Virtual Reality for Image-Based Quantitative Assessment of the Aortic Root

Michael Lu[1], Ahmed Aly, Ph.D.[1], Robert Gorman Jr., M.S.[1], Michael Goodwin, M.D.[2], Lourdes Al Ghofaily, M.D.[2], Michael Stauffer, M.S.[3], Robert C. Gorman, M.D.[4], Alison Pouch, Ph.D.[1]

[1]Penn Image and Computing Science Lab, [2]Department of Anesthesiology, [3]Institute for Biomedical Informatics, and [4]Department of Surgery at the Perelman School of Medicine, University of Pennsylvania

INTRODUCTION

- Bicuspid aortic valve (BAV) is the most common congenital heart malformation and is responsible for more deaths/complications than all other congenital cardiac defects combined (Ward, 2000).
- BAVs can progress to stenosis, regurgitation, and/or aortopathy. Aortic root size, measured by pre-operative imaging, is one of several measurements critical to deciding the timing of surgery and the type of intervention performed.
- Conventional 3D quantification of the aortic valve apparatus in pre-operative transesophageal echocardiography (TEE) involves interaction with a volume-rendered image and cross-sectional planes on a standard computer display.
- ITK-SNAP is an open-source, multi-platform software application to segment structures in 3D medical images

OBJECTIVE

- Evaluate quantitation of aortic root dimensions in pre-operative TEE using VR. Examine the potential of VR for improving visualization, depth perception, and ease of measurement in 3D images through immersive interaction, augmenting surgical planning for structural heart disease.

METHODS

- Oculus Quest 2 VR headset (Facebook Technologies LLC) and SyGlass annotation software (IstoVisio Inc.) were used to trace the trace the aortic root at the level of the sinotubular junction (STJ) and left ventricular outflow tract (LVOT) in pre-operative TEEs of 5 trileaflet aortic valves and 5 bicuspid aortic valves.
- The following measurements were computed from the aortic root reconstructions: STJ area, LVOT area, and aortic root length (defined as the distance from the center of the STJ to LVOT).
- VR measurements were compared to those obtained by conventional segmentation of the aortic root in ITK-SNAP.

Figure 1: Aortic Root Anatomy

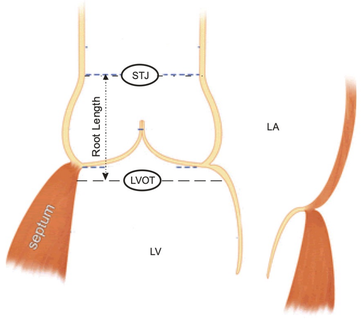


Figure 2: ITK-SNAP view of BAV TEE with STJ (pink) and LVOT (blue)

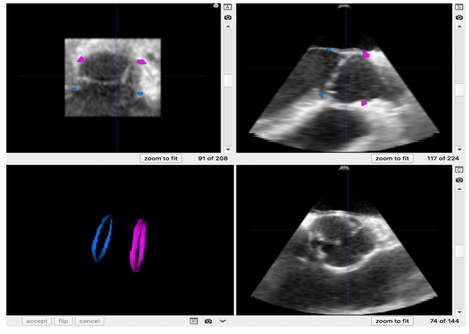


Figure 3: SyGlass VR view of BAV TEE with STJ (pink), LVOT (blue), and Reference Node of Mitral Valve (green)

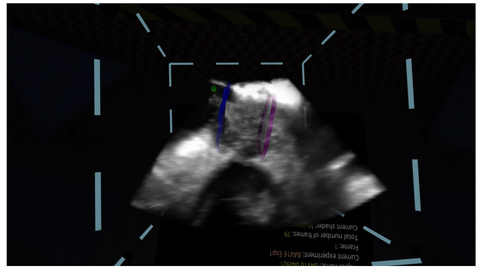
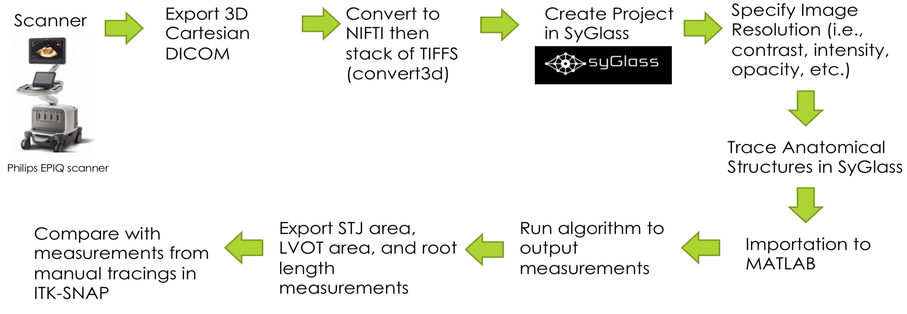


Figure 4: VR and Computer Setup

Figure 5: Simplified Pipeline of Methods



RESULTS

Figure 6: Aortic Root Geometry Area Comparisons in VR and ITK-SNAP

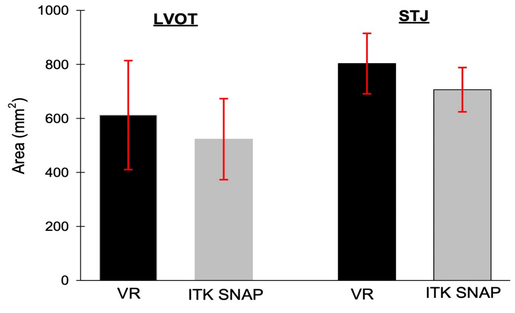
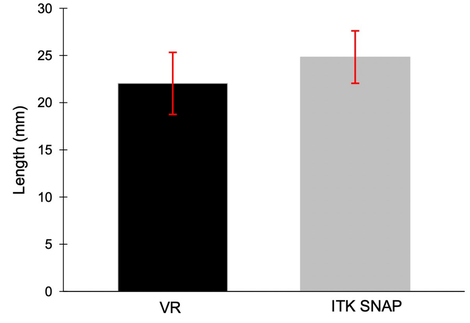


Figure 7: Aortic Root Length Comparison



- LVOT area measured using VR tended to be higher than that measured with ITK-SNAP (612.2 ± 282.9 mm2 vs. 523.0 ± 209.8 mm2, p = 0.024).
- Similarly, STJ area tended to be higher using VR than with ITK-SNAP (802.9 ± 156.4 mm2 vs. 706.2 ± 114.7 mm2, p = .0053).
- No significant difference was observed in measurement of aortic root length using VR and ITK-SNAP (22.0 ± 4.6 mm vs. 24.8 ± 3.9 mm, p = .091).
- The percent difference in measurements using the two methods averaged 12.6%.
- The average tracing time per image was 15 minutes.

CONCLUSIONS/DISCUSSIONS

- VR visualization and tracing of aortic root geometry shows potential for generating comparable measurements of aortic root dimensions from pre-operative 3D TEE to those from conventional methods via ITK-SNAP
- The average tracing time per image in VR was 15, suggesting efficiency in the process and ease of valve repair surgical planning.
- Future work will primarily focus on increasing the sample size, examining inter-observer variability, including additional landmark anatomical measurements, and investigating other imaging modalities such as CT/MRI.
- Geometric cusp height should be examined as another relevant measurement as it is a surrogate measure for quantifying how much cusp tissue is available for BAV repair

REFERENCES

- Liu T, Xie M, Lv Q, Li Y, Fang L, Zhang L, Deng W and Wang J (2019) Bicuspid Aortic Valve: An Update in Morphology, Genetics, Biomarker, Complications, Imaging Diagnosis and Treatment. Front. *Physiol.* 9:1921. doi: 10.3389/fphys.2018.01921
- Schäfers HJ, Schmied W, Marom G, Aicher D. Cusp height in aortic valves. *J Thorac Cardiovasc Surg.* 2013 Aug;146(2):269-74. doi: 10.1016/j.jtcvs.2012.06.053. Epub 2012 Jul 31. PMID: 22853942.
- Ward C. Clinical significance of the bicuspid aortic valve. *Heart.* 2000;83(1):81-5. PubMed PMID: 10618341; PMCID: PMC1729267.