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CASE REPORT

# Multimodal Imaging with 3D-Holograms for Preoperative Planning in Pediatric Cardiac Surgery: A Unique Case Report

**Federica Caldaroni[1], Massimo Chessa[2], Alessandro Varrica[1] and Alessandro Giamberti[1,*]**

[1]Department of Congenital Cardiac Surgery, IRCCS Policlinico San Donato, San Donato Milanese, Milan, Italy

[2]ACHD Unit–Pediatric and Adult Congenital Heart Centre, IRCCS Policlinico San Donato, San Donato Milanese, Milan, Italy

[*]Corresponding Author: Alessandro Giamberti. Email: alessandro.giamberti@grupposandonato.it

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**ABSTRACT**

Multimodal imaging, including augmented or mixed reality, transforms the physicians' interaction with clinical imaging, allowing more accurate data interpretation, better spatial resolution, and depth perception of the patient's anatomy. We successfully overlay 3D holographic visualization to magnetic resonance imaging images for preoperative decision making of a complex case of cardiac tumour in a 7-year-old girl.

**KEYWORDS**

Hologram; augmented reality; multimodal imaging; 3D; CHD; cardiac tumour; arrhythmia; anatomy

## 1 Introduction

Since the early seventies, when the idea of 3D reality was born, physicians dreamed about holographic technology applied to medical science, aiming to help in clinical diagnosis and surgical practice. Today, what once was only science fiction, has become a ready-to-use technology. Augmented or mixed reality, in fact, accounting for head-sets made of translucent glasses, allows for real-time rendering of holographic 3D contents in the surrounding world, while preserving the interaction with the actual environment [1]. This technology is currently used for education, simulation, and procedural planning in the surgical and/or trans-catheter treatment of patients with congenital and acquired heart disease [2–10], but still presents some limitations.

Multimodal imaging can be considered a further step towards personalized medicine. The combination of imaging modalities, in fact, overcomes the limitations of each separate technique [6]. We report our experience with magnetic resonance imaging (MRI) and 3D-holograms technology overlay in decision making of a complex case of cardiac tumour in a child.

## 2 Case Report

A 7-year-old girl, previously healthy, was admitted to the Emergency Department for syncope and wide QRS ventricular tachycardia of unknown origin. Physical examination was unremarkable, and no signs of hemodynamic decompensation were found.

She underwent electrical cardioversion and subsequent complete workup. The ECG-Holter 24 h monitoring demonstrated sinus rhythm with occasional premature ventricular contractions. Echo imaging

showed a hyper-echogenic mass in the postero-lateral wall of left ventricle (LV), with preserved ejection fraction (EF = 60%). Gadolinium cardiac MRI confirmed the hypodense enhancement of a focal lesion (38 mm × 11 mm × 25 mm) with intramural extension in the postero-lateral wall of the left ventricle, suspicious for cardiac tumour (fibroma or rhabdomyoma). However, MRI could not discriminate if all the cardiac layers were affected, nor cardiac catheterization and CT scan could exclude major vascularization of the cardiac mass from the circumflex artery.

Hence, we created a holographic 3D model to plan how to approach the tumour, discriminating the precise layer's involvement.

Cardiac MRI dynamic sequences in short axis view were used to build the holographic 3D model, using a prototype software platform (ARTINESS srl, Milan, Italy). The holographic 3D model and its overlay with MRI images confirmed that the extension of the tumour was limited to the epicardial and myocardial superficial layers, and thus the feasibility of surgical excision (Figs. 1 and 2).

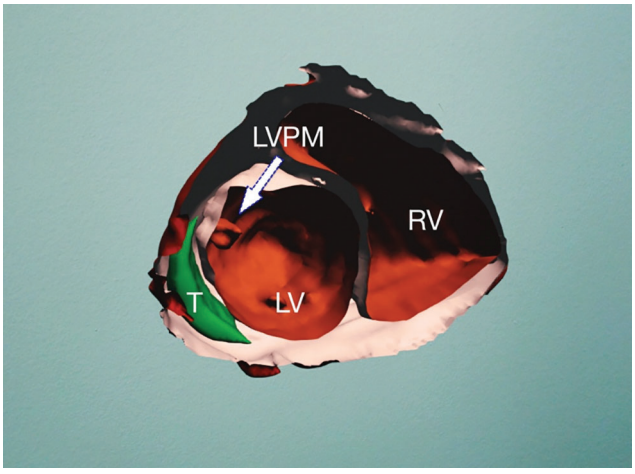


**Figure 1:** 3D hologram model in short axis view. *T: tumor; LV: Left Ventricle; RV: Right Ventricle; LVPM: Left Ventricular Papillary Muscle*

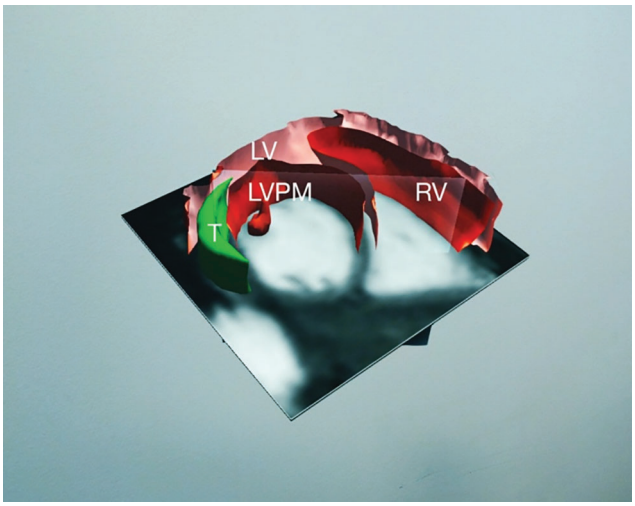


**Figure 2:** Overlay of the MRI image with 3D hologram projection. *T: tumor; LV: Left Ventricle; RV: Right Ventricle; LVPM: Left Ventricular Papillary Muscle*

During surgery, the same holographic 3D model was displayed in theatre to simulate the incisions and the surgical steps, in order to obtain the best and safest resection of the tumour edges (Fig. 3).

**Figure 3:** Intra-operative holographic 3D reconstruction to simulate the incisions and the surgical steps performed by the surgeons

Under cardiopulmonary by-pass and cardioplegic cardiac arrest, the patient underwent complete excision of the cardiac tumour without entering the LV cavity, as predicted by the augmented reality.

Histology exam confirmed that the tumour was a large fibroma. The girl was discharged on postoperative day 6$^{th}$, in good clinical conditions and with preserved ventricular function. No more episodes of rhythm disturbances were registered in the following 24 months.

## 3 Discussion

On October 2018 the United States Food and Drug Administration (FDA) authorized, for the first time, mixed reality medical solution HoloLens (Microsoft, Redmond, WA, USA) to be used as preoperative planning resource [7]. 3D analysis of CHD and holographic navigation quickly became promising tools for diagnostic and therapeutic applications and have since been used for education and simulation.

This advanced digital technology and the possibility to have a patient-specific virtual reality, represents a tangible improvement compared to the 3D printed models. In fact, it overcomes its limitation in term of materials selection, long processing times, and costs.

3D holographic technology is today common practice in the pre-operative evaluation of complex CHD in many specialized centres, where multidisciplinary teams try to offer a more “personalized” approach to the most complex patients [1–3,9–11].

Current clinical applications include minimally invasive cardiac procedures, mitral valve surgery, and trans-catheter interventional procedures [2,7–11].

The potential for the use of 3D-holograms in combination with different imaging modalities in CHD patients would overcome the limitations of each separate technique [6], developing the full potential of augmented reality.

In our case the co-registration with the overlay of functional and structural images from MRI and 3D holographic model was the key to success. To our knowledge, this is the first reported case of augmented reality applied to the surgical excision of cardiac tumours in paediatric patients.

**Ethics Approval:** The IRCCS San Raffaele institutional review board permitted use of retrospectively collected anonymized data for publication and waived informed consent for the case report.

**Funding Statement:** The authors received no specific funding for this study.

**Conflicts of Interest:** The authors declare that they have no conflicts of interest to report regarding the present study.

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