Three-dimensional printing in integrated multi-modality imaging approach for management of prosthetic valves infective endocarditis

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Abstract

After heart failure, infectious endocarditis is the second leading cause of death in patients with prosthetic valves. Aortic pseudoaneurysms are a serious complication of infective endocarditis in mechanical or bioprosthetic aortic prostheses. Diagnostic and management challenges are posed by aortic pseudoaneurysms. In these cases, a multi-modality imaging approach with a heart team is recommended. We described two cases of aortic pseudoaneurysms that developed as a result of infective endocarditis. The first case involved a transcatheter aortic valve implantation (TAVI) patient, who developed infective endocarditis as a result of diabetic foot complications. Because traditional echocardiography and computed tomography failed to show the anatomy of the lesion, we used 3D printing to show the anatomy, extension of the pseudoaneurysm, and proximity to the right coronary artery. The second case involved a patient who underwent Bentall's surgery with an aortic root and mechanical aortic valve and later developed infective endocarditis complicated by pseudoaneurysms. In this case, 3D printing was used for preoperative surgical planning.

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Introduction

Infective endocarditis (IE) is a common complication in patient with prosthetic valves. IE-related pseudoaneurysms are one of dreadful IE complications. Such complications impose diagnostic and management challenges. Integration of multimodality imaging had been advocated to guide management approach [1]. 3D printing is an additive manufacturing of multimodality imaging and represents the possibility to create objects (anatomical models) from geometrically defined digital models. We reported two cases of aortic pseudoaneurysms following transcatheter aortic valve implantation (TAVI) and Bentall's surgery in which we highlighted the importance of multi-modality imaging approach, including the use of three-dimensional (3D) printing, as a tool of medical and surgical management.

Case #1

A 66-year-old male with known case of hypertension (HTN), type 2 diabetes mellitus (T2DM), dyslipidemia (DLP), old ischemic stroke with no residual neurological deficit, and established coronary artery disease (CAD) for which he underwent coronary artery bypass graft surgery (CABG) in 2007. The patient underwent transcatheter aortic valve implantation (TAVI) in 2020 in context of severe symptomatic aortic stenosis (AS). In July 2022, the patient was admitted to intensive care unit (ICU) for septic shock secondary to infected diabetic foot ulcer. Blood cultures were positive for gram positive cocci and magnetic resonance imaging (MRI) of the infected foot confirmed the diagnosis of osteomyelitis which was treated medically. Transthoracic and transesophageal echocardiography (TTE/TEE), done to exclude IE, showed a mass on the aortic bioprosthesis. Few days later, he developed worsening shortness of breath and electrocardiographic (ECG) changes along with new regional wall motion abnormalities on TTE consistent with non-ST segment elevation myocardial infarction (NSTEMI) that was managed conservatively. TEE was repeated as the patient was persistently hypotensive and showed the presence of a new paravalvular leak (PVL). The aortic prothesis was well seated, there was increased gradients across the valve (peak/mean of 45/27 mmHg) and a pseudoaneurysm between the aorta and right ventricular out-flow tract (RVOT) was seen. Cardiac computed tomography (CT) scan showed a contrast-filled cavity extending along the right side of the aortic root communicating with the LVOT, grossly measuring 2 x 1 x 3 cm, with adjacent inflammatory changes, consistent with infected pseudoaneurysm (Figure 1). Additionally, an ill-defined low attenuation collection/abscess was seen on the interventricular groove and extending into the basal superior RV insertion site, grossly measuring 6 x 5 x 4 cm. As the lesion was complex and the extension of periaortic collection and pseudoaneurysm was not clear, 3D printing was done to clarify the lesion (Figure 2) (video 1). The 3D printing showed the pseudoaneurysm and its extension to the right coronary artery (RCA). The consensus of heart-team discussion with consideration of patient surgical risk and comorbidities was to keep him on medical therapy with no surgical intervention. Patient was discharged on long term antibiotics therapy.

Case #2

A 40-year-old male who underwent modified Bentall's surgery (aortic graft and mechanical aortic valve replacement) 4 years back, after developing severe aortic regurgitation, ascending aortic aneurysm and severe left ventricular (LV) dysfunction and dilatation in context of bicuspid aortic valve. He was admitted for acute ischemic stroke that was treated successfully by thrombolytic therapy with minimal residual neurological deficit but he developed a high-grade fever. Blood cultures were positive for *Brucella abortus*. TTE, done to rule out IE, showed an anterior aortic pseudoaneurysm communicating with left ventricle out-flow tract (LVOT) and no vegetation on the mechanical aortic prothesis. These findings were confirmed by TEE that showed the pseudoaneurysm was circumferential and there was moderate PVL. Antimicrobial therapy was stared. Cardiac CT with 3D reconstruction showed two separate pseudoaneurysms, one anteriorly and the other posteriorly encircling and communicating with LVOT with upward extension to the coronary ostia. There was no avid uptake of glucose in fluorodeoxyglucose-positron emission tomography (FDG-PET) around the aortic prothesis or aortic graft (Figure 3). After the heart-team discussion and the complex anatomy of the lesion displaced by TEE and CT image, 3D printing was requested to better understand the anatomy and plan the surgical intervention. The 3D model clearly showed the tridimensionality of the lesion, its extension, relation with the coronary arteries in addition to the communication with LVOT (Figure 4).

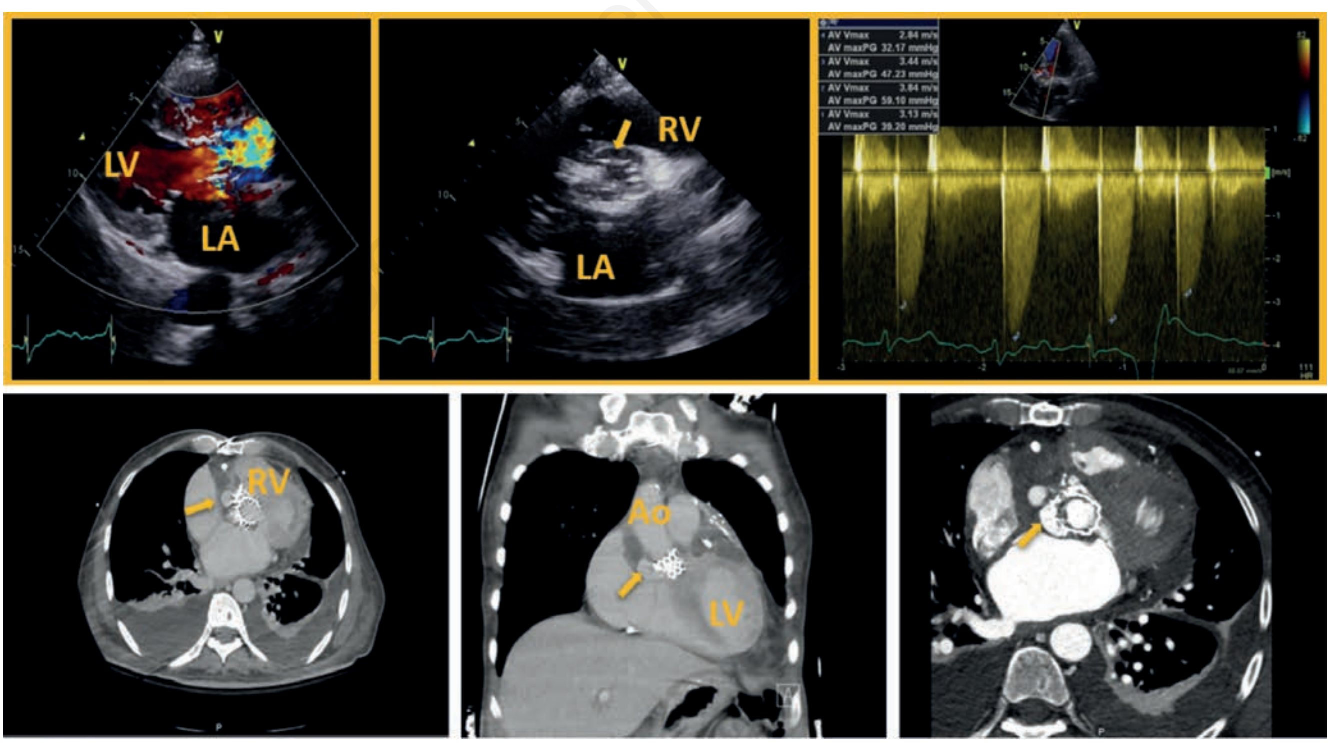

Figure 1. Transthoracic echocardiography (upper panel) with flow acceleration across the aortic bioprosthesis in parasternal long axis view (left); anterior pseudoaneurysm in parasternal short-axis view (middle); continuous-wave doppler across the aortic bioprosthesis with Vmax 3.8 m/s (right). Cardiac computed tomography (lower panel) showing the pseudoaneurysm (arrow) in axial cut (left) and coronal cut (middle); on the right, contrast axial images with pseudoaneurysms (arrows). LV, left ventricle; LA, left atrium; RV, right ventricle; Ao, aorta.

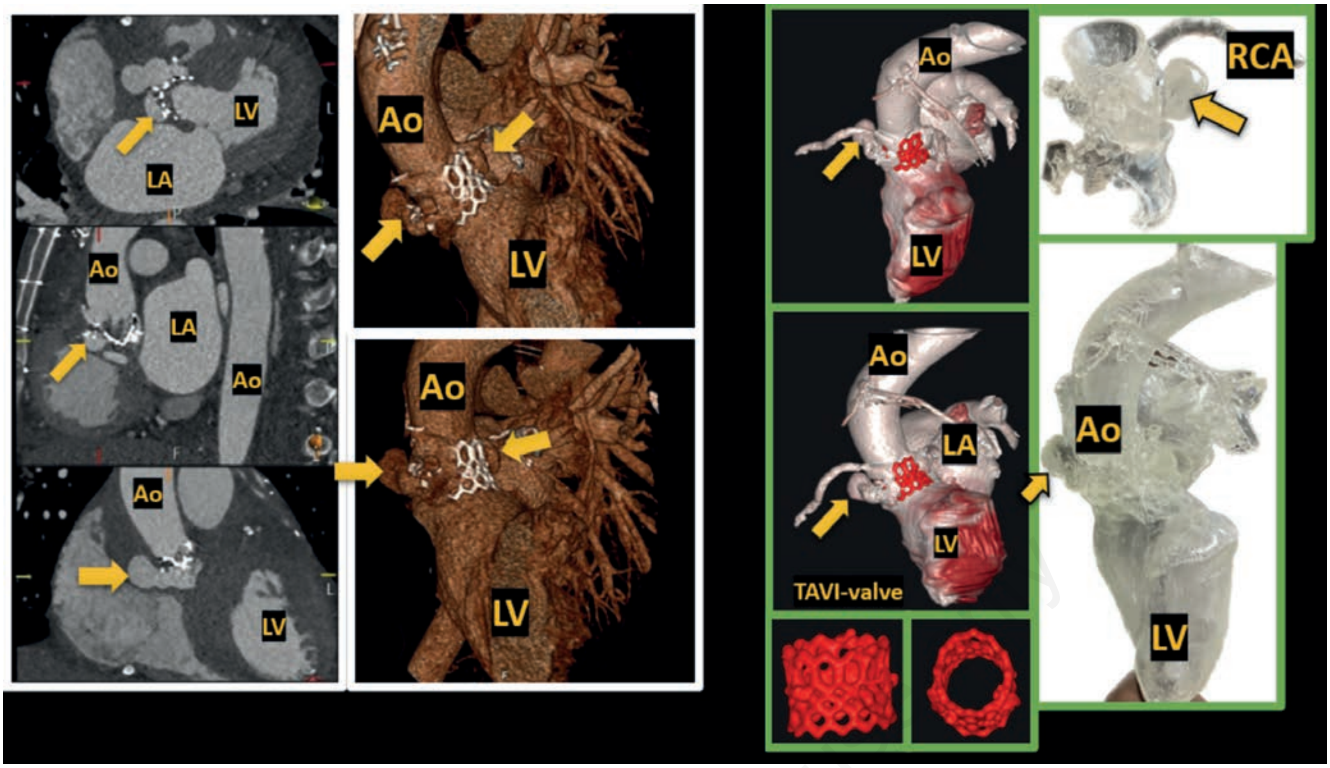

Figure 2. Multiplanar views of computed tomography scan (white frame panel) with 3D reconstruction showing the pseudoaneurysms (arrows), processed 3D format and 3D printing (green frame panel). LV, left ventricle; Ao, aorta; LA, left atrium; TAVI, transcatheter aortic valve implantation; RCA, right coronary artery, 3D, three-dimensions.

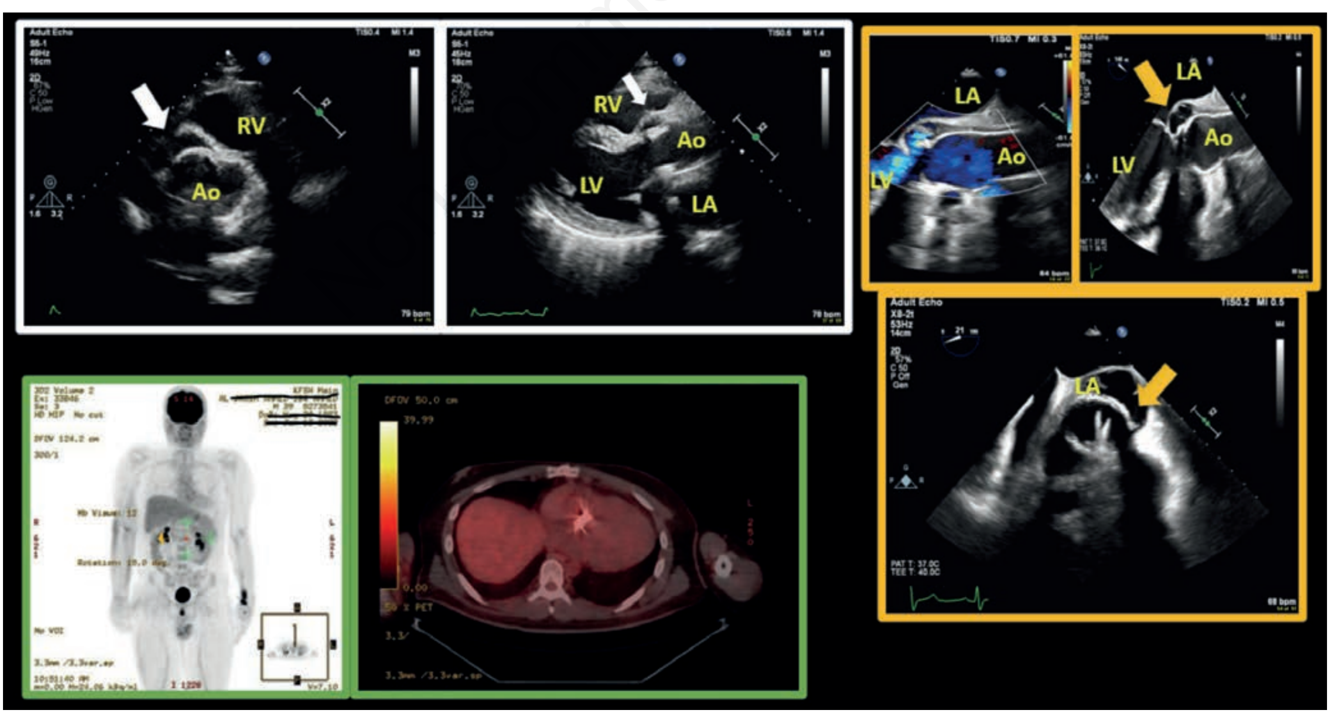

Figure 3. Transthoracic echocardiography (white frame panel) showing the anterior pseudoaneurysm (white arrows) in short and long axis views. Transesophageal echocardiography (yellow frame panel) showing the posterior pseudoaneurysm (yellow arrows). FDG-PET (green frame panel) showing no avid glucose uptake around the aortic prothesis. LV, left ventricle; RV, right ventricle; Ao, aorta; LA, left atrium; FDG-PET, fluorodeoxyglucose-positron emission tomography.

Discussion

Prosthetic valve endocarditis (PVE) accounts for more than 20% of total IE cases, it can occur early (within the first year of surgery) or late (after the first year of surgery). PVE can affect both mechanical and bioprosthetic valves. Aortic PVE had a risk of 0.57% per year [2] and the diagnosis of PVE can be challenged. For this reason, in addition to the traditional armamentaria, 3D printing can add significant information [3].

Aortic pseudoaneurysms, in setting of IE can occur following TAVI or surgical aortic valve replacement (SAVR) which is most common implicated mechanism [4,5]. TAVI was firstly described in 2002 by Cribier and since then it became a common procedure at the point that now, it is approved even for low-risk patients [6]. The incidence of IE post TAVI is ranging from 0.1-3%, the risk increases with the use of orotracheal intubation and a self-expandable valve system with no difference between TAVI or surgically replaced valves SAVR [7,8]. Pseudoaneurysms post TAVI can impose management concerns, especially because TAVI patients are at high surgical risk in the first place. In one observational study, 44 patients with IE post TAVI were kept on medical therapy despite having surgical indication because of high or prohibitive surgical risk [9]. The present case of TAVI related pseudoaneurysms, echocardiography and CT images could not describe completely the lesion, so 3D printing was obtained. 3D model showed the complexity of anatomy in real time (proximity of the pseudoaneurysm to right coronary artery and surrounding structures) and combined with the clinical status, there was the consensus that the patient was at very high risk for surgical procedure and medical therapy was the option. This was in line with aforementioned registry by Santos *et al*. when only 11% with TAVI related IE with surgical indication underwent surgery with poor outcomes post-operatively [7]. Bentall's surgery is the gold standard for ascending aortic aneurysm associated with aortic valve disease [10,11]. The common sites of aortic pseudoaneurysms post Bentall's surgery are coronary ostia and distal and proximal suture lines [12]. The case here described of pseudoaneurysms post-Bentall's surgery, multi-imaging approach, included 3D printing, was essential as the echocardiogram and cardiac CT were not sufficient to visualize the lesion and its relation with the coronaries and other structures. In particular 3D printing was used by surgical team for surgical planning. Aortic pseudoaneurysms diagnosis can be challenging and multi-imaging approach is recommended along with heart-team discussion [13,14].

3D printing is novel diagnostic tool that opens to a wide number of opportunities, in particular in cardiovascular intervention, improves the understanding of cardiovascular disease and offers a unique visualization of patient`s specific anatomy. Actually, the images used are from MRI and CT. Echocardiography, in particu-

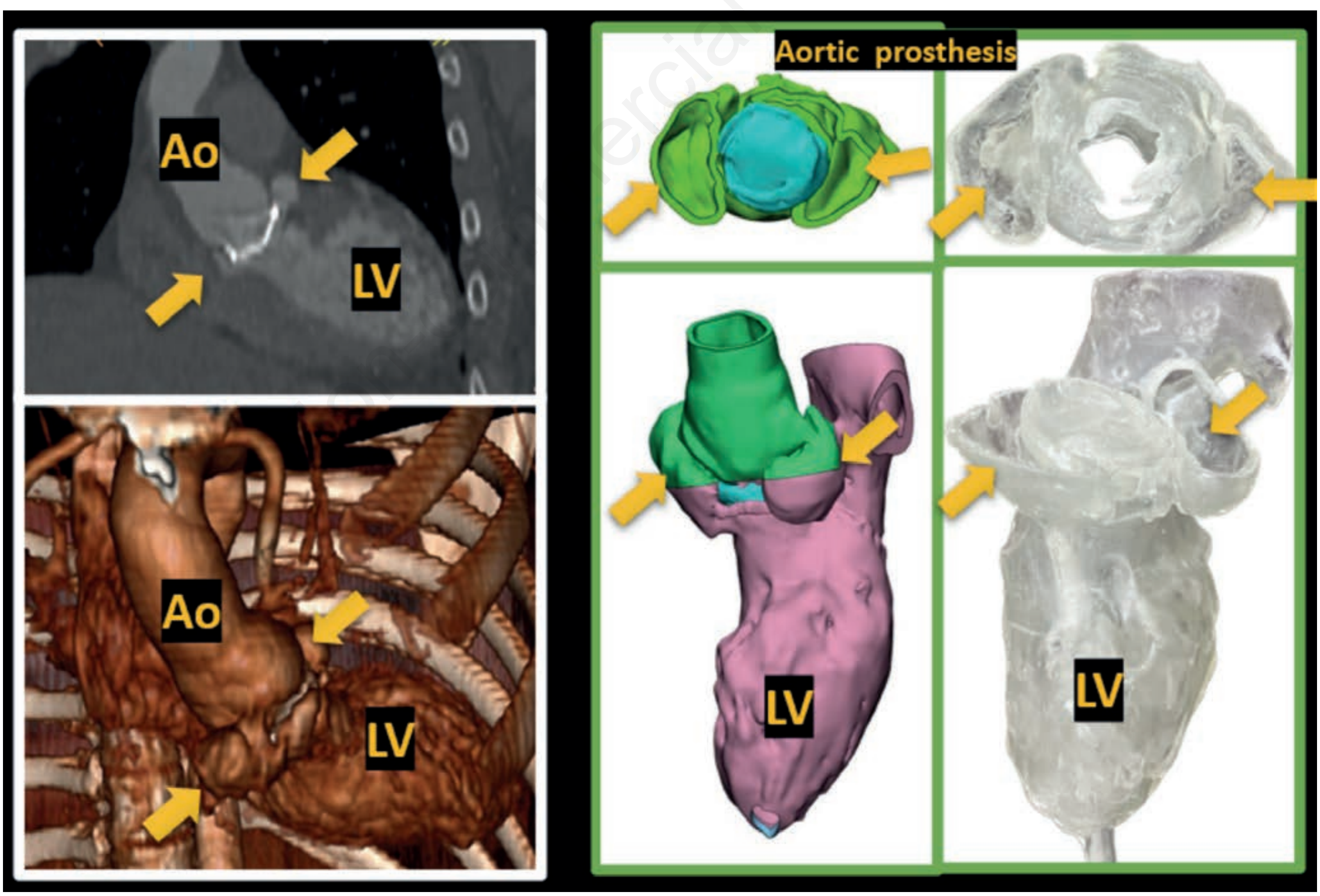

Figure 4. Multiplanar sagittal view of computed tomography scan and 3D reconstruction showing the pseudoaneurysms (arrows) (white frame panel). I 3D printing with pseudoaneurysms (arrows) (green frame panel). LV, left ventricle; Ao, aorta; 3D, three-dimensions.

lar 3D TEE can be used although it is limited by special resolution, acoustic window and 3D volume capacity [15]. The current technology can offer different opportunity. For example, the fused deposition modeling can produce highly detailed models or the polyjet technique can produce complex, multi-colored, and multi-material models [3,16]. 3D printing still an underdeveloped area but with promising results in cardiology and cardiac surgery in particular.

Conclusions

3D printing can be part of multimodality-imaging approach in which can be valuable adjunct tool for medical and surgical management, preoperative planning of complex procedure and as teaching tool for heart-team members.

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