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THE MANY TECHNICAL CONTRIBUTIONS OF THE ANATOMAGE TABLE: SEEING ANATOMY DIFFERENTLY

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ABSTRACT

The Anatomage Table was originally marketed to medical schools as an anatomical training tool and to hospitals for preoperative planning. When Medtronic employees began to understand the power of the Anatomage Table for product development and data analysis, the uniqueness of how the table was utilized led to its many valuable contributions. The Anatomage Table has significantly reduced product development time with its ability to immediately render anatomical models in a way that allows the development team to evaluate outcomes and react with clear direction. It also reduces cognitive load for the users thereby expediting the interpretive process. The technology has become a tool to enhance research and training outcomes. This paper serves as an example to stimulate the use of this type of technology in similar applications. Hard data originating from controlled studies are not provided in this report due to the technology's early use at Medtronic and the proprietary nature of the development processes on which the technology was used.

Keywords: virtual anatomy, virtual fitting study, Anatomage Table

NOMENCLATURE

Anatomage Table	Virtual dissection table
PRL	Physiological Research Laboratory
DICOM	Digital Imaging Communications in Medicine
STL	Standard Triangle Language

1. INTRODUCTION

The Anatomage Table (AT) (Anatomage, Inc, Santa Clara, CA) was originally marketed to medical schools as an anatomical training tool and to hospitals for preoperative planning. Medtronic's Physiological Research Laboratories (PRL), a research and medical education facility, primarily acquired the table for similar reasons. It was noted quickly that the table added value also in research. When PRL staff and Medtronic study sponsors began to understand the power of the AT for product development and data analysis, the uniqueness of how we utilized the table led to its many valuable contributions. After initiating a confidentiality agreement with Anatomage, Inc., a collaboration began in a way that stretched both organizations to discover unrealized capabilities and boost the table's unique abilities. As a result of this collaboration the AT has evolved into a regularly scheduled asset for research studies and training events. Medtronic contributions led to the addition of an animated cardiac angiogram workflow in the latest table software update 7.0. The uniqueness of our work with the table caught the interest of the Anatomage company which led to an expanding awareness of medical device industry utilization. As such, Greg Sand, Training and Education Study Director at PRL, was invited to present Medtronic's table utilization at the annual Anatomage Table Users Group Conference in July 2020, before it was cancelled due to COVID-19.

What differentiates Medtronic's utilization from the standard user is our growing dependence on the table as a key tool in the product development process. Specifically, the table is being used guide discussions with clinicians on anatomical requirements for future implantable devices. Teams have used the table intraoperatively to evaluate the accuracy of cardiac

mapping systems through comparative analysis of mapping system models with the actual preplanned computed tomography (CT) model rendered on the AT. The table contributed appreciably to the development of silicone heart models used for training physicians and employees in ablation skills which has reduced the number of animals previously used for this training. In all these examples, the table has noticeably reduced product development time with its ability to immediately render models (measured in seconds versus hours) in a way that allows the development team to evaluate outcomes and react with clear direction.

2. MATERIALS AND METHODS

Given the unique and dynamic manner in which Medtronic has used this technology, there have not been controlled studies to compare standard development processes or reductions in animal use to those that utilized the described techniques. While the AT technology is highlighted in this manuscript, the described techniques and concepts are transferable to other similar technology tools. It is anticipated that controlled studies will be performed in the future to compare the performance of this technology with standard learning and development paradigms.

The AT is being used by multiple teams during the development process to evaluate a multitude of variables in design and anatomy. The utilization follows a consistent approach to collect imaging data and render it within the AT. In brief, imaging data is collected from animal models or human cadavers obtained through approved channels using PRL's CT scanner or using DICOM files sourced externally. DICOM files are then uploaded into the AT and processed according to the company's standard protocols. A full body CT scan can be fully rendered on the table in less than one minute. Once the data has been rendered, the team can view the anatomy and its interactions, import STL files of medical devices, or measure values between structures of interest.

In one use example, cardiac surgeons were invited to PRL by the product development team for a human factors study. The surgeons were asked to implant the novel and highly complex device system in a human cadaver, perform post-operative CT imaging of each model, and present a grand rounds explanation of their implant process using the unique and interactive tool to display and narrate their work, as shown in Figure 1. The incorporation of the AT contributed to reduced cognitive load for the physician advisors, thereby expediting the interpretive process.

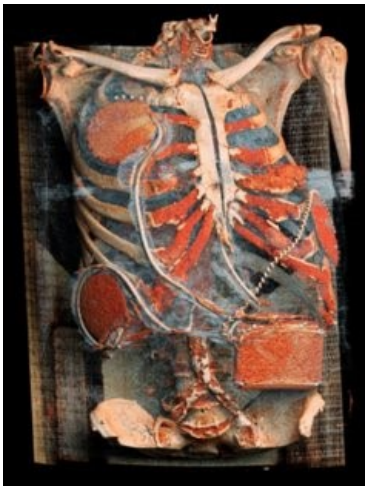

FIGURE 1. The post-implant rendering of a product under evaluation using the AT.

The medical education teams have realized the potential of the table and have integrated it into their training programs. For example, a single program has trained over 90 physicians and 60 field representatives using the AT.

Research and development teams have used the table to answer anatomical questions, confirm anatomical changes induced during model development, or look at organ interactions following implant by uploading DICOM files into the table. PRL developed a new preclinical model for the creation of aneurysms. CT scans collected at PRL were uploaded into the table to allow the study team to view the aneurysms from any angle, measure them, and refine their methods for model creation and therapy delivery.

The table is used in PRL education classes for employees. The table's broad library gives employees a real-world look at real patients with a variety of diseases. This knowledge allows them to design devices that will better serve the patient.

3. RESULTS AND DISCUSSION

The value that the AT brings to research and development initiatives and training is evident in the number of tables currently owned by Medtronic. In addition to the tables located in Minneapolis, tables have been acquired by Medtronic groups located in other geographies with additional interest in placing tables in various Asia Pacific and European locations. After PRL purchased its table, the interest in its capability spread rapidly and led to several corporate news stories and invitations to local and national events. The table has been featured at the Minnesota Science Museum Women in Science and Engineering events, internal conferences and product fairs, executive-level technology showcases, clinical investigator training programs, and several national conventions. This exposure has translated into additional innovative uses of this tool.

What differentiates Medtronic's utilization from the standard user is our growing dependence on the table as a key component in the product development process. PRL has

invested in a second table to meet the demands for its use. In all user groups and applications, the cognitive load is reduced for the user because the anatomical relationships are clearer and easier to understand rather than having to mentally reconstruct 2D images into a 3D mental image. This reduced cognitive load coupled with easily accessed images can contribute to reduced development times because procedures, tools, and devices can be better conceptualized with fewer iterations, as observed with next generation device development in product development sessions.

The contributions of the AT utilization at PRL are numerous and cover a wide range of areas including training curricula, workflow development, procedural development, and answering complex anatomical questions. Perhaps one of the most significant contributions is the table's ability to demystify the complexities of anatomy for development engineers who would otherwise find anatomy interpretation challenging. To interact with the table and custom build models to suit a specific need helps to expand knowledge and build confidence in product development and the implant approach. Other contributions include:

- Assessments of comparative anatomy between human cadavers and multiple animal models to guide product development or research approaches.
- Guide discussions with clinicians on anatomical requirements for future implantable devices.
- The table contributes to easy access of anatomical models stored in the vast imaging database at PRL which helps to reduce cadaver and animal numbers.
- Incorporating the table into training events dramatically enhances the learning experience which is seen in positive course evaluations and physicians asking how they can get a table for their institution.
- The resolution of the preloaded gross anatomy models in the AT provides visibility to fine anatomical structures that would not be visible with CT or MRI.
- The ability to import STL files of medical devices allows engineers to verify the fit and alignment and use conditions of devices within the anatomy and has guided them in implant procedure development.
- Using the AT has provided teams with a clear understanding of target anatomy and adjacent structures to enable accurate development of anatomical training models.
- The easy importation of DICOM files for rapid 3D reconstructions allows for pre-procedural planning and post-procedural evaluation.
- Anatomical questions concerning the location and relationship of structures are easily answered. Several teams have used the ability to select and remove organ system to identify the ideal route for implantation or identify optimal placement sites to deliver therapy.

Additional work is required to quantify the benefit this emerging technology has on training and development efforts through controlled studies.

4. CONCLUSION

In all these examples, the AT has been a valuable tool that reduced product development time with its ability to immediately render models (seconds versus hours) in a way that allows the development team to evaluate outcomes and react with clear direction. The incorporation of the AT into feedback sessions contributed to reduced cognitive load for the physician advisors thereby expediting the interpretive process. As a dissection tool, the table has allowed scientist, engineers, and clinicians to better understand the anatomical relationships in diseased and normal models, leading to more informed decision making. While formalized comparative studies are warranted, the feasibility of this technology to advance medical device development has been proven.

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REFERENCES

[1] None

