneurysm is very atypical to the usual aneurysms we tend to see in post infarction LV aneurysms and there was a very prominent moderator band-like structure at the neck of the aneurysm. Furthermore, it was not clear where the ideal anchor location would be for our patch to achieve optimal conical LV geometry. Therefore, to optimally plan the aneurysmal excision, a CT-derived 3-dimensional (3D) printed model of the heart was created to determine what the residual ventricular volume would be without any significant restriction, the size of the patch required to achieve a conical LV geometry, and the ideal entry point into the aneurysm to maximize exposure to incision size ratio based on the patch anchor location (**Figure 3**).

MANAGEMENT

The patient was transferred to the operating room for surgical repair and underwent Swan-Ganz catheter placement and transesophageal echocardiography. Median sternotomy, central aortic and bicaval cannulation were performed. The aorta was clamped and heart arrested with antegrade and retrograde Buckberg cardioplegia. The LV apex was then inspected. As previously planned with the 3D heart model, the aneurysm was incised and a transition zone established between the healthy myocardium and an area of fibrotic, thin myocardium. The neck of the aneurysm was encircled with interrupted 4.0 pledgeted Prolene sutures and bovine pericardial patch implanted (**Figure 4**). Excess aneurysmal myocardium was resected and edges closed with bovine pericardial felt. After aneurysmal repair, the mitral valve was reassessed on intraoperative transesophageal echocardiography in optimally loaded conditions. Moderate to severe mitral regurgitation was observed and it was elected to re-arrest the heart and repair this. The mitral valve was approached via transeptal incision. A mildly thickened and restricted posterior leaflet was identified in addition to annular dilation. A 30-mm Profile 3D full rigid annuloplasty ring was implanted and trace central regurgitation was noted on a saline test. The atrium closed in the usual fashion. After de-airing maneuvers, the aortic cross clamp was removed and sinus rhythm restored spontaneously. Patient came off cardiopulmonary bypass easily with minimal inotropic support. Microscopy of the resected tissue showed transmural, near-complete fibrosis in several foci favoring an ischemic etiology for the aneurysm (pathology figures). However, the immediate subendocardium was not spared, which is not typical of an ischemic etiology (**Figure 5**).

ABBREVIATIONS AND ACRONYMS

3D = 3-dimensional
CT = computed tomography
LV = left ventricle
TTE = transthoracic echocardiography

DISCUSSION

Apical aneurysms are a known complication of myocardial infarctions. Other etiologies for

FIGURE 1 3-Dimensional Reconstruction of the Cardiac Computed Tomography

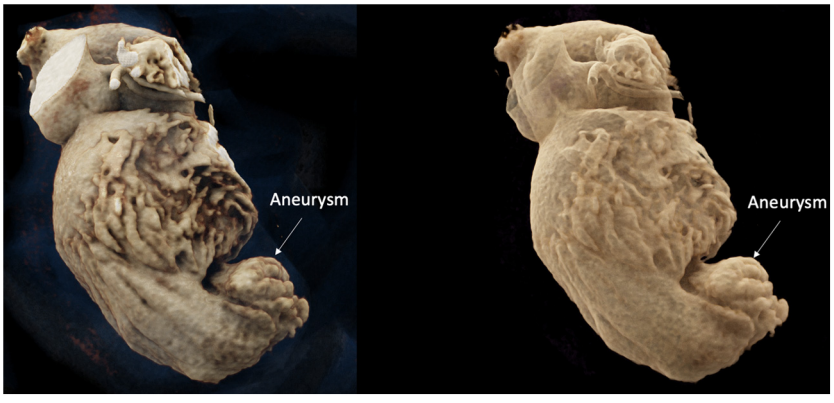
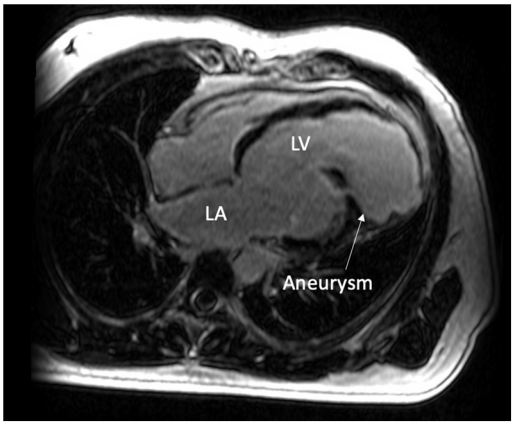


FIGURE 2 Single-Shot Cardiac Magnetic Resonance Imaging Showing Delayed Thinning and Near-Transmural Delayed Enhancement of the Apical Walls



LA = left atria; LV = left ventricle.

ventricular aneurysms include hypertrophic cardiomyopathies and congenital aneurysms.[2,3] Despite having no risk factors for ischemic cardiac diseases and no sign of coronary artery disease, this patient's apical aneurysm had ischemic characteristics as revealed on cardiac MRI, suggesting a possible embolic event. In ischemic LV aneurysms, endoventricular circular patch plasty repair is correlated with postoperative improvement in cardiac contractility, as evidenced by the immediate rise of the patient's ejection fraction.[4] Although recent studies had cast doubt on the utility of mitral valve intervention during ventricular reconstruction in a cohort of middle-aged and elderly population with functional mitral regurgitation, the multidisciplinary team opted to repair the mitral valve in this patient because of his young age and the risk of progression.[5]

Multimodality imaging of the LV was essential in establishing the diagnosis and severity of the ventricular disease. However, cardiac 3D printing with detailed segmentation of the LV and mitral valve leaflets had a major role in hands-on conceptualization of the surgical procedure and access routes to the aneurysm and mitral valve in this case, supporting the growing use of 3D printing in cardiac surgery planning.[6,7] 3D printing was essential in this unusual case; however, its role is not clear for regular uncomplicated cases of LV aneurysms.

FOLLOW-UP

On postoperative TTE, LV ejection fraction improved to 36% and mitral valve regurgitation was reduced to mild severity. Follow-up TTE showed an excellent result with complete reduction of the aneurysm (Video 5). The patient had an uneventful postoperative recovery and was discharged on day 5.

CONCLUSIONS

Embolic ischemic apical aneurysms are rare in young patients. 3D printing played a critical role in guiding the management this unusual presentation.

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The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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FIGURE 3 Computed Tomography-Guided 3-Dimensional Printed Model of the Heart Showing Apical Aneurysm

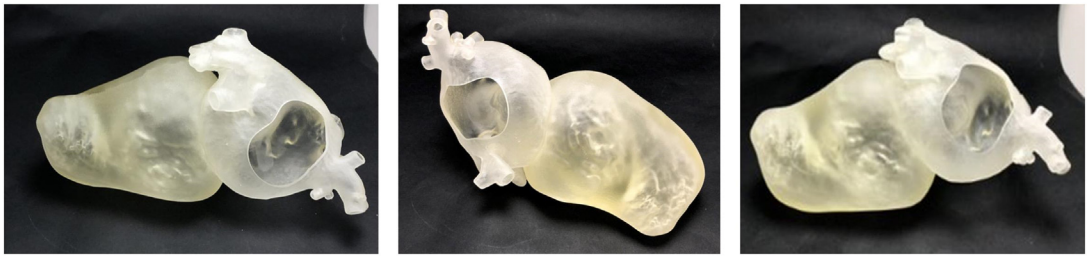


FIGURE 4 Pericardial Patch Implantation

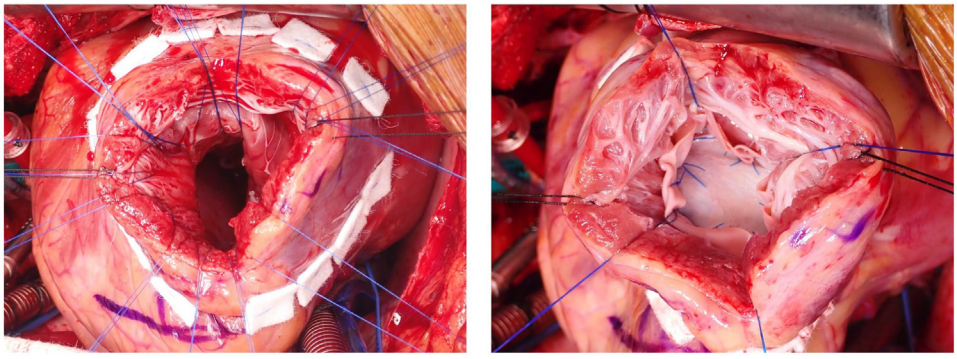
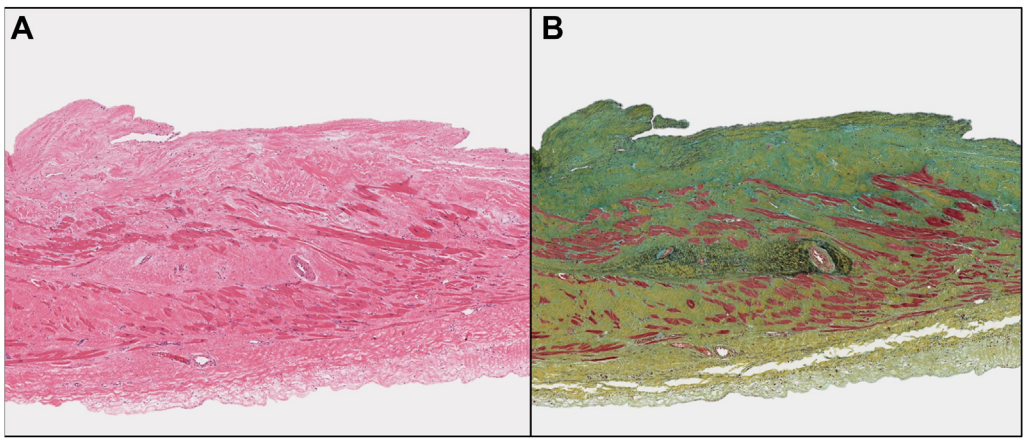


FIGURE 5 Histology of Left Ventricular Aneurysm



The microscopic findings of the patient's resected aneurysm **(A**: hematoxylin and eosin stain, **B:** Movat pentachrome stain, original magnification ×40). There is severe interstitial fibrosis (eosinophilic in **A**, **yellow in B**) which nearly replaces the compact zone of the myocardium. The Movat shows minimal elastosis of the endocardium (black fibers). The fibrosis affects the subendocardial layer and trabecular muscle, which are typically spared in ischemic injury.

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KEY WORDS 3-dimensional printing, cardiomyopathy, imaging

APPENDIX For supplemental videos, please see the online version of this paper.