

Development of 3D-Printed Congenital Heart Disease Models Using Feasible Low-Cost Workflow

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Dear Editor

The publication on “Development of 3D-Printed Congenital Heart Disease Models Using Feasible Low-Cost Workflow - A Potential Tool to Improve Pediatric Cardiology Education¹” is hereby discussed. This study presents an interesting concept of using 3D printing technology to create low-cost models of congenital heart disease, a potential approach to support anatomical and pathophysiological learning. However, a significant limitation of the study lies in its evaluation of outcomes, which relies primarily on subjective opinions from participants. Only resident physician satisfaction questionnaires were used, without quantitative learning achievement measures such as pre- and post-test scores or comparisons with other teaching aids like 2D images or digital models. Furthermore, the sample size of the evaluators was not clearly specified, potentially limiting the reliability of conclusions regarding educational effectiveness. Additionally, the “100% agreement” rating on several issues may reflect social desirability bias.

Methodologically, there are limitations regarding the anatomical validity of the model. The modeling process uses data from CT scans combined with heart valve data from echocardiography using height mapping techniques, which may lead to errors due to the integration of data from two image sources with different resolutions and viewing angles. Moreover, the use of desktop 3D printers and low-cost materials may affect structural resolution, particularly for small

structures such as valve leaflets or trabeculations. The lack of quantitative indicators regarding dimensional accuracy or comparison with original imaging data, along with statistical analysis or testing for differences between models or learner groups, limits the interpretation of the results to descriptive levels only.

A reinterpretation of the study results suggests that low-cost 3D models are valuable not only for their anatomical realism but also play a crucial role as a tool for enhancing learning engagement. This engagement may be a key factor in learners’ perceived understanding of spatial structures. Creating a comprehensive set of models covering multiple CHD types may also facilitate comparative morphology learning, beneficial for developing clinical thinking skills. However, this effectiveness should be further investigated through experimental study designs comparing these models to standard teaching methods, such as digital 3D visualization or virtual reality.

Future discussion questions include: Do low-cost 3D models outperform digital media in the long term? What is the minimum resolution required for models to maintain educational value? How effectively can the use of these models impact communication with patients or families? Furthermore, could the creation of an open-source CHD model database help reduce educational disparities between institutions? This will be a key direction for the future development of this technology.

References

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Reply

Francisco Candido Monteiro Cajueiro¹Universidade de Pernambuco,¹ Recife, PE – Brazil**Dear Editor,**

We thank the author for their interest in our work and for the thoughtful comments regarding our study on the development of low-cost three-dimensional (3D) printed congenital heart disease (CHD) models.

Our study was conceived with a specific and clearly defined objective: to describe a feasible, reproducible, and low-cost workflow for the development of 3D-printed CHD models and to provide a shareable educational resource. In this context, the work was intentionally designed as a descriptive, “do-it-yourself”-style study, focused on accessibility and practical implementation rather than on quantitative validation or comparative performance analysis. We believe this distinction is essential for the appropriate interpretation of our findings.

The growing interest in 3D printing in cardiology has led to the development of highly sophisticated models with excellent anatomical fidelity, often relying on advanced software, multimodal imaging integration, and high-cost materials. While these approaches represent important advances, they may not be readily accessible in many institutions, particularly in low- and middle-income settings. For this reason, cost-effective strategies have been increasingly explored, demonstrating that simplified workflows based on open-source software and desktop 3D printing can still produce models with meaningful educational value.

Within this framework, the methodological choices adopted in our study (including the use of low-cost hardware, simplified anatomical representations, and alternative techniques for valve modeling) were deliberate and aligned with the intended purpose of the models. As explicitly stated in the manuscript, these models were not designed for clinical decision-making or surgical planning, but rather as educational tools aimed at improving spatial understanding, communication, and engagement among learners and non-specialist audiences.

The evaluation strategy was similarly aligned with this objective. Qualitative assessment by both expert physicians

and trainees was used to explore usability, clarity, and perceived educational benefits. While we acknowledge the inherent limitations of subjective evaluation and the potential for bias, these aspects were recognized and discussed in the manuscript. In early-stage educational innovation, such approaches provide valuable insight into user experience and real-world applicability.

We also recognize that additional studies incorporating quantitative validation, comparative designs, and long-term assessment of knowledge retention would further strengthen the evidence base in this field. These directions represent important opportunities for future research and were beyond the scope of the present study, which was primarily focused on feasibility and accessibility.

An important contribution of our work is the open sharing of the developed models through a freely accessible platform (<https://sites.google.com/view/3dpequenoscoracoes>), allowing replication, adaptation, and dissemination across different contexts. We believe that this approach may help expand access to educational tools in congenital cardiology, particularly in resource-limited settings, while contributing to the broader democratization of advanced educational technologies in cardiovascular medicine.

In addition, we would like to highlight a recent short editorial addressing the role of low-cost 3D printing in CHD education, which provides a thoughtful and balanced perspective on several of the issues discussed here.¹ We also refer interested readers to a related videocast interview that further explores the motivations and practical aspects of this initiative.²

In summary, our study aims to complement existing advances in 3D printing by demonstrating that meaningful educational resources can be developed using accessible methods. We appreciate the opportunity to clarify these points and to contribute to the ongoing discussion on innovative and inclusive strategies in congenital heart disease education.

References

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