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HEART FAILURE

CASE REPORT: CLINICAL CASE

# 3D Printing for Left Ventricular Assist Device Exchange

## Insights From Real-World Experience

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ABSTRACT

Left ventricular assist devices (LVADs) are used in end-stage heart failure. Inadequate positioning of the inflow cannula may necessitate replacement of the LVAD. We present the successful use of a three-dimensional printed model used to optimize surgical planning and allow for simulation and training for the LVAD exchange procedure. (J Am Coll Cardiol Case Rep 2024;29:102194) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

## HISTORY OF PRESENTATION

A 55-year-old male patient with guideline-directed medical therapy for heart failure was classified as Interagency Registry for Mechanically Assisted Circulatory Support level 3.[1] The patient had nonischemic dilated cardiomyopathy and was ineligible for heart transplantation due to his HIV-positive status and active drug use.

## PAST MEDICAL HISTORY

A HeartMate II (HMII, Abbott Cardiovascular) device surgical implant as destination therapy was implanted, and the surgical procedure was considered successful. However, 3 months after the implantation, the patient began to experience syncopal episodes.

**LEARNING OBJECTIVES**

- To be able to list complications of LVADs.
- To understand how 3D models can be used to optimize surgical planning.
- Assess the costs and benefits of 3D models in surgical planning.

## DIFFERENTIAL DIAGNOSIS

The differential diagnosis for syncope in patients with left ventricular assist devices (LVADs) includes postural hypotension due to loss of pulsatility, hypotension due to blood loss from gastrointestinal bleeding, malignant ventricular arrhythmias, stroke, and device thrombosis.

## INVESTIGATIONS

During a routine medical consultation 5 months after the LVAD procedure, the patient experienced a syncopal episode while in the clinic, and an electrocardiogram revealed a sustained ventricular arrhythmia (79 beats/min) (**Figure 1**) with a mean

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arterial pressure of 40 mm Hg. A computed tomography scan showed the HMII inflow cannula inserted toward the free wall of the left ventricle (Figure 2).

## MANAGEMENT

The decision to replace the HMII device with the new HMIII model was based on the clinical benefits shown in the MOMENTUM 3 (Multicenter Study of MagLev Technology in Patients Undergoing Mechanical Circulatory Support Therapy with HeartMate 3) trial. In addition, the HMIII has a shorter entry cannula and greater mobility of the role system, which reduces the chance of cannula malposition after left ventricular remodeling.[2]

An LVAD exchange procedure is a complex cardiac surgery, and our group therefore decided to train using a three-dimensional (3D) model of the patient's heart printed with a novel technology from Bio-Architects in Sao Paulo, Brazil. The objective was to be able to evaluate the case more accurately, plan all steps of the procedure in advance, and train the surgical team to correctly position the entry cannula. This technique had not been previously performed in Brazil.

The 3D printing describes the process in which a digital data set is transformed and printed into physical models and is one of the most promising technologies in medicine.[3,4] The creation of patient-specific digital 3D models from computed tomography data sets was performed by using Mimics software (Materialise). To enable the simulation of complex surgical procedures, the Stratasys Polyjet J7503D printing technology was chosen due to its ability to print multiple-density materials and colors on the same model, allowing for realistic simulations. This technology can produce a range of Shore A hardness measurements for polymers and up to 360,000 color tones in a single model. The 3D printing process involves the deposition of successive layers of material, with a layer thickness of 14 μm.

The model was printed in 3 parts, the aorta in semirigid material (Shore 85), the cardiac structure with rigid material, and the apex of the heart with flexible material (Shore 30) (Figure 3). The entire 3D process took 36.5 hours and a total of 4,567 g of material (2,664 g of construction and 1,903 g of support material). Due to the high cost of equipment and raw materials, the complete cost of the project was U.S. $5,500.

The utilization of 3D printing technology in the medical field has significantly improved surgical planning and patient outcomes.[5] In this study, the incorporation of different materials into the 3D model allowed for the surgical team to train and improve

**FIGURE 1 24-hour Holter With Sustained Ventricular Arrhythmia**

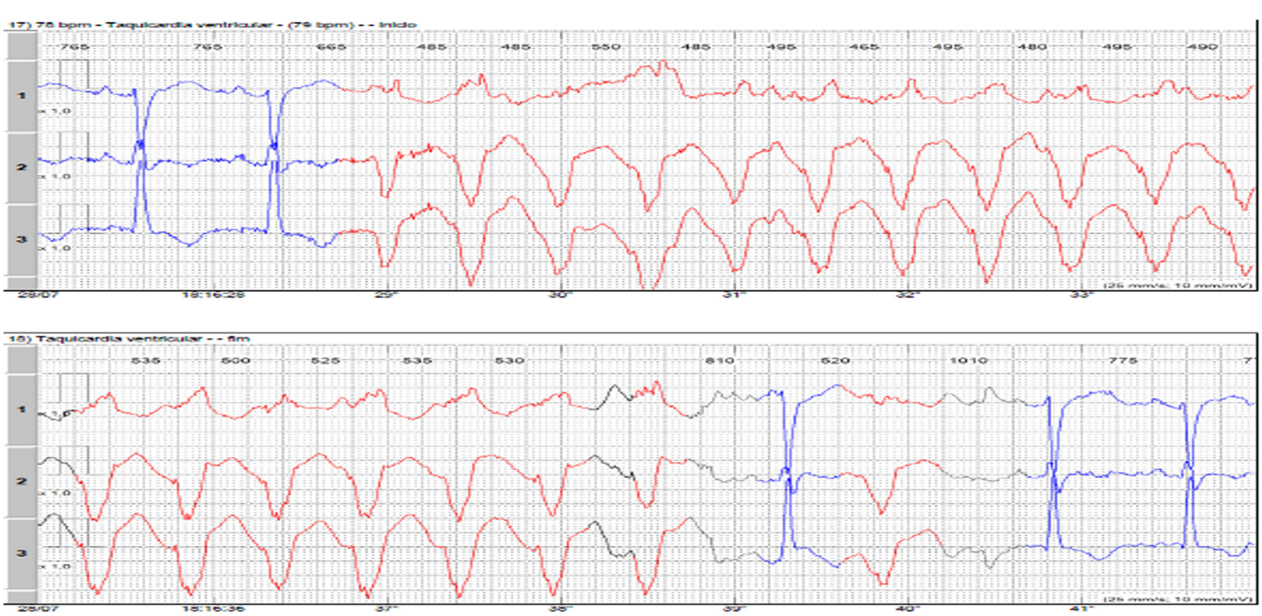
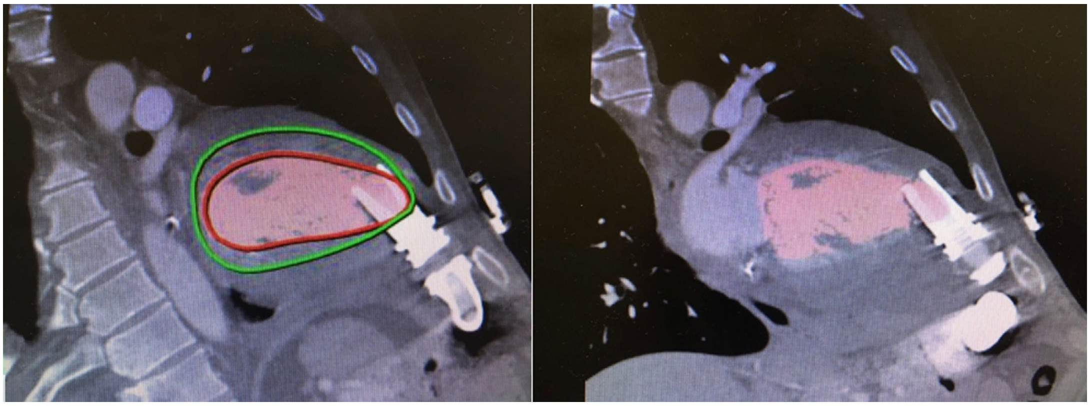


**FIGURE 2** LVAD CT Images

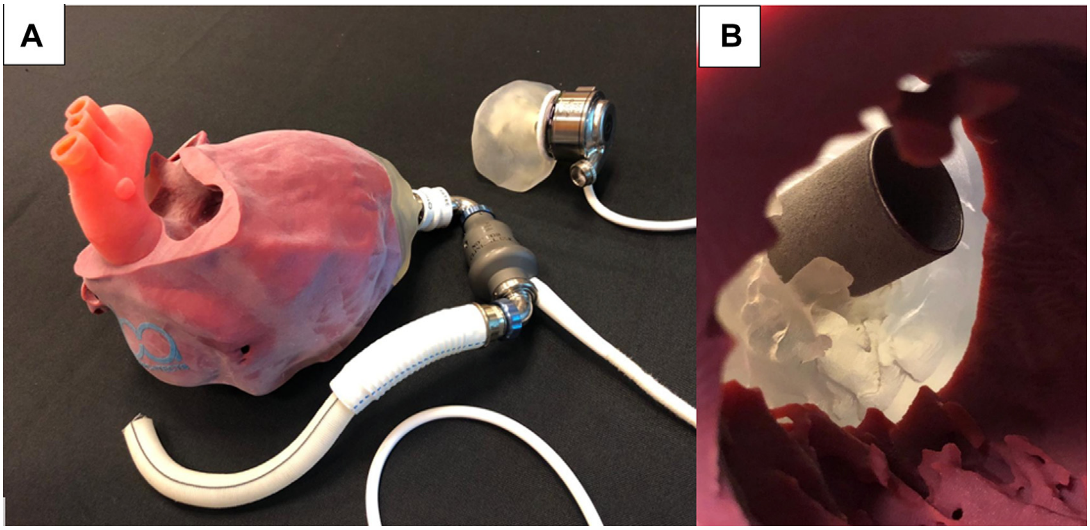


Left ventricular assist device (HeartMate II) computed tomography scan images of inflow cannula malposition, systole (red circle) and diastole (green circle) cardiac cycles.

their skills, not only to correctly position the inflow cannula but also to determine the best length of the graft and how to connect the device to the aorta.

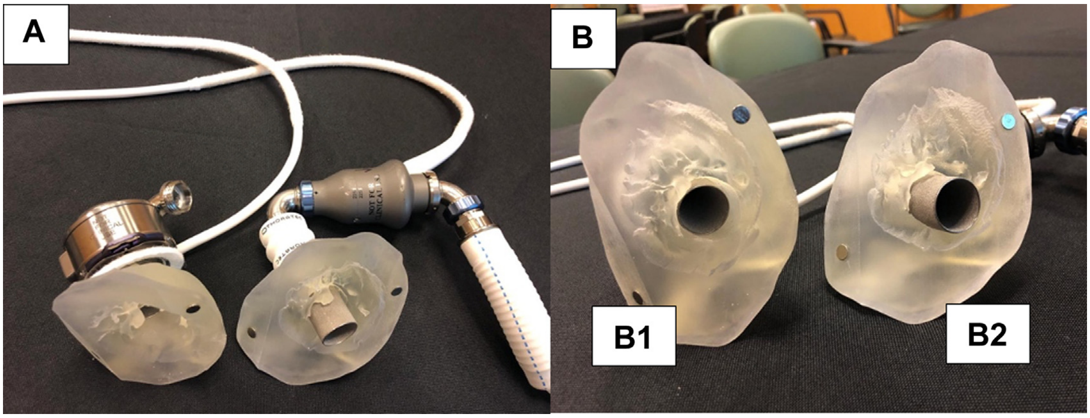
The surgeon fixed the HMIII on the left ventricular (LV) apical sewing ring with large strips of felt, placing pledgets on the outside of the LV apex. The correct geometric positioning was guided by the 3D printed model and exhaustive presurgical training. Confirmation of correct angulation after HMIII implantation was performed with intraoperative transesophageal echocardiography. Furthermore, the 3D model provided an excellent platform for clinical discussions, which further improved patient outcomes (Figures 4 and 5).

**FIGURE 3** 3D Bio Model Printings




(A) LVAD models proposed in the study for the exchange from HMII to HMIII. (B) The hole in the rigid myocardial frame provides internal visualization of the correct positioning of the inflow cannula, regardless of the model.

**FIGURE 4** **Inflow Cannula for the LVADs**



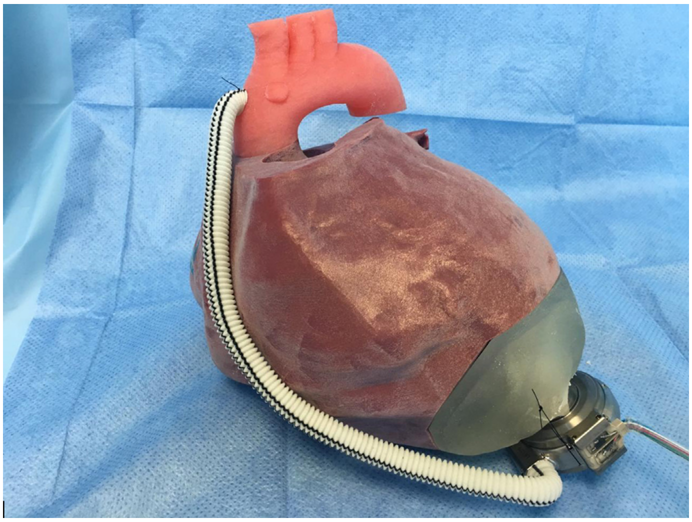

(A) Flexible structure, Shore 30, movable due to the magnetic spots providing 360 degrees of visualization for optimal surgical planning. (B) Difference in length of the inflow cannula of the 2 devices. (B1) HeartMate III left ventricular assist device. (B2) HeartMate II left ventricular assist device.

## DISCUSSION

In complex cases, the use of 3D printed biomodels can allow for a better spatial understanding that optimizes clinical and industrial teaching, provides a mechanism to explain the procedure clearly to the patient and family, and enhances preprocedural planning.

Despite the high initial cost, the adequate formulation of the prototype in modules promotes future printing of only the suture areas that are attached in the rigid main module, printed only once. This strategy made the biomodel more profitable, with greater durability due to the possibility of its future use in other complex cases such as in university training research centers.

**FIGURE 5** **Patient LVAD Biomodel**



Visualization and complete planning of implantation of a HeartMate III left ventricular assist device with emphasis on the biomodel identical to that of the patient studied, providing an exact measurement.

## FOLLOW-UP

In this specific case, the 3D printing technology reduced operating time and contributed to the successful surgery, which resolved the ventricular arrhythmias and syncope caused by improper positioning of the inflow cannula. The patient recovered without complication and was discharged on postoperative day 22, with complete resolution of symptoms.

The use of this expensive technology is not routine in our service. It is only used in challenging cases in which the high cost of bioprinting is outweighed by the enormous benefit provided by diagnostic clarity, clear communication with patients and families, surgical planning and team training, and pioneering surgeries.

The 3D printing technology has a promising applicability in the fields of tissue engineering and regenerative medicine in the form of bioprinting that involves the process of laying down cells in a predefined spatial arrangement with or without use of a biocompatible scaffold.[6] The use of 3D bioprinting as a training and decision-making model in complex cases or associated with tissue engineering will likely continue to be a driving force, allowing us to practice individualized medicine in an era in which "precision medicine" and "personalized medicine" are synonymous with high-quality patient care.

## CONCLUSIONS

Our results with the present patient is one of the few successful cases using this technology and the first in Latin America. It suggests that the use of 3D printed models can enhance surgical planning, improve the clinical decision-making process, and facilitate training of the surgical team, ultimately leading to better patient outcomes.

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**KEY WORDS** biotechnology, cardiac assist device, heart failure, three-dimensional printing