Accurate 3D Prints for RVOT Interventions: A Quantitative Study

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Background

Three-dimensional printed models (3DPMs) are increasingly used in congenital heart disease for pre-procedural planning, but quantitative data about printer and material accuracy is lacking. We investigated the accuracy of 3DPMs of right ventricular outflow tracts (RVOTs) derived from time-resolved cardiac magnetic resonance angiograms (TR-CMRAs) to better define printer characteristics.

Methods

TR-CMRAs from 11 patients with RVOT lesions were collected. Images were segmented using Mimics (version 18.0, Materialise) and solid blood pool standard tessellation language (STL) files were created. Each RVOT STL was printed on 2 printers: a Z Corp 650Z (3D Systems) with ZP151 powder material (ZP151) and ZB63 binder; and a Projet 3510HD (3D Systems) with Visijet M3 Crystal (M3C) material. Standard post-processing was performed. The 3DPMs were then CT scanned at 0.5 mm resolution, and resulting DICOM files were resegmented to create derived STL files. The derived STLs were compared to the originals through overall size and geometric disagreement (1-Dice Similarity Coefficient) as a percent of volume. Comparisons were performed using Wilcoxon signed-rank and Kruskal-Wallis testing, with $p<0.05$ considered significant.

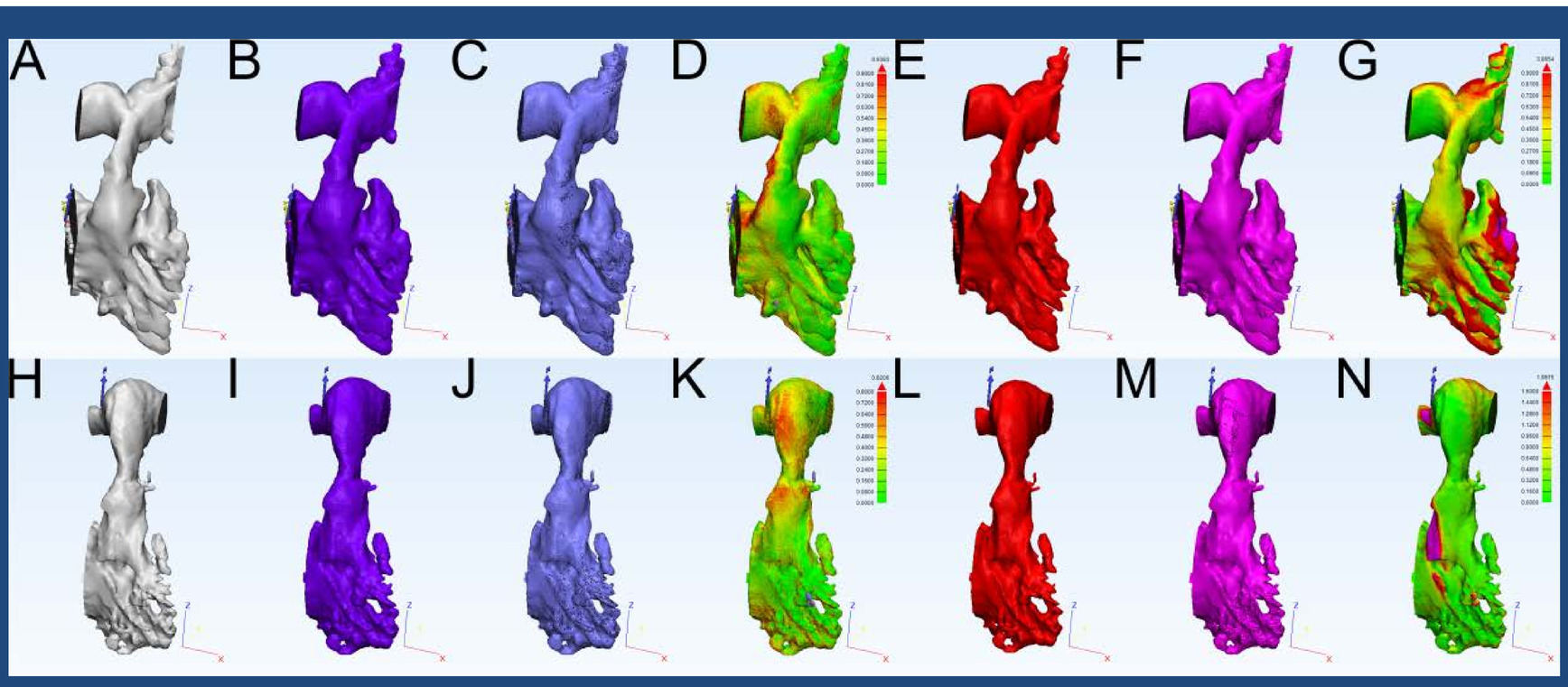

Figure 1. Example RVOT STLs and processing. A, H: Original RVOT STLs, segmented from time-resolved CMRAs. B, I: STLs created from CT scans of models made from ZP151. C, J: The union of the differences between ZP151 and the original STLs (1-Dice Similarity coefficient). D, K: Wall thickness heat maps of the differences between ZP151 and original STLs. E, L: STLs created from CT scans of models made from M3C. F, M: The union of the differences between M3C and the original STLs (1-Dice Similarity coefficient). G, N: Wall thickness heat maps of the differences between M3C and original STLs.

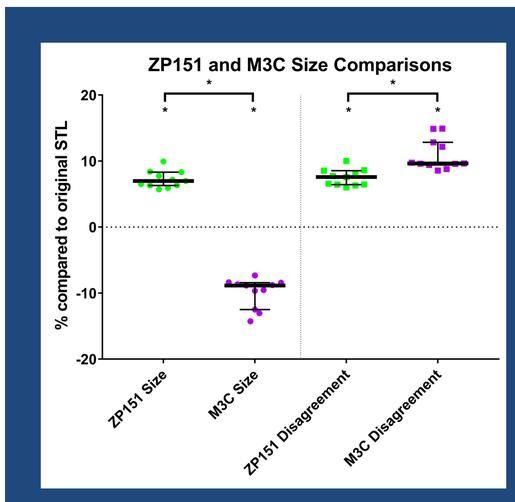

Figure 2. ZP151 and M3C size comparisons. ZP151 3DPMs were significantly larger, and M3C significantly smaller, than original STLs, as a percentage of volume. There was statistically significant geometric disagreement for both models, and was higher in M3C models compared to ZP151. * indicates p=0.001.

Results

ZP151 models had a significantly larger volume (median 7.0%, IQR 6.3 to 8.3%, p=0.001) and M3C were significantly smaller (-8.8%, -12.5 to -8.4%, p=0.001), compared to the original STLs, and their sizes were significantly different than each other (p=0.001). There was statistically significant geometric disagreement for both models (ZP151 median 7.6%, 6.4 to 8.5%, p=0.001; M3C 9.6%, 9.4 to 12.8%, P=0.001), and was higher in M3C models compared to ZP151 (p=0.001).

Conclusion

3DPMs may not always accurately represent the underlying patient anatomy, and differences exist as well between different printers. Care must be taken before using 3DPMs for pre-procedural planning in congenital heart disease. More studies to evaluate the consistency of printers, and the ideal method of printing, are required. Future directions include comparisons of the cross-sectional areas and diameters of the RVOTs across models.

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Conflicts of Interest
The authors report no conflicts of interest.

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