Proceedings of the 2021 Design of Medical Devices Conference
DMD2021
April 12-15, 2021, Minneapolis, MN, USA

DMD2021-1014

INTERACTIVE COMPUTATIONAL MEDICAL DEVICE DEPLOYMENTS WITHIN VIRTUAL REALITY

Alex J. Deakyne
University of Minnesota
Department of Surgery, Bioinformatics and Computational Biology
Minneapolis, MN

Paul A. Iaizzo, PhD
University of Minnesota
Department of Surgery, Institute for Engineering in Medicine
Minneapolis, MN

ABSTRACT

3D modeling of anatomical features and medical devices are being used at increasing rates within the medical field. These 3D models allow for a wide variety of uses, such as educational or for medical device optimization. Next steps in such utilization are to perform computational and simulated device deployments within unique human anatomies. Such computational deployments have and will yield new perspectives and understandings relative to how given devices fit within the varied anatomies of varied patient populations. While these simulated device deployments offer many benefits, they are often time consuming to both develop and perform. Here, we present new functionalities to perform computational cardiac device deployments within virtual reality (VR). This functionality offers increased control of where the device is to be deployed, reducing the times required to perform computational device deployments in unique anatomical models.

Keywords: Virtual Reality, Computational Modeling, Simulation

1. INTRODUCTION

3D modeling has seen increased uses in the fields of medical device development and has been deemed beneficial when used for preoperative planning and clinical education [1]. Much of this is because these models retain all spatial 3D information of the original human anatomies. In addition, the FDA has committed significant resources into further supporting the utilities of computational modeling for medical device innovation; due to their significant cost-saving potentials [2].

When designing medical devices, studies are typically conducted by performing many device deployments within unique target anatomies. By deploying devices within varied anatomies, medical device innovators can gain invaluable insights relative to the device tissue interactions. These virtual device deployments yield insights into many crucial details about how the next generation device might be best designed; such as how the device fits within the volume of varied anatomies [3].

With the exponential increased uses of 3D modeling of patient specific anatomies, there exist opportunities to perform computational deployments of devices to understand optimal and sub-optimal device tissue interfaces. Computational and simulated deployments of devices within unique anatomies has already been performed for a variety of devices, such as pulmonary valve deployments and intracranial aneurysm stenting [4,5]. Previously, our lab has performed computational deployments of a variety of cardiac devices within several unique cardiac specimen models [6]. While these methodologies of computational device deployments we used were effective, it was often very time consuming. The process of correctly aligning a given device with the target anatomical implant site was difficult to do correctly using a mouse and keyboard on a computer. Often, numerous adjustments were needed before the device had been computationally placed in the correct site.

Here, we propose a methodology for performing computational device deployments within the Visible Heart® Laboratories' Virtual Reality platform [7]. With a generated 3D model of the device and anatomical model, in a Virtual Reality environment, the user can pick up the device with their controller and position as desired. The user positions the device by moving their controller which allows for increased maneuverability of the device compared to a mouse and keyboard. With this increased control, users can more easily perform endless computational device deployments within anatomical models.

2. MATERIALS AND METHODS

A 3D model of a Medtronic Micra^{TM} transcatheter pacing system (TPS) (Medtronic, Minneapolis, MN, USA) and anatomical human heart models were placed within a virtual reality environment in Unity (Unity Technologies, San Francisco, CA, USA) per the methodology of [7]. The third-party asset VRTK (Extended Reality Ltd., Evesham, United Kingdom) was imported into our Unity workspace. VRTK uses abstractions that allow for easier implementations of object interactions within VR. In order to interact with the Micra within the virtual environment, a VRTK interaction script was added to both the VR controller and the Micra within Unity.

Next, a custom collider was added to the Micra object in Unity. A collider is a set of coordinates that create a unique object/device mesh. A collider registers anytime an object is touched by another object in the virtual environment. This was a necessity since a user needs to be able to touch an object in order to pick it up. In this case, the collider was a capsule shape that surrounds the entirety of the Micra. We then added functionality that changed the rendering color of the Micra to light grey whenever the controller was touching the Micra collider. Feedback such as this was considered important to notify a user when they had appropriately grabbed an object within a virtual environment; since there is no haptic feedback.

FIGURE 1: A MICRA WITHIN A VIRTUAL ENVIRONMENT WHEN IT IS NOT BEING TOUCHED (LEFT) AND WHEN IT IS BEING TOUCHED BY THE VR USER (RIGHT).

In the example presented here, functionality was added that allows the user to grab the Micra by pressing the grip buttons on the side of the VR controller. Whenever the user was touching the Micra, pressing the grip buttons allowed them to pick up and hold the Micra. The Micra was attached to the controller precisely where the controller was touching it when the grip buttons were pressed. Once attached, the Micra will follow the controller wherever it moves within the virtual environment. This allows the user to navigate the Micra to any location within the heart and then deploy it. Whenever the user has the Micra at the desired implant site within the heart, the Micra can be computationally deployed by again pressing the grip buttons on the controller. A custom script was written so that the transform information (position and rotation) of the Micra is recorded whenever the Micra is deployed.

3. RESULTS AND DISCUSSION

Here we have utilized this system to perform many computational Micra deployments within multiple detailed human hearts, each with unique anatomies. Each heart model was obtained from the Visible Heart® Laboratories human heart library. To date, the utilized heart number, along with select information for each heart, is listed in table 1 below.

Heart Number	Gender	Age	Heart Weight (g)	Known Cardiac Medical History
HH0102	F	14	333	None
HH0229	F	44	394	Hypertension
HH0248	F	64	441	Hypertension
HH0311	F	20	161	None

TABLE 1: HUMAN HEART NUMBER AND RELEVANT INFORMATION.

In this study the Micra leadless pacemaker, was virtually deployed at various locations within the right ventricular of each heart. A collage of these deployments within these hearts are depicted in Figure 3 below. This developed methodology allows a user to quickly perform multiple computational device deployments within the virtual environment. For example, in our hands, each deployment was performed in less than one minute, allowing for many implants in multiple hearts to be completed in a short period of time. We estimate that it would take up to one hour to perform each of these same deployments when using a mouse and keyboard.

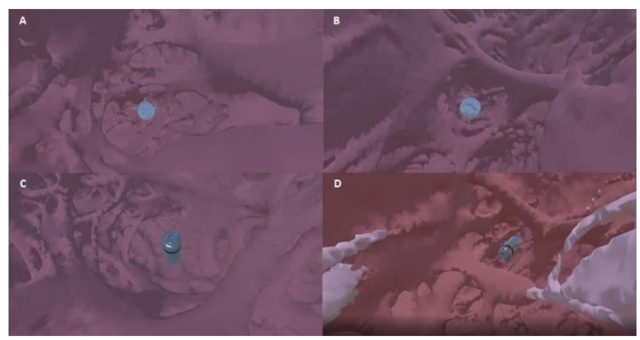

FIGURE 2: A COLLAGE OF MICRA PACING SYSTEMS THAT WERE COMPUTATIONAL DEPLOYED IN VR INTO THE RIGHT VENTRICULAR APEX OF HUMAN HEART MODELS (A) HH0248, (B) HH0311, (C) HH0102, AND (D) HH0229. THE VR USER IS OBSERVING THE COMPUTATIONAL DEPLOYMENTS WHILE STANDING IN THE TRICUSPID VALVE ANNULUS OF EACH HEART.

4. CONCLUSION

Computational modeling has seen increased uses in the medical field broadly. While performing computational device deployments has many benefits, to date, it has often been a time-consuming process; i.e., to correctly align a device within complex human anatomies at the desired implant locations. Here, we propose a methodology for performing rapid computational deployments of a leadless pacemaker within human heart models within a VR environment. Performing these types of deployments allows the users to gain important insights relative to theses device tissue interfaces at different deployment sites within a variety of human heart anatomies. Additionally, this provides one to learn how the different anatomies will attribute to a viable device deployment within a given heart.

ACKNOWLEDGEMENTS

Thank you to everyone at Medtronic and the Visible Heart® Laboratories that assisted with this project. We also would like the organ donors and their families for providing these critical research specimens for 3D model generations.

REFERENCES

[1] Jurgaitis J, Paskonis M, Pivoriunas J, et al. 2008. "The comparison of 2-dimensional with 3-dimensional hepatic visualization in the clinical hepatic anatomy education". Medicina (Kaunas) 44:428

[2] Morrison, T. M., Pathmanathan, P., Adwan, M., & Margerrison, E. 2018. "Advancing Regulatory Science with Computational Modeling for Medical Devices at the FDA's Office of Science and Engineering Laboratories". Frontiers in medicine, 5, 241.

[3] Omdahl P., Eggen M.D., Bonner M.D., Iaizzo P.A., Wika K. 2016. "Right ventricular anatomy can accommodate multiple Micra Transcatheter Pacemakers." Pacing Clin Electrophysiol. 39: 393-397.

[4] Capelli C., Taylor A.M., Migliavacca F., Bonhoeffer P., and Schievano S. 2010. "Patient-specific reconstructed anatomies and computer simulations are fundamental for selecting medical device treatment: application to a new percutaneous pulmonary valve". Phil. Trans. R. Soc. A.3683027–3038.

[5] Appanaboyina S., Mut F., Lohner R., Putman C., and Cebral J. 2009. "Simulation of intracranial aneurysm stenting: Techniques and challenges." Computer Methods in Applied Mechanics and Engineering. 198:3567–3582.

[6] Deakyne, A.J.; Iles, T.L.; Mattson, A.R.; Iaizzo, P.A. 2020. "Virtual Prototyping: Computational Device Placements within Detailed Human Heart Models." Appl. Sci. 10, 175.

[7] Gaasedelen, E.N., Deakyne, A.J. et al. 2021. "Virtual reality and visualization of 3d reconstructed medical imaging: Learning variations within detailed human anatomies." Proceedings of the Future Technologies Conference (FTC) 2020, Volume 3, pages 217–227, Cham. Springer International Publishing.