Interactive Surgical Depiction
for the Electronic Medical Record

by
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A thesis submitted to Johns Hopkins University
in conformity with the requirements
for the degree of Master of Arts

Baltimore, Maryland
March, 2017

ABSTRACT

Prior to the adoption of the electronic medical record (EMR), the written documentation of operations in patients' paper charts were frequently supplemented by a sketch by the surgeon. This image enhanced the understanding of the operation, especially for complex or re-operative procedures. With the recent transition to comprehensive EMR systems, traditional paper charts are seldom used and less accessible to clinicians. Surgeons currently lack a means to include a drawing in the patient record to aid in the communication of post-operative anatomy.

An accurate understanding of post-operative anatomy is critical to providing optimal care. Deprived of this knowledge, subsequent care providers expend considerable time and resources attempting to understand the patient's current anatomy. This is particularly true when the patient falls under the care of a different doctor or team, or is transferred from another hospital. Ultimately, the patient's safety is compromised, as they may be subjected to greater periods of time under anesthesia and unnecessary radiation dedicated solely to visualizing their altered anatomy.

No tools are currently available that allow a meaningful depiction of post-operative anatomy to be included in the medical record. This thesis explores the design of a digital interactive tool to enable surgeons to quickly and accurately document the patient's post-procedural anatomy in an image. This tool is unique in that it presents a pre-existing 3D model which the user may split, remove, move, and reconnect to represent changes to the patient's GI tract. Through an intuitive interface, the surgeon will manipulate a 3D model of normal anatomy to accurately depict resections and reconnections of bowel at appropriate distances and configurations and include elements such as drains, measurements, and annotations. The surgeon can then save the image with the post-operative note to follow the patient. As a part of the EMR, the image is available for viewing by practitioners responsible

for post-operative care and subsequent diagnoses and procedures, contributing to overall patient safety. Over thirty user interviews provided feedback vital to the design of the user interface and features list during the development stage of this novel resource.

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Introduction

Background and Problem Statement

In 2015, 96% of all non-federal acute care hospitals and 98% of large hospitals (defined as 400 or more beds) possessed certified Electronic Health Record (EHR) technology.[1] This was the outcome of the Health Information Technology for Economic and Clinical Health (HITECH) Act, included in the 2009 American Recovery and Reinvestment Act. HITECH provided $19 billion in incentives to hospitals and practices that demonstrated "meaningful use" of Electronic Medical Record (EMR) systems.[2]

While initially controversial, the widespread mandated use of EMR technology has improved the accessibility of health records across institutions by allowing for immediate communication of patient information between providers in different departments and specialties. Despite the inherent benefits of digital record keeping, a key adjunct has been lost: doctors are no longer able to include drawings in patient records. Paper charts allowed surgeons to easily include diagrams and drawings with the record (Fig. 1). According to surgeons interviewed, this practice was commonplace (and continues to be in several other countries).

In some specialties such as gastrointestinal (GI) surgery, the loss of the ability to include drawings with the operative note is of particular significance, as drawings and diagrams are a
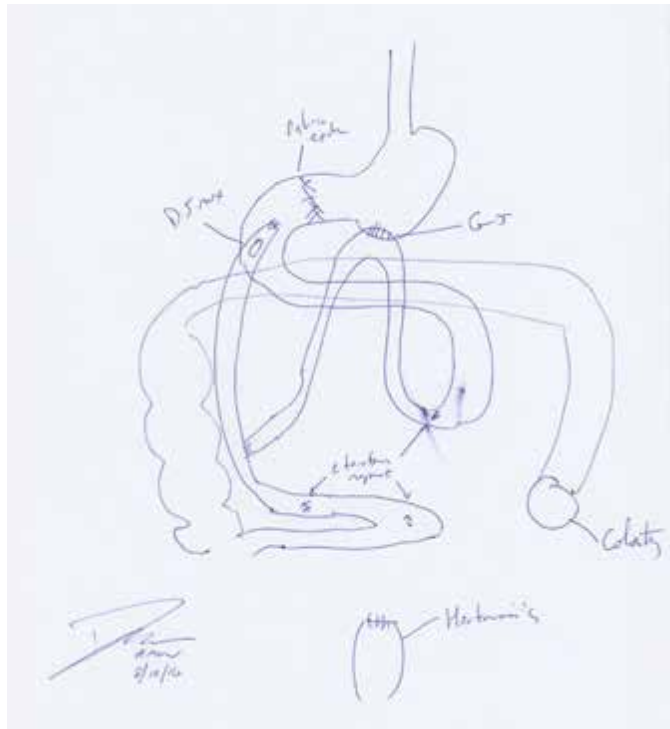
Figure 1. Sample operative note drawing by a JHH surgeon

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valuable asset in recording and communicating altered and complex post-surgical anatomy. An estimated 6.5 million GI operations are performed in the United Stated each year.[3] These largely include straightforward procedures such as appendectomies and simple bowel resections, which result in minimally altered anatomy of the GI tract. However, an estimated 20% of operations (1.3 million cases per year) are considered to be complex in nature. These cases carry an elevated risk of complication and often require re-operation.[4, 5]

The current standard operative note is dictated to reflect the flow of an operation, frequently emphasizing relevant points to optimize billing. It covers key aspects of the operation but is not required to provide any comprehensive information about resultant anatomy. Understanding of patients' post-operative anatomy is critical to providers of downstream care. Prior drawings often served as an adjunct to clarify this gap. Surgical intensive care unit (SICU) nurses benefit greatly from knowing the position of a surgical drain relative to the post-operative GI anatomy. For an endoscopist, an incomplete understanding of altered GI anatomy carries a greater risk of perforation due to uncertainty about the anatomy and potential confusion about the appropriate length scope to use. Similarly, interventional radiologists and surgeons should comprehensively understand the patient's post-surgical anatomy before a later procedure or operation. In all of these cases, there is a direct risk from intervention without a complete knowledge of the patient's current anatomy, or an indirect risk resulting from the means by which the physician seeks to understand the anatomy (such as increased time under anesthesia and increased radiation from imaging).

Since the implementation of the EMR, when known, the operating surgeon communicates this critical information directly to these members of the patient's care team by drawing on a white board or scrap paper, a temporary solution. In the words of one Hopkins interventional radiologist, "a bad drawing on a napkin is better than reading the post-op note."

Solution

This thesis explores the design of a digital interactive tool to enable doctors to visually document post-surgical GI anatomy. When the user writes the post-operative note, they are prompted to make an image. The user creates this visual operative depiction by manipulating a 3D model of normal GI anatomy to accurately reflect the alterations made during surgery. The user can also annotate the anatomic model with text such as notes, labels, and measurements, as well as drains, stomas, and various devices.

Once the depiction is complete, the surgeon digitally signs it, and a link is added to the operative note in the EMR. Including an image of the altered anatomy in the patient's record allows the image to be created only once and to be viewed by the entire care team immediately and repeatedly.

Enhancing communication with visuals

The audience of this program comprises the GI surgeons who use it to create the image and the providers of downstream care who view the image in the medical record. Visuals are a natural mode of communication and documentation for these audiences. Surgical training relies heavily on visuals, as observation and surgical atlases remain among the dominant learning resources. This holds true for other medical professionals, as resources for learning medicine and biology are largely reliant on illustrations and diagrams.

There are several inherent benefits in documenting operations visually. Images transcend language; therefore, visuals in a patient record can be understood in different parts of the world without translation. Dictation of operative notes is neither taught nor standardized. However, the quality of a visual depiction cannot be compromised by poor dictation skills. In general, images are definitive, consistent, and objective. There is no need for interpretation of an image, especially of a 3D depiction. Because this tool utilizes the power of a pre-existing model, no visual elements are created by the user. It is independent of the user's drawing ability.

The program designed in this thesis project has potential for several applications beyond documentation. Because the model is built in code, it is possible to extract data from these depictions on a large scale for research applications. There are significant educational implications as well. Such a program can be used to demonstrate intended anatomic outcomes before the procedure. This capability also has potential for surgical planning and competency testing.

Patient safety

This program is a communication tool in that it facilitates the transfer of critical information among healthcare providers. Enhancing communication within the care team helps to manage complications, reduce risk in interventional and diagnostic procedures, and improve patient safety. The primary beneficiary of this program is ultimately the patient. Particularly when the patient is transferred or moves to the care of a different physician, a clear understanding of the post-operative anatomy is crucial in safely managing their care.

Radiologic imaging is often utilized to determine anatomy resultant from previous GI operations. A visual depiction of an operation serves as a valuable supplement to the post-operative note. This depiction of the configuration of a patient's anatomy can aid significantly in interpretation of the imaging study and improve the accuracy of a reading. In many cases, a visual depiction is more effective than radiologic imaging in communicating altered anatomy. An image of a 3D model is definitive whereas common imaging modalities require further interpretation. For example, in order to understand where anastomoses reside in the small bowel using a CT image, one must trace the intestine through many layers. This is challenging at best, and sometimes impossible. Radiologic imaging is also limited by clinical and logistical factors such as time constraints, pregnancy, patients' ability to assume or maintain a position, and body mass. For instance, in CT imaging, bowel is more difficult to discern when it is packed closely together rather than separated by fatty tissue. Ultimately, avoidable imaging increases costs, use of resources, and the patient's exposure to radiation.

During surgical interventions, the patient may be subjected to increased time under anesthesia (and associated risks and cost) dedicated to identifying and understanding previously reconstructed anatomy through careful tedious dissection of adhesed bowel. In less invasive procedures involving endoscopy or interventional radiology, fluoroscopy is commonly utilized to the same end, exposing the patient to radiation.

Objectives and Scope of this Thesis Project

Due to the market potential, technical complexity, and large scope of this project, it has taken the form of a startup business. It was therefore necessary to identify early on the portions which would be undertaken as the thesis project. Many tasks were approached by or divided among the team as a whole, such as user interviews and market research. In general, the project is divided into the following four phases:

- Research potential competitors, and conduct user interviews.
- Design a minimum viable product with a user-friendly interface and necessary features to be introduced in a clinical setting.
- Collaborate with programmers and IT specialists to implement the tool and integrate it with EMR technology currently in use at Johns Hopkins Hospital (JHH).
- Evaluate the product in a pilot study at JHH.

Project management and specific tasks were the responsibilities of a designer and technical lead on the team (the writer). The objectives for the design of the product are as follows:

- Identify the necessary anatomic elements of the model; create a mockup model including textures and materials.
- Define the in-program functions and user workflows.
- Design a minimal user interface including icons, styles, and branding.
- Design a preliminary usability testing module using wireframes.
- Collaborate with programmers to implement the design in building a pilot product.

Materials and Methods

Pre-Accelerator Course and Subsequent Milestones

In 2014, Dr. David Efron, Chief of Acute Care Surgery at JHH approached the Department of Art as Applied to Medicine with an idea to design a means for creating a real time graphic depiction of post-surgical anatomy in the EMR. A proof of concept was developed by iSO-FORM, based in Ames, Iowa. This web-based module demonstrated the possibility of creating a program that allows a 3D anatomic model to be reconfigured by the user.

In July 2016, an opportunity arose to pitch the concept in the Johns Hopkins Medicine Technology Innovation Center's (TIC) shark tank competition. The project was awarded a top prize: full tuition toward the TIC business *Pre-Accelerator* course. Throughout this course (a six month weekly seminar), a business plan was developed, and extensive market research was conducted, enabling the project to begin the process of forming a startup company, the goal of Johns Hopkins Tech Ventures (JHTV).

The following milestones were achieved during the *Pre-accelerator* course:

- Lukas Manka, current MBA candidate at Johns Hopkins Carey Business School joined the team as a business consultant.

- A business pitch and presentation were developed and critiqued weekly by various judging panels.

- The program was given the name, DEPICTATION, a combination of the words depiction and dictation.

- Preliminary wireframes were created and reviewed.

- A "Business Model Canvas" was created (via LaunchPad Central).

- "User stories" were defined.

- Functional requirements were identified.

- The competitor landscape was identified.

- The features of the minimum viable product (MVP) were defined.

- Over 30 user interviews were conducted.

- A business model and "Go-to-Market" strategy were developed.

The *Pre-Accelerator* course concluded with a pitch showcase event attended by potential investors, JHH administrators, and a panel of judges. The final pitch, presented by Dr. Efron was extremely well received.

Following the *Pre-Accelerator* course, the following milestones were achieved:

- A potential team of developers were interviewed, and an estimate was received.

- An application was submitted for a Maryland Innovation Initiative grant (Appendix C).

- An application was submitted for a grant from the Louis B. Thalheimer Fund for Translational Research.

Brief Summary of the Business Model

Identifying the target audience

Image creators include the operative surgeons who add the pictorial representation of the operation they have performed to the EMR. This is the user group considered most carefully in the design of the program because they interact with all aspects of it directly. The program is intended to enable surgeons to communicate more effectively to providers of downstream care, thereby improving accuracy and safety. There are approximately 18,000 general surgeons in the United States[6] of which an estimated 6,500 perform complex GI surgery.

Image users or "readers" account for the downstream care providers who rely on or benefit from the information conveyed by the operative depiction. This can include nurses, surgeons, endoscopists, radiologists, medical trainees, and others responsible for subsequent care. Cumulatively, this accounts for tens of thousands of potential users for GI surgical procedures alone. This secondary user classification also includes patients and their families

who are interested in learning the particulars of the reconstructed anatomy. Ultimately, the patients are the primary beneficiaries of this new technology.

Market opportunity

While the program users (identified above) provide the market desire and demand for the program, the financial consumers are the platform providers. This group can consist of individual practitioners and private practices, though the more likely consumers would exist at the institutional level, such as acute care hospitals. There are 5,564 acute care hospitals in the United States,[7] with a 97% average adoption of certified health IT (EMR capability).[8]

User interviews (Stakeholder feedback)

Over thirty user interviews were conducted, the majority at JHH, and several with physicians at Indiana University, and the University of Texas. The comments and feedback from these interviews aided in shaping the design of the product from the earliest stages. User groups interviewed included GI surgeons, interventional radiologists, endoscopists, and SICU nurses. Stakeholders were asked when they began their careers to determine if including drawings in paper charts was common practice at any point during their careers. Most who had experience with paper charts mentioned this practice without prompting, and one mentioned missing this aspect of documentation after leaving the UK where drawing in charts is still common.

Interviews with potential users demonstrated a keen interest in the availability of the program. Though user apathy is a concern in any new program or application, users expressed an enthusiastic willingness to adopt this tool in regular practice. Furthermore, several potential users interviewed suggested additional applications for such a tool.

Identifying key competitors

Extensive analysis of the current market was conducted during the research phase of this thesis project. Potential competitor applications that include visuals largely fall into one

of two categories: 1) EMR and EHR programs and 2) educational software (Fig. 2).

Several small-scale EMR and EHR programs, intended for private practices, enable the user to include custom visuals or drawings to a minimal degree. In several examples, the user is provided with a default line drawing of a figure in anatomical position on which regions of concern can be indicated. Other programs include free-hand drawing tools comparable in functionality to Microsoft® Paint. These programs are limited by the users' drawing ability and the hardware available to them. Unless the practice owns digital drawing tablets, users would be limited to drawing with the computer mouse.

There is a large selection of educational applications featuring 3D anatomic models. While these are helpful resources in learning anatomy, the anatomy itself cannot be manipulated by the user to show pathology or surgical modifications. Educational applications also include simulation modules designed to help medical students and professionals learn and practice procedures. Within simulation programs, the user's action is confined to the pre-programmed steps of an operation.

Category	Product	Normal (realistic) Anatomy	Manipulatable Image	No Artistic Skill Required	Surgical Relevance	3D	EMR Embeddable
	DEPICTION	✓	✓	✓	✓	✓	✓
EMR programs	Modification Medicine	✓	✗	✗	✓	✗	✓
	Imatis	✓	✗	✗	✗	✓	✓
	Nextech	✓	✗	✓	✗	✗	✓
Educational programs	BioDigital Human	✓	✗	✓	✗	✓	✗
	Essential Anatomy	✓	✗	✓	✗	✓	✗
	Touch Surgery	✓	✗	✓	✓	✓	✗

Figure 2. Competitor matrix showing 1) EMR programs utilizing visuals and 2) educational programs featuring 3D anatomic models

Identifying the Minimum Viable Product

Because the initial concept presented by Dr. Efron had expansive potential for growth, every discussion seemed to reveal new insights about possible features and directions. The vision quickly broadened to include a more complete depiction of anatomy and more

features, becoming too large a project to undertake in a single iteration. It was therefore necessary to forgo the prospect of immediately creating a tool that could do everything envisioned, and to define a clear starting point, or minimum viable product (MVP).

Through a process learned from the TIC *Pre-accelerator* course, all plausible features for this first iteration were recorded on paper and sorted into five categories: launching the program, altering the model, annotating the model, signing and embedding the image in the EMR, and later reading the depiction. The features were then prioritized by necessity for the program to function. Features such as dividing the model were prioritized above features such as support for vasculature. A line was drawn across all categories, dividing the features of the initial iteration of the product from those which would be explored after the initial pilot was released. This feature list was later revised based on stakeholder interviews and ease of programming.

Identifying the Program's Technical Specifications

Platform

Much consideration was given to the choice of a platform for this tool. The program could potentially exist purely on the web, or it could be downloaded to the user's computer and run locally. The option to create the program on a "thin," or web-based platform seemed to have more merit initially. All software installed on operating room workstation computers must be tested against all other software to endure compatibility at all times. This complication could potentially be avoided by creating a program which runs only on the web browser. Additionally, Epic®, the EMR system in use at JHH, has a web browser built-in, so a web-based platform could potentially eliminate the need to launch other software. The program could allow for graphics to load in a web browser without the need for a plugin, so new software would not need to be installed on operating room computers.

However, after further research and discussion with programmers, it became clear

that a web-based platform had potentially serious drawbacks. Only the most current browser versions would be able to handle the necessary graphics for a manipulatable 3D model. Many of the hospital computers run older browsers and default to Microsoft® Internet Explorer which does not support functions common in other browsers. It would be more feasible to install a program on necessary work stations than to update all hospital workstations and compromise compatibility with software currently in use.

Ultimately, the option to build the program for a locally run, computer-based platform was selected. This would give the programmers complete control over the environment in which the model resides. Furthermore, the code could be applied to mobile and tablet applications, in addition to the desktop version.

Epic integration

The program is designed to function seamlessly with current EMR technology. When the user creates an operative note, the EMR program will prompt the user to create a visual depiction of the post-operative anatomy. When the program is launched, the patient's relevant information will auto-populate from the medical record. This is an important security measure to ensure that a busy user creates the correct image for the correct case. When the user completes and digitally signs the image, any added text will then import back into the operative note. Given the security measures in place to protect sensitive patient data, a team of Epic IT specialists at JHH were consulted to assist with the back-end communication between the program and the EMR software.

The Johns Hopkins Medicine TIC has committed to a pilot study of the program at JHH. Because Epic is the EMR system in use at JHH, it will be the first platform with which to integrate. Epic is the top EMR system in use at large academic medical centers, teaching facilities, and hospitals. The program will ideally be compatible with all major EMR platforms in the future.

Designing the Anatomic Model

With careful consideration of user interviews and necessary program features, it was decided that the first iteration of the product should include the following structures:

- Esophagus
- Stomach
- Duodenum
- Jejunum
- Ileum
- Appendix
- Ascending colon

- Transverse colon
- Descending colon
- Sigmoid colon
- Rectum
- Anus
- Biliary tree
- Pancreatic ducts

A draft 3D model (Fig. 3) was created for the purposes of planning, testing materials and textures, and communicating requirements to the programmers. Although this model is static, it was useful to discover potential challenges in implementation of the manipulatable configuration. It also provided a means to demonstrate the final program's capabilities in business pitches and grant applications.

The mockup model of the GI tract was created in Maxon® Cinema 4D. An emphasis was placed on limiting its construction to parametric components. In contrast with solid or direct modeling (3D models composed of points and polygons), parametric assets are constructed within finite parameters so that all aspects can be understood by CAD (computer aided design) software and distilled into code. This can be likened to the distinction between bitmap (pixel-based) and vector (point-based) construction of 2D images. This high degree of control through code is an important element in designing a model to be manipulated by the user.

Another important consideration in the design of all 3D assets within the program was the degree of realism to which the model adheres. While one might assume a general preference toward the most realistic model possible, it was important to be aware of the degree to which the "reader" would or *should* trust that the information communicated represents the reality of the case. For instance, if the image depicts a photographic degree of realism, the reader might assume that the length of bowel depicted is just as closely representative of reality.

On a continuum of style from diagrammatic to photographic imagery, the aesthetic selected falls closer to the diagrammatic end. A somewhat diagrammatic style improves the clarity of the final image; the inclusion of extraneous information or anatomy can distract or detract from the information the surgeon intends to communicate. For instance, the amount of small bowel depicted in the model is significantly diminished from reality, and all of the organs included are spaced out in a slightly "exploded" view so that any modifications to the anatomy can be better appreciated. The mesentery is not included in the model because it could detract from the main purpose of the model: to clearly depict the new configuration of a patient's GI anatomy.
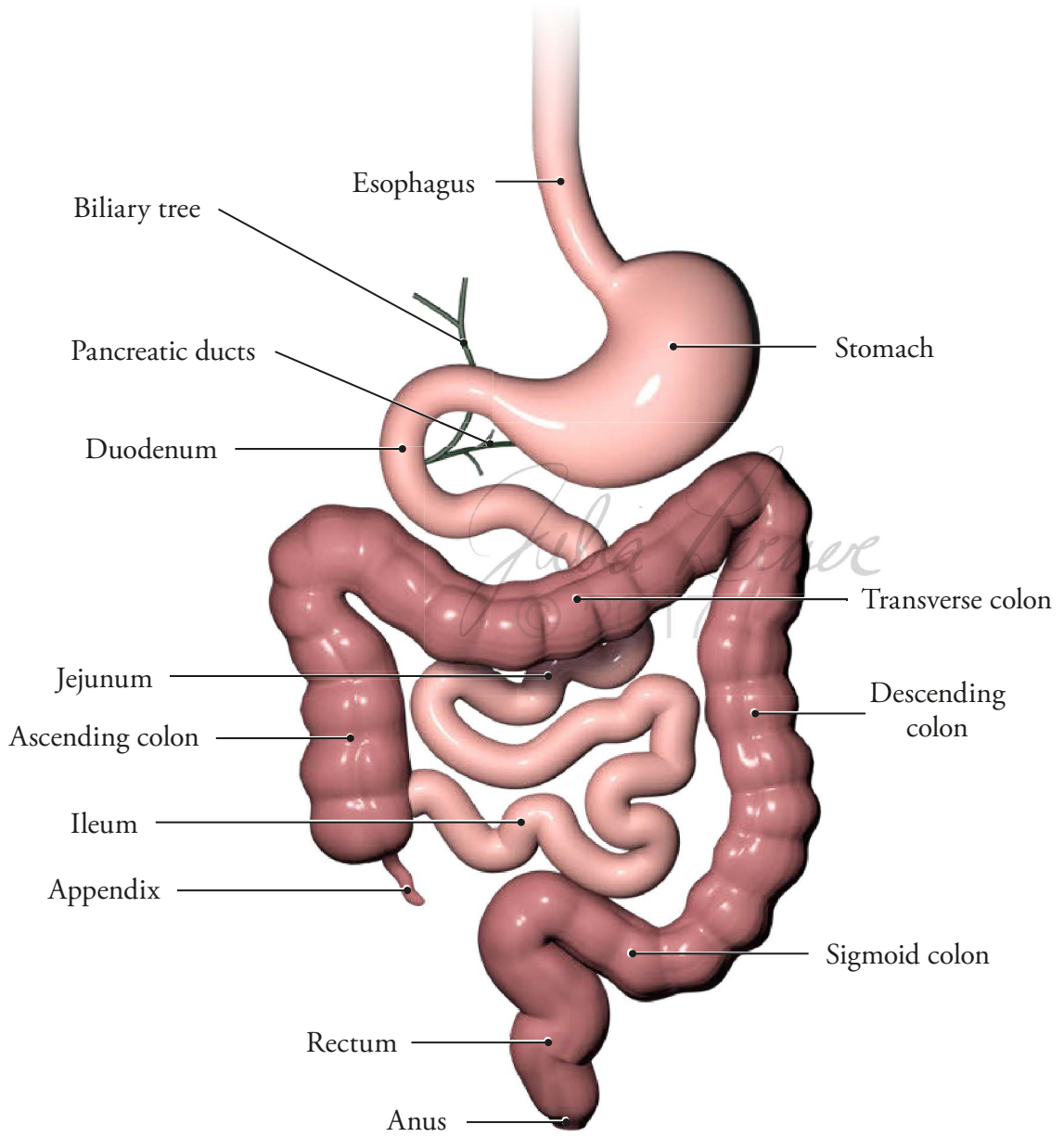
Esophagus

Biliary tree

Pancreatic ducts

Duodenum

Stomach

Transverse colon

Jejunum

Descending
colon

Ascending colon

Ileum

Appendix

Sigmoid colon

Rectum

Anus

Figure 3. Mockup model depicting unaltered anatomy

Defining the In-Program Functions

The functions of the tool were determined with stakeholder feedback in mind. They are divided into four categories: manipulation of the model, adding assets and annotation to the model, camera control and navigation, and completion of the image.

Manipulation of the model

The user can divide the model at any point. In the bowel, the model splits perpendicular to the tangent of the spline it follows (Fig. 4). In the stomach, the user can define the line along which the organ is divided (Fig. 5).

The user can remove (resect) a section (Fig. 6). The portion to be removed must first be selected. A selection extends in both directions to the nearest user-defined cut. If no division has been made by the user, the selection extends to the border of the organ.

The user can reconnect two free ends of the model (Fig. 7, A-F). Once a division has been made, 3D handles appear which may be dragged to reconfigure the model. When a handle (free end) is dragged toward another handle, they connect. The program then asks the user to indicate the configuration of the anastomosis created (end-to-side, side-to-side, end-to-end, etc.) The program asks the user whether the anastomosis is created using sutures or staples. Bowel can be positioned in a retrocolic or anticolic fashion (in front of or behind the transverse colon); the program provides an option to toggle between these two configurations because movement along the z-axis requires the additional step of rotating the model. Existing anastomoses may be modified or removed (Fig. 7, G-K; Fig. 8)

The user can undo and redo actions. The undo and redo functions only edit changes to the model (not to annotations or other assets).

The user can reset the model to normal anatomy. When the reset option is selected, a dialog box appears to confirm the action. If annotations or assets exist, the user has the option to 1) reset only the configuration of the model, or 2) reset the configuration of the model and delete all annotations and assets.

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The user can occlude a hollow portion of the model without dividing it (non-dividing staple or suture line), for instance to indicate pyloric exclusion.

The user can close a free end of the model without reconnecting it to another portion of the model, for instance a Hartmann's rectal pouch.

Adding assets and annotation to the model

The user can add the following assets to the model:

- Text, including annotations, measurement, and labels
- Drain or feeding tube (one end attaches to the model)
- Stoma (attaches to free end or loop of bowel)
- Ulcer and other pathological findings
- Mesh

An annotation is indicated by a number on the relevant part of the model. Each asset can be moved or deleted.

Camera control and navigation

The user can zoom in and out, rotate the model in 3D, pan (linear translational movement), and reset the camera view to the default frontal view.

Completion of image

The user selects a button to digitally "sign" the depiction. The image saves to the EMR in a read-only format.

The addition of a feature to "self check" the anatomy was suggested by several technical and business consultants. For instance, the program could display a caution dialog if the user creates a depiction of anatomy that is not clinically appropriate. It was decided that a feature to correct the user was not included in the initial product because it might hinder the user's ability to depict aspects of a case.

User Interface Design and User Experience Considerations

It was important to keep the audience in mind in every stage of the design process. The intended user demographic, surgeons, are extremely busy and therefore require a tool that is easy and fast to use. Concepts of user experience design were considered with an emphasis on minimizing cognitive load.

User interface (UI) design focuses on anticipating what a user needs to do and ensuring that the interface has the necessary elements organized in such a way that the user understands how to accomplish the action. User experience (UX) design focuses on maximizing usability, accessibility, and pleasure when interacting with a product or UI.

Function wireframes

Given the complexity of the program's functions, wireframes were created to plan each potential alteration to the model. These helped to answer questions such as "How would the user split the stomach?" or "How does the user reconnect loose ends of the small bowel?" and then to communicate each solution to the programmers. For each possible function, there was an intentional amount of redundancy, providing multiple ways in which the same end might be achieved. For example, a user wishing to resect a portion of the small bowel after selecting it would have three options: the user could click on the "resect" option that appears over the segment when it is selected, the user could select a trash icon, or the user could press the "delete" key on the keyboard. This redundancy is important because users represent a wide variety of competencies and backgrounds in using computers and a large generational range. In short, it was best to provide as many paths to the "right" answer as possible, rather than increase the learning curve by forcing the user to adhere to one path.

The wireframes depicting functions were created in Adobe® Illustrator CC 2017 as a series of line drawings with limited spot color. They combine aspects of wireframes (including functional components of areas on the page) with the chronology of flowcharts. To distinguish the model from the interface, organic components (the anatomic model)

were drawn by hand with a vector calligraphy brush, and the 3D handles and surrounding interface were created with the pen and line tools.

These functional wireframes were invaluable in communicating necessary functions of the program to the developers. Additionally, the wireframes helped in the design of the interface and to confirm or invalidate several of its existing components.

Designing the user interface

The UI design takes into account the users' diverse range of technical literacy. While it was important to adhere to existing conventions in 3D UI design, it was also necessary to recognize that a vast majority of users of this program have no experience interacting with 3D modeling interfaces.

Once essential functions were established, preliminary wireframes were created, taking into account the main functions the program performs. Wireframes are made for the purpose of arranging the functional elements of an interface into a preliminary layout. Early iterations depicted a linear series of functions a user might follow to create a simple operative depiction from start to finish.

Mockups of the interface were created using Illustrator. The interface, as well as the icons it contained, were converted to "symbols" in Illustrator. Symbols are objects or groups of objects that can be used multiple times throughout a design. When a symbol is altered, every instance of that symbol takes on the same change. This saved time and allowed for more freedom in design because it was not necessary to commit to a specific design element before duplicating it to every page. This process became instrumental in designing the user testing module.

Scalpel tool

No tool selected

Split

A

B

C
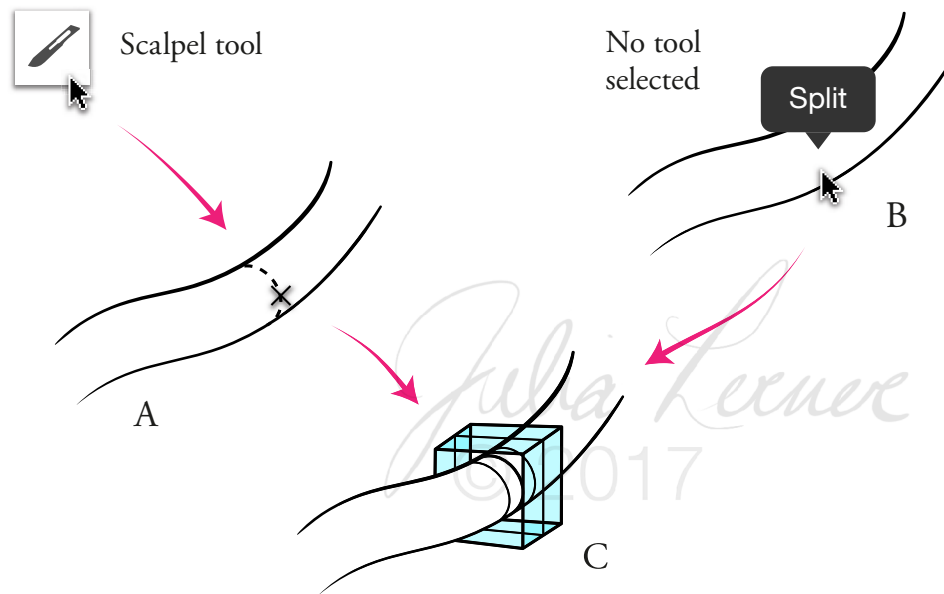
Figure 4. Function wireframes depicting division of the model. Using the scalpel tool (A) or selecting the "split" prompt (B); each result in a cut perpendicular to the tangent of the spline (C).

Scalpel tool

A

B

C
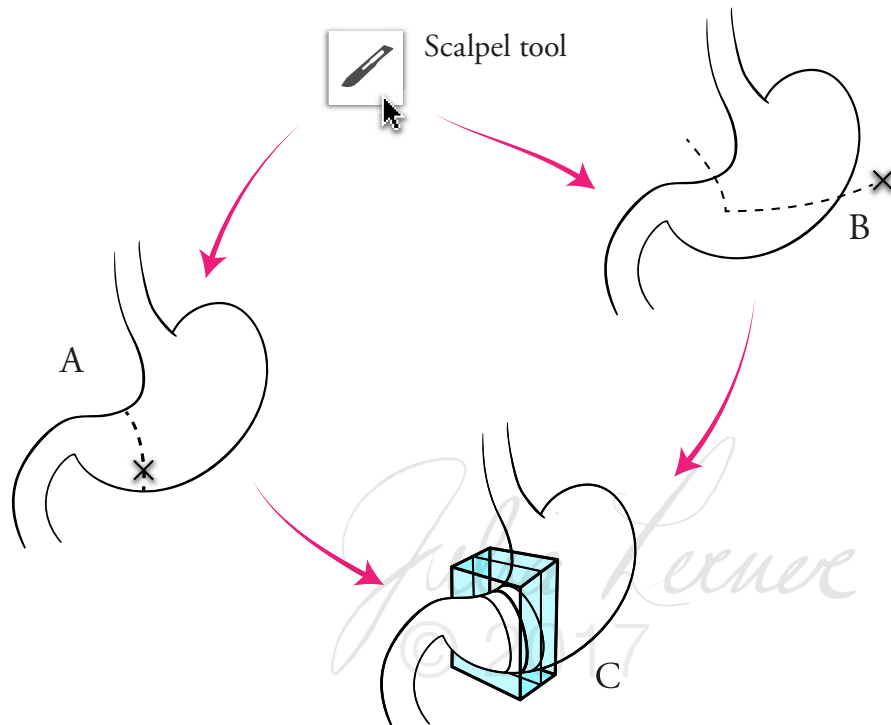
Figure 5. Function wireframes depicting division of the model at the stomach. Cuts are perpendicular to tangent of spline (A) or the user can click and drag to define the path along which to cut (B).

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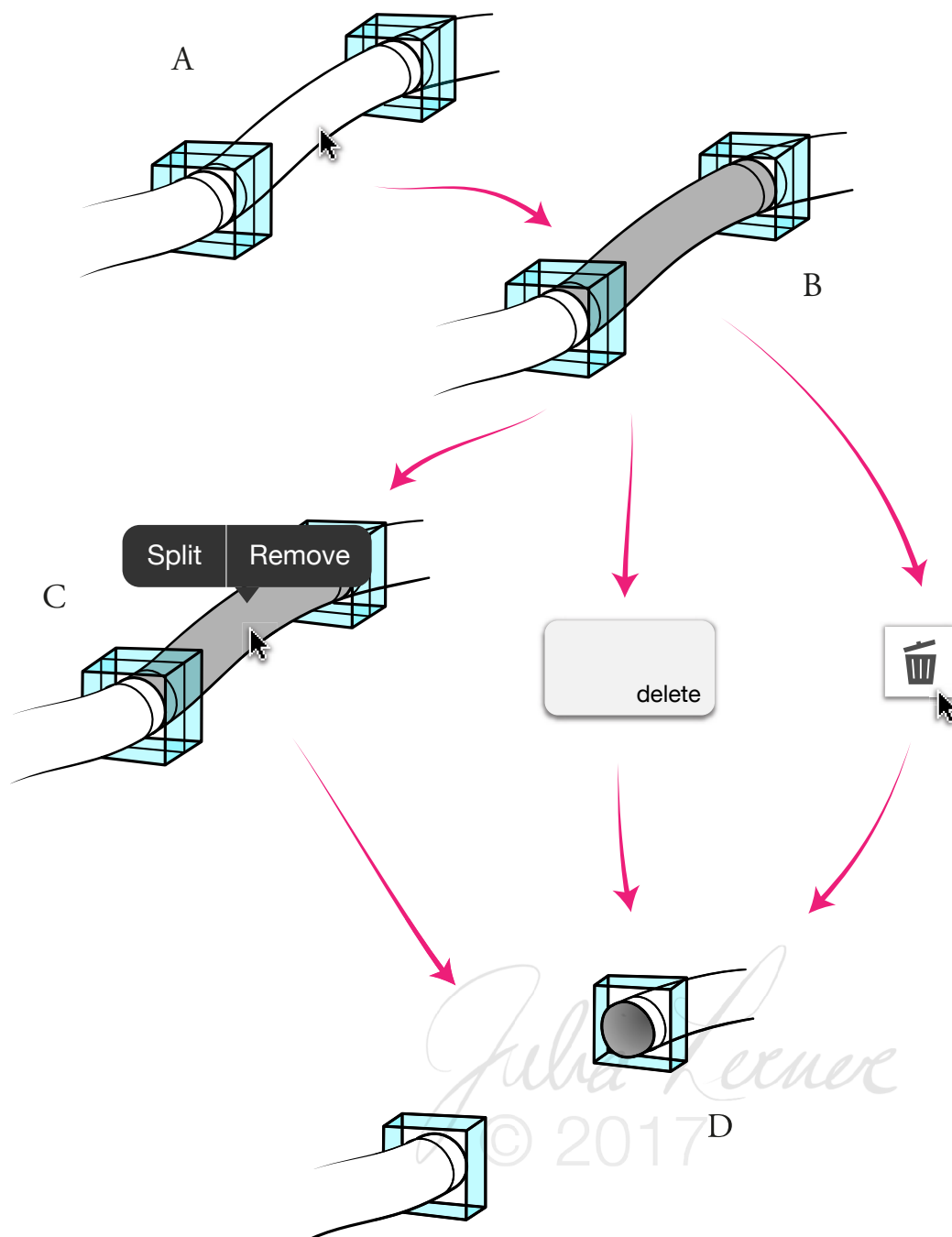
Figure 6. Function wireframes depicting selection and removal of a portion of the model. A segment may be selected (A) if two divisions already exist (B). A selected segment can be removed by selecting the "Remove" option above the segment, pressing the "delete" key, or selecting the trash icon (C). Free ends of the model are indicated by handles (D).
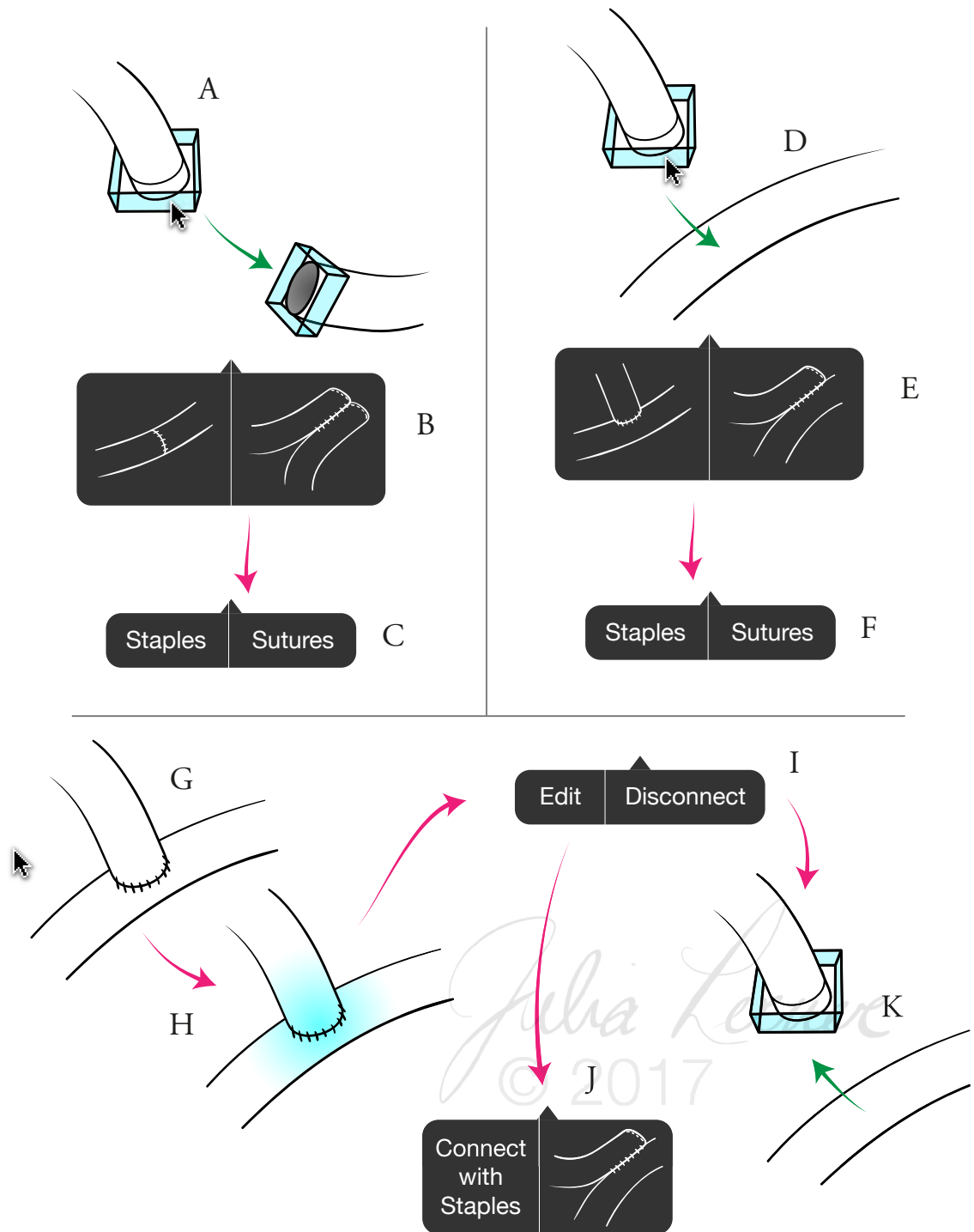
Figure 7. Function wireframes depicting connection of cut ends of the model (top) and the option for the user to revise a connection (bottom). The user can connect two free ends (A) or connect a free end to the side of the bowel (D). The user then selects the configuration of the anastomosis (B, E). Then the user is asked whether the anastomosis was made with staples or sutures (C, F). If the user wishes to modify an anastomosis (G), the anastomosis can be selected (H), and an option appears to "edit" or "disconnect" it (I). Selecting "edit" allows the user to modify the connection (J), and selecting "disconnect" breaks the connection (K).
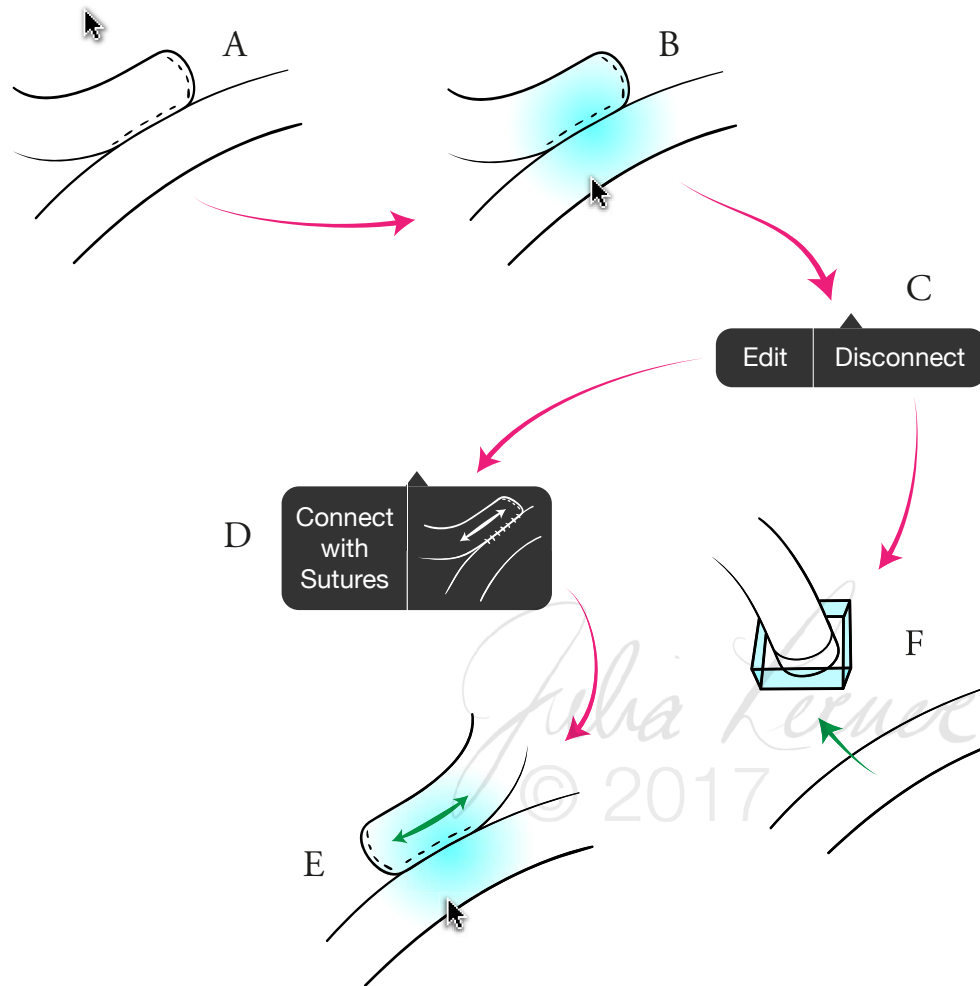
Figure 8. Function wireframes depicting an edit to a connection (continued). As in Figure 7, an existing anastomosis (A) may be selected (B). An option appears to "edit" or "disconnect" the anastomosis (C). Selecting "edit" calls an option (D) to modify the anastomosis (E). Selecting "disconnect" breaks the connection (F).

Elements of the user interface

Toolbar

The toolbar (Fig. 9) contains eight buttons which include icons and text labels:

- **Select** allows the user to select portions of the model

- **Divide** allows the user to split the model

- **Annotate** allows the user to attach text annotations to the model

- **Add Object** allows the user to attach objects such as drains, feeding tubes, stomas, devices, etc.

- **Center view** resets to the default camera view

- **Zoom in** increases the viewing size of the model

- **Zoom out** decreases the viewing size of the model

- **Reset model** clears any conformational modifications to the model
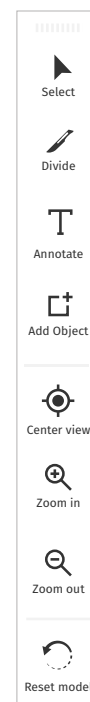
Figure 9. Toolbar *

Accordion menu

The accordion menu (Fig. 10) contains two sections:

- The "Information" section (open) contains relevant information about the case which auto-populates from Epic.

- The "Annotations" section (closed) shows a list of text notes the user has attached to the model. These notes are numbered and correspond to numbers on the model.
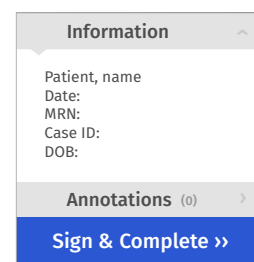
Figure 10. Accordion menu *

Mouse control instructions

The mouse control instructions (Fig. 11) appear when the "Information" button is selected.

Model viewer

In the center section (Fig. 12), the user can interact with the model.

* Text in these figures is not intended to be read at this scale.
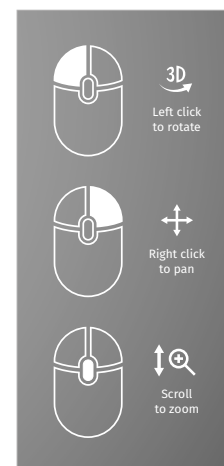
Figure 11. Mouse control instructions *
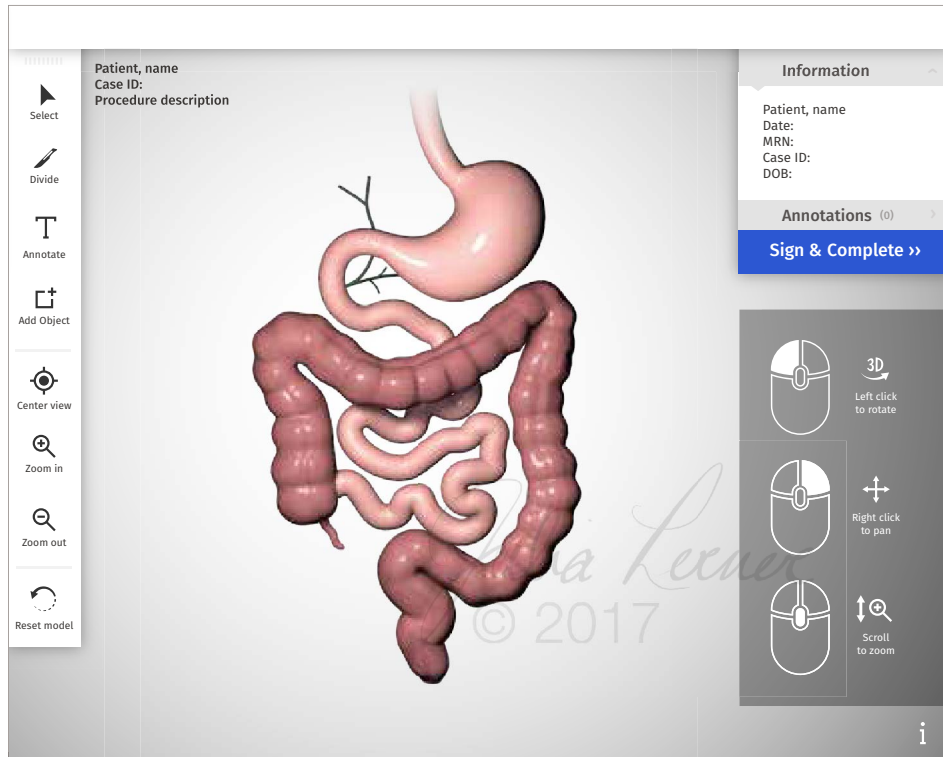
Figure 12. Mockup of the user interface before editing. Text in this figure is not intended to be read at this scale.
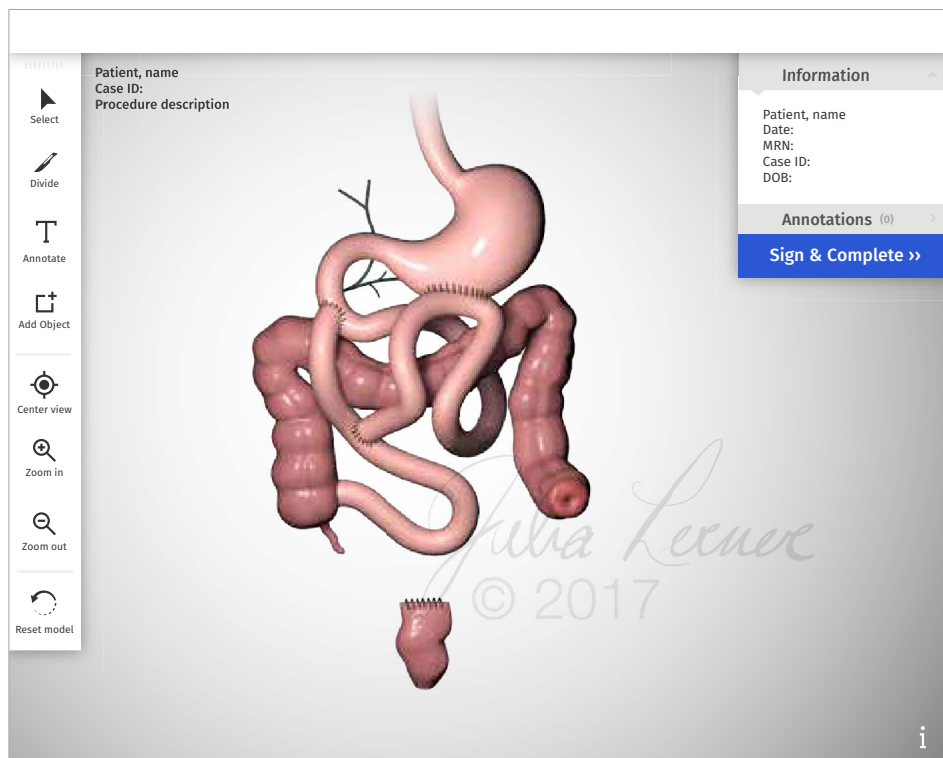
Figure 13. Mockup of the user interface after editing. Text in this figure is not intended to be read at this scale.

User testing

A series of modules were created for the purpose of user testing. Early user testing allows for immediate implementation of feedback and further evaluation of new components. User testing modules were designed with an increasing level of complexity of tasks.

The first round of user testing was designed with the goal of assessing interface and usability, preceding the implementation of the model. This round evaluates design and UX considerations, such as order of functions to complete a desired task, placement of buttons, willingness of the user to interact with buttons versus with the model directly, and clarity of symbols in interface icons. This round of testing was designed around very simple requests such as "How would you cut the model" or "How would you rotate the model?"

The first testing module was designed based on wireframes, or preliminary layouts of the functional elements of the interface (Appendix B). This included the interface design, incorporating a series of rendered images of the mockup model.

A script was created containing each task the user would be asked to complete and the desired responses. Flowcharts were created alongside the script to plan intended functions and desired user responses for each screen shown. These flowcharts helped to plan a few alternate pathways in which the course was not necessarily linear or functions are intentionally redundant. For example, the user might divide the tube by first selecting the "divide" tool from the tool bar or else by clicking on the model directly, calling up a dialog box asking if the user wants to "divide the model here."

These mockups were initially designed with the intent of creating the module in a slideshow (Apple® Keynote/Microsoft® Powerpoint) format and video recording users to observe their interaction with the module. However, it was decided that a web platform would allow for the possibility of using mouse-tracking. As an alternative to video recording users, which introduces observer bias, an online cursor-tracking tool called Mouseflow was used to provide video documentation of users' cursor movements and clicks. A simple

website was created, using flat images as backgrounds with floating invisible buttons over the corresponding active area which advanced to the next image in the sequence.

Conclusion

Past use of surgeons' drawings in paper patient records, coupled with the absence of a practical replacement, demonstrates the potential demand for this program. This novel technology provides an adjunct to the medical record that is independent from language and surgeons' drawing ability. In addition to the myriad of safety and efficiency benefits pursuant from improved communication, this program has significant implications in the areas of education, competency testing, and research. Further exploration into potential applications for this communication tool, throughout the design phase of the project, illuminated additional possibilities for future directions.

Following a pilot study of the initial GI iteration of this program, it can be expanded beyond GI surgery to other high volume specialties including vascular and orthopedic surgery. There is potential for future development of effective anatomic models for niche surgical sub-specialties as well. For instance, pediatric cardiac surgery and urology often involve a series of reconstructive procedures spanning several years of the child's development. Improved communication in such cases improves safety and outcomes.

The program also has significant potential in the growing area of personalized medicine. Making information about variant or altered anatomy clearly available in the record will encourage its consideration in treatment decisions. It also stands as a true representation of a specific patient's current state.

Additionally, current documentation practices in the military are often rudimentary, involving such practices as writing or drawing on bandages in the field or field hospital. In these extreme cases in which records exist temporarily, access to faster and more accurate methods of documentation can encourage more permanent and reliable record keeping.

The aim of this project was not only to regain a valued supplement to the record, but to improve upon it. The design and research completed for this tool provide a foundation on which it can grow as a product. The design of the program can set a high expectation for visual documentation that becomes the standard, and its successful, universal implementation can have significant impact in methods and expectations for future surgical documentation.

Asset Referral Information

Images and media resulting from the work of this thesis will be partially found at **julialerner.com**. Access to this media can be granted by contacting the author through this website or through the Department of Art as Applied to Medicine at The Johns Hopkins University School of Medicine at **medicalart.johnshopkins.edu**.

References

Cited References

1 Office of the National Coordinator for Health Information Technology. 'Percent of Hospitals, By Type, that Possess Certified Health IT,' Health IT Quick-Stat #52. dashboard.healthit.gov/quickstats/pages/certified-electronic-health-record-technology-in-hospitals.php. May 2016.

2 "Health IT Legislation." HealthIT.gov. USA.gov, 12 May 2016. Web. 11 Jan. 2017. https://www.healthit.gov/policy-researchers-implementers/health-it-legislation.

3 "Surgery statistics." Stanford Health Care (SHC) - Stanford Medical Center. March 16, 2015. Accessed October 19, 2017. https://stanfordhealthcare.org/medical-clinics/surgery-clinic/patient-resources/surgery-statistics.html.

4 McAleese P, Odling-Smee W. The effect of complications on length of stay. Ann Surg. 1994;220:740–744.

5 Dindo D, Demartines N, Clavien PA. Classification of Surgical Complication; a new proposal with evaluation in a cohort of 6,336 patients and results of a survey. Ann Surg. 2004; 240: 205–213.

6 "A Shortage of General Surgeons: Coming Soon?" Physician's Weekly. December 15, 2015. http://www.physiciansweekly.com/general-surgeons-shortage/.

7 AHA Hospitals. "Fast Facts on US Hospitals." American Hospital Association. December 01, 2016. http://www.aha.org/research/rc/stat-studies/fast-facts.shtml.

8 Charles D, Gabriel M. Searcy T. Adoption of Electronic Health Record Systems among U.S. Non-Federal Acute Care Hospitals: 2008-2014. ONC Data Brief No. 23 April 2015. https://www.healthit.gov/sites/default/files/data-brief/2014HospitalAdoptionDataBrief.pdf.

General References

- Cameron, John L., and Corinne Sandone. Atlas of Gastrointestinal Surgery. Vol. 2. Shelton, CT: People's Medical Publishing House, 2014.

- Krug, Steve. Don't make me think, revisited: a common sense approach to Web usability. Berkeley, CA: New Riders Pub., 2014.

- "The Maryland Innovation Initiative (MII)." Tedco. Accessed March 1, 2017. http://tedco.md/program/the-maryland-innovation-initiative-mii/.

Software References

- Unity (initially considered for 3D interactive capability)
  https://unity3d.com

- BioDigital Human
  https://www.biodigital.com

- Essential Anatomy
  http://applications.3d4medical.com/

- Visible Body
  https://www.visiblebody.com

- Touch Surgery
  https://www.touchsurgery.com

- Modification Medicine
  https://www.modmed.com

- Nextech
  http://www.nextech.com

- Imatis
  http://imatis.com

- Apple® Keynote

- Microsoft® Powerpoint

Appendix A

Manipulation of the model:
- The user can divide the model at any point.
  - If in the bowel, the model splits perpendicular to the tangent of the spline it follows.
  - If in the stomach, the user can define the line along which the organ is split.
- The user can remove (resect) a section.
  - The portion to be removed must first be selected. A selection extends in either direction to the nearest user-defined split. If no division has been made by the user, the selection extends to the pre-defined border of the organ.
- The user can reconnect two free ends of the model.
  - Once a division has been made, 3D handles appear which may be dragged to reconfigure the model.
  - When a handle (free end) is dragged toward another handle, they connect together.
    - The program then asks the user in which configuration the anastomosis is created (end-to-side, side-to-side, end-to-end, etc.)
    - The program asks the user whether the anastomosis is created using sutures or staples.
  - Bowel can be positioned retrocolic or anticolic (in front of or behind the transverse colon); there is an option to simply toggle between the two configurations because movement along the z-axis requires the additional step of rotating the model.
- The user can undo and redo actions.
  - The undo and redo functions only edit changes to the model (not to annotations or other assets).
- The user can reset the model to normal anatomy.
  - When the reset option is selected, a dialog box appears to confirm the action.
  - If annotations or assets exist, the user has the option to reset only the configuration of the model, or both reset the configuration and delete all annotations and assets.
- The user can occlude a hollow portion of the model without dividing it (non-dividing staple or suture line).

- The user can close a free end of the model without reconnecting it to another portion of the model.

Adding assets and annotation to the model:

- The user can add the following assets to the model. An annotation is indicated by an icon on the relevant part of the model.
  - Text, including:
    - Annotation
    - Measurement
    - Label
  - Drain or feeding tube (one end attaches the the model)
  - Stoma (attaches to free end or loop of bowel)
  - Ulcer and other pathological findings
  - Mesh
- Each asset can be moved.
- Each asset can be deleted.

Camera control and navigation:

- The user can zoom in and out.
- The user can rotate the model in 3D.
- The user can pan (linear translational movement).
- The user can reset the camera view to the default AP view.

Completion of image:

- The user selects a button to digitally "sign" the depiction. The image saves to the EMR in a read-only format.

Appendix B

Preliminary user testing module in which the user is asked to divide and remove a segment of bowel
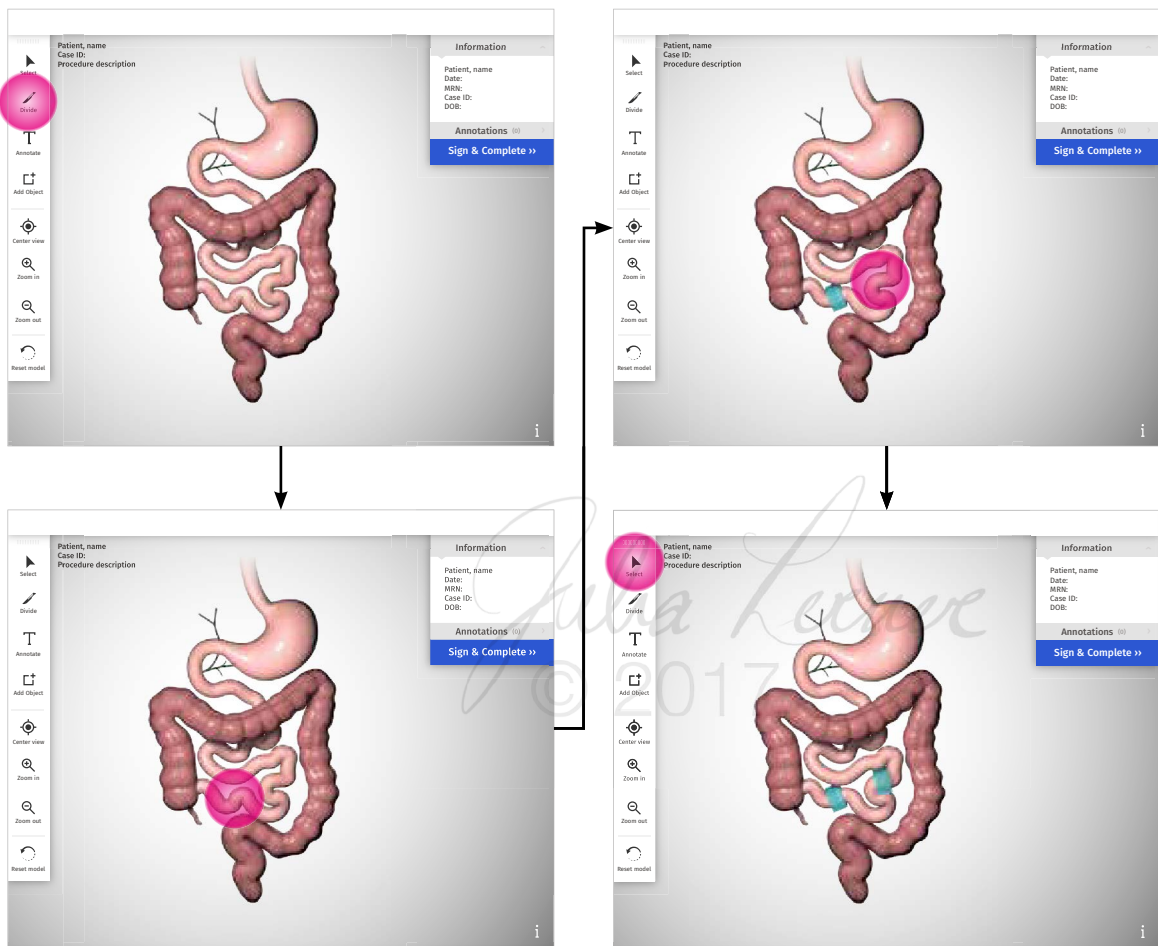
Continued, next page

Continued from previous page
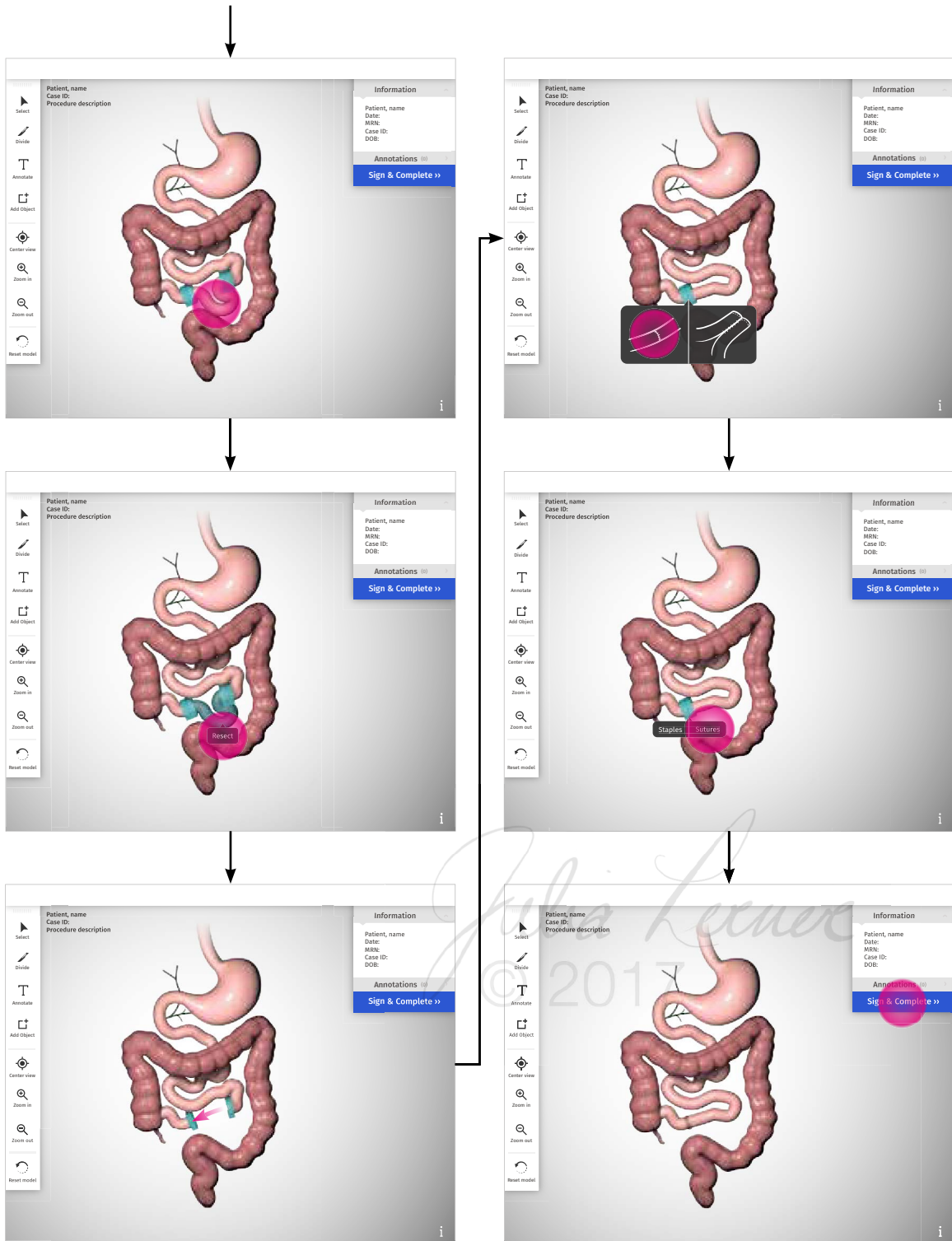
Appendix C

Maryland Innovation Initiative grant application

Johns Hopkins University

DEPICTATION: an Interactive Surgical Depiction
for the Electronic Medical Record

1.   Introduction

With the recent transition to comprehensive electronic medical record (EMR) systems, traditional paper charts are seldom used and less accessible to clinicians. While standard dictated operative notes are easily translated into the EMR, often visual representation enhances communication of non-standard or complex reconstructed anatomy.

We have designed a digital interactive tool to enable surgeons to quickly and accurately document the patient's post-procedural anatomy. Through an intuitive interface, the surgeon can manipulate a 3D model of normal anatomy to accurately depict resections and reconnections of bowel at appropriate distances and configurations and include elements such as drains, measurements, and annotations. The surgeon can then save the depiction to the electronic medical record to follow the patient. As a part of the EMR, it is available for viewing by practitioners responsible for post-operative care and subsequent diagnoses and procedures.

An accurate understanding of post-operative anatomy is critical to providing appropriate post-operative care. In the absence of this knowledge, subsequent care providers waste time and resources attempting to understand modified anatomy, ultimately compromising patient safety. According to interviews with GI surgeons, interventional radiologists, endoscopists, and surgical intensive care unit (SICU) nurses at Johns Hopkins Hospital (JHH), Indiana University, and the University of Texas, a significant amount of time and resources are dedicated to understanding reconstructed anatomy following an operation, primarily when the patient falls under the care of a different team or attending or is transferred from another hospital. This puts patients at risk, as they are subjected to greater periods of time under anesthesia and unnecessary radiation dedicated solely to visualizing their anatomy.

Ultimately, concern for safety drives the need for this product. Surgeons are concerned about proper record keeping to ensure that complications are avoided or managed effectively. With the advent of the EMR, the current standard for communicating reconstructed anatomy is incomplete and inefficient and is immensely time consuming for downstream care providers

to interpret. Preliminary investigations with 12 JHH GI surgeons tell us that we can estimate intraoperative time savings alone very conservatively at 30 minutes per case that could be eliminated entirely when altered anatomy is already known. Interviews with interventional radiologists and endoscopists yielded similar estimates. Note that these figures do not reflect avoided imaging time and resources or the added benefit to patients due to decreased radiation exposure. We will continue to validate these savings with the testing of the pilot product.

2. Technology Description, Status, and Intellectual Property

There are no tools available that allow post-operative anatomy to be included in the medical record in a 3D format. Current EMR software that emphasize visual documentation either allow the user to mark up a line drawing of a figure to indicate areas of concern or else offer the ability to draw freely with the cursor. These are limited solutions as drawing with a mouse is difficult and unintuitive, and in the unlikely event that practices invest in drawing tablets, the result is still limited to the drawing ability of the user. Our tool is novel in that it relies on a pre-existing 3D model which the user may split, remove, move, and reconnect to represent changes to the patient's GI tract.

In 2014, a proof of concept was developed, demonstrating the possibility of creating a program that allows a 3D anatomical model to be reconfigured by the user. This web-based program allows the user to select, remove, and reconnect portions of the model. It employs a model with simplified anatomy with no color and pre-existing break points. Throughout the Fall of 2016, we conducted over thirty user interviews which largely shaped our current product. Since December, we interviewed and selected a programming team and have been collaborating with them for an estimate for the initial product.

Intellectual Property

To facilitate the commercialization of this technology, we submitted our invention disclosure entitled "Interactive Surgical Depiction for the Electronic Medical Record" to Johns Hopkins University on Jan 25, 2017. It has been assigned JHU reference **#C14559**. The Johns Hopkins University Office of Technology Transfer (JHTT) Intellectual Property (IP) Management team is conducting a basic patentability search for this invention. This search will help us to establish different options for how to protect the technology further. The university is also considering other forms of intellectual property to support the commercialization of this technology. This will include copyright as well as trademarks. Preliminary patent searches have revealed no conflicts at this time with our specific application of this technology. Patents describing similar technology in this space fall primarily into three categories:

A. 3D anatomical educational resources with no capability for manipulation of the model by the user

B. User-end manipulation which is largely limited to ultra-advanced computer aided design programs for open-ended design (for example, modeling and animation) across all industries, rather than for directed modification of a pre-loaded anatomic depiction as our technology provides.

C. Protocols or algorithms for acquiring or extracting 3d data from imaging (such as CT scanning), translating to clinically or therapeutically relevant technology (for example custom vascular stents).

3.   Application of Technology as a Product/Market Assessment

We are seeking MII Phase I funding to construct the initial platform of the surgical depiction. This will concentrate on gastrointestinal (GI) surgery and anatomy. The initial version will be a computer based program allowing the surgeon to recreate the post-operative GI anatomy of the procedure performed, add relevant annotations, and sign and embed the image within the patient's electronic medical chart. The commercial product is anticipated to be offered as a personal or institutional subscription-based program. Future versions will expand the platform to afford depiction of surgical manipulation available to all parts of the human anatomy and all surgical disciplines. Future versions may also include the capability to begin manipulating a model from a previous depiction.

An estimated 6.5 million GI operations are performed in the United States each year; many are straightforward, anatomically simple procedures (such as appendectomies or simple bowel resections). However, about 20% (1.3 million) are noted to be complex in nature. These cases carry an elevated risk of complication and ultimately re-operation,[1,2] and as such are the most important cases to accurately depict.

The forces for market demand consist of several stakeholders:

Image Creators consist of the operative surgeons who add the pictorial representation of the operation they have performed to the EMR. While initially this is not expected to replace the dictated operative note, it serves as an adjunct to the medical record enhancing communication and therefore accuracy and safety. There are an estimated 18,000 general surgeons in the United States[3] of which 6,500 are estimated to perform complex GI surgery. The current standard operative note documents the flow of the operation, emphasizing relevant points for billing. It covers key aspects of the operation, but surgeons are not required to provide any comprehensive information about resulting anatomy. Our technology provides the surgeon a means to communicate this information in an image. The primary time savings are realized in downstream user procedure time.

Image Users are all those in the medical and surgical community that provide care to the patient and rely on or benefit from the added information derived from the operative depiction. Users include surgeons, gastroenterologists, radiologists, endoscopists, nurses and medical trainees. Cumulatively, the number of potential users would be in the tens of thousands for gastrointestinal surgical procedures alone. Improved communication and therefore increased understanding of post-surgical anatomy is realized in significant time and resource savings. Surgeons must review prior patient records and images recorded in the EMR to prepare for follow-up procedures. Our studies indicate an efficiency gain of conservatively, on average 30 minutes for each procedure assisted by DEPICTION graphical records.

Platform Providers consist of the entities that provide access to the program and the link to the EMR, and ultimately will be the payers for the service to aid in better utilization of their surgical staff. This could consist of individual surgeons or private practices. However, the most likely provider would be acute care hospitals. There are 5,564 acute care hospitals in the United States,[4] home to operating general surgeons, with 75% adoption of an EMR platform and 97% having the certified capability.[5] While the image creators and users provide the market desire, the platform providers are the financial consumer; it is anticipated that this would be through a licensing for use model. In a facility the size of Johns Hopkins Hospital, savings approaching 1,000 surgeon hours per year in both intraoperative and surgical prep time could be realized. That represents approximately $2.5M in resources that could be directed to other revenue generating activities.

In order to assure the key functions of the minimum viable product, including accurate anatomic depiction, appropriate additional documentation (annotation), and ease of use, the initial assessment of the product is to be performed at the JHH and linked within their medical record system, Epic. Following this pilot study at JHH we anticipate the project will be ready for venture investment to expand the platform to the other realms of surgery and anatomy.

Competitor Landscape

No major EMR vendor offers any capabilities similar to DEPICTATION. Two classes of vendors offer potential competition: smaller EMR programs and educational software. Some smaller EMR vendors offer limited functionality of a pre-loaded visual supplement to their notes. None offer the ability to manipulate the image in any meaningful way other than to annotate a static image using freehand drawing technology similar to Microsoft Paint. This requires technical and artistic skill from the surgeon to create an accurate and worthwhile depiction.

Several educational apps incorporating 3D models are emerging on mobile and web platforms. These are digital surgical atlases, allowing users to selectively view, rotate, and sometimes annotate 3D anatomical models, but most lack the capability for modifying the anatomy. There are also several simulation programs for surgical training in which the user's action is confined to the steps of the operation.

Category	Product	Normal (realistic) Anatomy	Manipulatable Image	No Artistic Skill Required	Surgical Relevance	3D	EMR Embeddable
	DEPICTATION	✓	✓	✓	✓	✓	✓
EMR programs	Modification Medicine	✓	✗	✗	✓	✗	✓
	Imatis	✓	✗	✗	✗	✓	✓
	Nextech	✓	✗	✓	✗	✗	✓
Educational programs	BioDigital Human	✓	✗	✓	✗	✓	✗
	Essential Anatomy	✓	✗	✓	✗	✓	✗
	Touch Surgery	✓	✗	✓	✓	✓	✗

4.   Commercialization Pathway and Risk Assessment

The successful development of a viable commercial product will require the following steps:

Milestone 1: Development of a Pilot Version for use by JHH Surgical Department

A preliminary pilot version will be available on operating room and surgeon office computer workstations and personal computers for documentation use prior to EMR integration capability. 25 GI surgeons will document their complex or re-operative cases (approximately 30% of their total cases). Data will be collected to validate estimations of user compliance, image creation time and ease of use. The program will undergo a series of usability and efficiency-focused revisions.

Milestone 2: Integration with EMR System at JHH (Epic)

Successful integration of the pilot version with EPIC will include storage, HIPAA compliance, and capability for auto-populating with pertinent information about the surgical case from the EMR. Following the initial usability trial and revisions and integration into Epic, DEPICTATION will be available for clinical use. During a three month pilot study, quantitative data from 40 surgeons will be collected from 150 complex and 250 routine GI cases and all consequent re-operations. Data from re-operative cases set against known averages will quantify time and resource savings, and patient safety impact.

Milestone 3: Development of Comprehensive DEPICTATION Platform

Concurrent with pilot testing during Milestone 2, DEPICTATION will be expanded to include other high-volume surgical sub-specialties (vascular, orthopedics) within the Epic platform, the top EMR platform in use at large academic medical centers, teaching facilities, and hospitals.

Milestone 4: Nationwide/Worldwide Distribution

This phase will focus on presentation and promotion at the American College of Surgeons Annual Meeting, direct demonstrations to surgical departments, promotion and attendance at conferences and regional meetings, and further marketing.

Milestone 5: Expansion into Niche Surgical Sub-Specialties

Development of effective anatomical models for niche surgical sub-specialties such as pediatric cardiac, ENT and plastics, pediatric urology, etc.

Risk and Mitigation

Maintaining first-mover advantage is critical to our commercial success. To ensure early adoption and popularity, expedited development of the DEPICTATION tool, which requires low artistic talent to create accurate and realistic images in matter of minutes, is critical to earning a strong market position.

Another area of risk is user apathy. Creating a depiction introduces an extra step in the workflow of busy surgeons. The use of the tool has to be simple and has to fit naturally in surgeons' workflow. It is critical that the tool will be accessible directly from the EMR where surgeons document their operations. We will educate surgeons about the 'Picture Superiority Effect,' which proves that individuals remember 5.5 times more information when it is presented as a combination of text and image rather than text alone.[8] Unanimously, surgeons interviewed report that they would use this tool to depict operations which leave the patient with complex anatomy; all interventional radiologists, endoscopists, and SICU nurses report that they would view the depiction if the surgeon created one. We seek to validate these statements with adoption of the pilot program.

The program itself will not store identifying patient information because it will only link to the patient EMR record using a unique identifier. To mitigate any HIPAA compliance risk, the program will be physically stored only on the network of the health system that uses it. Securing secondary funding for nationwide promotion and distribution of the tool and for expansion into various medical sub-specialties is also an area of risk. Our intention is to create a company allowing us to apply for further MII funding and other types of grant/seed funding.

5. Project Descriptions, Milestones, Detailed Budget/Justification

As mentioned in section 2, a proof of concept (POC) for the tool was developed to demonstrate the possibility of manipulating a 3D anatomical model of the bowel. This POC allows the user to divide and attach parts of the bowel only in predefined areas. A pilot version of the program allows users to divide organs at any point to depict accurate post-surgical anatomy. The tasks listed below, to be completed in 4-6 months, outline the milestones necessary for development and launch of a functioning pilot version.

Task 1: Wire framing, artistic design, textures & colors (Month 1-2, $0)

Development of complete wire frames, user interface, and artistic design of organs including colors and textures has been completed by Julia Lerner as a part of her graduate thesis.

Key deliverables: Layout wireframes incorporating all interface assets, anatomic mockup models

Task 2: Shape construction and manipulation code (Month 1-3, $52,140)

Tubular Bézier polygon constructor, organ construction, Bézier movement, Bézier intersection, Bézier stitching, and boundary constraints must be coded so that shapes can be manipulated in realistic manner. The user will have the ability to divide the model at any point (and in the stomach, along any path). They can also reconnect free ends of the model in virtually any configuration (end-to-end, end-to-side, etc.). Support for ability to annotate the model with text and devices will also be completed in this phase.

Key deliverable: Primary model construction

Task 3: Input code (Month 4-5, $20,400)

This phase of development will include flow logic and conditions, tool use, smoothing, filtering, data recording and tracking.

Key deliverable: Capability for manipulation of model by user

Task 4: Rendering code (Month 4-5, $20,250)

This phase will include integration of the model into the interface, HSV geometry rendering, 2D and 3D (openGL) graphics engines, and support for later EMR integration.

Key deliverable: Full support for Epic platform on program end

Task 5: Integration with Johns Hopkins Medicine (JHM) EMR system (Month 5-6, $4,000)

JHM Technology Innovation Center has agreed to assist with integrating the tool with the Epic EMR system so that it can be launched by surgeons from the post-operative note editing field. The signed operative depiction will be accessible by any subsequent care provider within the system.

Key deliverable: Full communication with Epic

Budget Justification

Task/Expense	Deliverable as outlined above		Comments
1. Product Design	Wireframes, mockup models		Contributed by Design Lead, free of charge
2. Shape construction/ manipulation code	Primary model construction	$42,150	Estimated by developers*
3. Input code	Capability for manipulation of model by user	$18,600	Estimated by developers*
4. Rendering code	Full support for Epic platform on program end	$15,250	Estimated by developers*
5. Integration with JHH EMR	Full communication with Epic	$4,000	JHM TIC
Tech Transfer (including patent cost)		$10,000	Copyright & trademark filing expenses, JHTV
Faculty salary support		$10,000	Project management
Subtotal			$100,000
I-Corps		$5,000	
Marketing & Branding		$5,000	Post-grad work
IT and HIPAA Security Consult		$5,000	
TOTAL including Commercialization Plan			$115,000

* Developers are Omar Ahmad and Promit Roy, Software engineers with JHHReferences

1. McAleese P, Odling-Smee W. The effect of complications on length of stay. Ann Surg. 1994;220:740–744.
2. Dindo D, Demartines N, Clavien PA. Classification of Surgical Complication; a new proposal with evaluation in a cohort of 6,336 patients and results of a survey. Ann Surg. 2004; 240: 205–213.
3. http://www.physiciansweekly.com/general-surgeons-shortage/
4. www.aha.org/research/rc/stat-studies/fast-facts.shtml
5. Charles D, Gabriel M; Searcy T. Adoption of Electronic Health Record Systems among U.S. Non-Federal Acute Care Hospitals: 2008-2014. ONC Data Brief No. 23 April 2015. (https://www.healthit.gov/sites/default/files/data-brief/2014HospitalAdoptionData Brief.pdf)
6. Macario, A. What does One Minute of Operating Room Time Cost? J. of Clinical Anesthesia, Vol. 22, 2010. Available online July 2013.
7. Shippert, R. A Study of Time-Dependent Operating Room Fees and How to Save $100,000 by Using Time-Saving Products. Am J. of Cosmetic Surgery, Vol. 22, No. 1, 2005. Available online July 2013.
8. Defeyter, M, Russo R, McPartlin P, The picture superiority effect in recognition memory: A developmental study using the response signal procedure. Cognitive Development. Volume 24. Issue 3. July–September 2009. Pages 265-273. ISSN 0885-2014. (http://dx.doi.org/10.1016/j.cogdev.2009.05.002)

Appendix D

Software used

- Maxon® Cinema 4D

- Adobe® Illustrator CC

- Adobe® Photoshop CC

- Adobe® InDesign CC

- TextWrangler (code editor)

- FileZilla (ftp client)

- MouseFlow (online cursor tracking)

- LaunchPad Central (Business Model Canvas)

Vita

Julia Lerner was born and raised on Long Island, New York. An early fascination with medicine and patterns in nature initially drew her to the field of scientific illustration. She completed her undergraduate studies at Arcadia University in Glenside, PA. At Arcadia, Julia majored in Scientific and Pre-Medical Illustration with a concentration in Pre-Medicine. Tutoring scientific subject matter throughout her undergraduate study reinforced her love of teaching, communication, and learning. She received her B.A. in Scientific Illustration and graduated early with departmental honors in December, 2014.

Julia began her graduate studies in August 2015, in the Department of Art as Applied to Medicine at The Johns Hopkins University School of Medicine in Baltimore, MD. During her time at Johns Hopkins, Julia developed an appreciation for 3D and interactive media which she was thrilled to explore through this thesis project. Following her first year, Julia was awarded the Association of Medical Illustrators 2016 Salon Award of Excellence in the student molecular/biological/life sciences illustration category. In 2017, she was awarded a Vesalius Trust research grant toward this thesis. Julia is currently a candidate to receive a Master of Arts in Medical and Biological Illustration in May, 2017.