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Urologic Sequelae Following Phalloplasty: An Explanation of Common Complications Following Transmale Gender Affirmation Surgery

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Urologic Sequelae Following Phalloplasty: An Explanation of Common Complications Following Transmale Gender Affirmation Surgery

by
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TABLE OF CONTENTS

Following Transmale Gender Affirmation Surgery

ABSTRACT

Medical advancement and societal acceptance in recent years has paved the way for gender affirmation surgery to become a growing subspecialty, with more transgender individuals seeking permanent methods to treating gender dysphoria. In a 2016 report from the American Society of Plastic Surgeons (ASPS), there had been a 20% increase in female-to-male gender affirmation surgeries over the past year, totaling over 1,700 surgeries (Schardein, 2020). Those seeking genital gender affirmation surgery, also known as 'bottom' surgery (Puckett, 2018), often have goals pertaining to the ability to urinate upright, with secondary goals relating to sexual penetration functions. Gender reconstruction procedures, such as phalloplasty, often have many urologic complications, or sequelae, that arise within the first few months post operation (Nikolavsky, 2017). These complications can have grave consequences if left untreated including sepsis, renal failure, etc., and overall decreased quality of life (Schardein, 2020). Thus, it is important to manage these urologic complications early.

In an effort to highlight the importance of the urologic complications of radial free forearm flap (RFFF) phalloplasty in transmen[1] patients, a short (3 minute) animation was created in two parts: (1)"Phalloplasty" and (2)"Urologic Complications". This animation would provide contextual background information for the RFFF phalloplasty procedure, as well as highlight the most common urologic sequelae associated with this procedure. It was created with the intention of being presented to fellow urologists and the medical community, and serve as a precursor to Dr.Nikolavsky's larger presentation regarding the use of various surgical techniques to repair the presented urologic sequelae on a case-by-case basis.

[1] Individuals who were born female but identify as being male.

INTRODUCTION

Sexual orientation and preference has become an evergrowing subject, with many adults identifying with genders other than their assigned sex at birth. According to Gallup[2], the United States has seen an increase in the number of people identifying as a part of the LGBTQ+ community from 4.5% in 2017 to 5.6% of the adult population in 2020 (Jones, 2021). Of those individuals within the LGBTQ+ community, 11.3% identify as transgender, equating to 0.6% of all US adults (Flores, 2016).

Puckett et. al. (2018) defined the term 'transgender' as a general term that can be used to describe individuals that feel they exist beyond the social binary construct. Said individuals can be transwomen, transmen, or gender nonconforming, also known as non-binary, agender, or genderqueer. They explained that gender dysphoria[3] is an experience among the transgender or gender nonconforming (TGNC) community. Not all TGNC individuals experience gender dysphoria, but individuals who do may seek to pursue a form of gender affirmation therapy.

Gender affirmation therapy refers to various medications and procedures that help align a person's body with their identifying gender (Passos, 2019). These can include hormone therapy, puberty blockers, mastectomy or chest reconstruction surgery, otherwise known as 'top' surgery, and vaginoplasty or phalloplasty/metoidioplasty, otherwise known as 'bottom' surgery (Puckett, 2018); which will be discussed later. Overall, the therapies can improve an individual's quality of life physically, psychosocially, and emotionally. Recent research on 'bottom' surgery has shown an overall positive effect on patients' well-being, self-esteem and sexual function (Passos, 2019). In particular, a common goal for transmen patients is the ability to urinate standing up. This can be achieved through various techniques of penile and urethral reconstruction.

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[2] Gallup is an American analytics and advisory company based in Washington D.C., known for its public opinion polls conducted worldwide.

[3] The DSM-5 terms as "clinically significant distress or impairment related to a strong desire to be of another gender, which may include the desire to change primary and/or secondary sex characteristics (psychiatry.org)".

In an attempt to visually depict the process of transmale gender affirmation surgery, a short (3 minute) animation was created. The animation was separated into two sections that: (1) described the surgical technique of a "tube-within-a-tube" used in RFFF phalloplasty, and (2) showcased the common urologic sequelae following transmale gender affirmation surgery. Dr. Dmitri Nikolavsky, Director of Reconstructive Urology from SUNY Upstate Medical University, encountered these sequelae in his cases of urethral reconstruction, utilizing various surgical approaches for repair, and utilized this animation in his presentation to fellow urologists and the general public on the importance of maintaining urethral pathways post gender affirmation surgery. This paper will discuss the creation process of the animation in detail and explain the scientific information presented in the animation.

SCIENTIFIC BACKGROUND

Transmale genital gender affirmation surgery (GAS) typically involves the reconstruction of the urethra, known as a *neourethra*, construction of the neophallus, and the construction of the scrotum (Nikolavsky, 2020). One conceptual challenge to this type of reconstruction is the creation of the neophallus, as there is no comparable anatomic structure in the female body (Lin, 2020). Utilizing the tissue on the body, the procedure must recreate a complex structure with functional and aesthetic properties.

There are two common types of procedures to create the neophallus: metoidioplasty and phalloplasty (Nikolavsky, 2017). Metoidioplasty involves using local genital tissue to create a phallus, scrotum, and neourethra (Nikolavsky, 2017). As mentioned earlier, a common goal for patients undergoing GAS is to be able to urinate standing up, with more than 98% of patients reporting this to be their main goal; a secondary goal is often sexual function (Nikolavsky, 2017). Metoidioplasty is the less invasive operation of the two, utilizing tissue from the labia minora to extend the urethra into two parts: the proximal native urethra and the distal neourethra; and utilizing tissue from the labia majora to create the scrotum and the shaft of the neophallus (Nikolavsky, 2017). While metoidioplasty provides patients with the ability to urinate upright, the lack of length and girth of the neophallus, as well as limited vasculature, hinders satisfaction of penetration function for sexual intercourse.

In contrast, phalloplasty utilizes distant tissue flaps for the penile and urethral construction (Akhavan, 2021), providing patients with an increased length and girth allowing for penetration during intercourse in addition to the ability to urinate upright. Patients report up to 85% sexual satisfaction, a 5% increase in sexual satisfaction compared to patients completing metoidioplasty (Akhavan, 2021). There are numerous tissue donation sites that can be utilized, such as the arm, thigh, and back. This project focused on the radial free forearm flap, the most common form of phalloplasty. The numerous nerves available for anastomosis, typically consistent anatomy allowing easy dissection, and thinner skin to construct the neourethra using a 'tube-within-a-tube' technique provide ideal conditions for phalloplasty (Akhavan, 2021); this will be discussed further. Phalloplasty utilizes the labia minora as well as the RFFF for the neourethra to be constructed in multiple parts. From proximal to distal, the urethra is elongated into these distinct sections: native female urethra, fixed urethra known as the *pars fixa*, anastomotic urethra, phallic urethra known as the *pars pendulans*, and finally the meatus at the end of the neophallus (Nikolavsky, 2017). The 'tube-within-a-tube' technique is utilized to create the phallic portion of the urethra and the external surrounding structure, the neophallus (Lin, 2020). Typically, the graft is extracted from the non-dominant forearm to ensure the use of the dominant hand post surgery. To allow urethral continuity, the ulnar portion of the graft is longer than the radial portion when extracted from the forearm. Forearm hair is typically removed ahead of surgery to ensure decreased risk of urethral obstruction from urethral hair (Lin, 2020). The radial artery, cephalic vein, and medial and lateral musculocutaneous nerves are kept intact to be anastomosed later (Lin, 2020). A 1 cm strip is de-epithelialized in between the radial and ulnar portions of the graft, medial to the radial artery (Lin, 2020). This step is crucial as it allows the two skin sections to be fully encased in vascular tissue, essentially serving as a connecting bridge between the two sections. To construct the form of the neophallus, the ulnar flap border is rolled over a foley catheter, previously inserted into the native urethra, 'skin-side-in' to form the phallic urethra. Afterwards, the radial portion of the flap is rolled over the constructed urethra in the opposite direction, 'skin-side-out' to form the shaft of the phallus, resulting in the 'tube-within-a-tube' structure. Various procedures are done in tandem with the construction of the neophallus in order to achieve the patient's desired goals. These include: hysterectomy[4], oophorectomy[5], vaginectomy[6], scrotoplasty[7], glansplasty[8], and possibly the addition of a penile implant for erection (Lin, 2020).

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[4] Hysterectomy is the surgical removal of the uterus.
[5] Oophorectomy is the surgical removal of the ovaries.
[6] Vaginectomy is the surgical removal of the vagina.
[7] Scrotoplasty is the use of the labia majora to create the scrotum, either with or without testicular implants.
[8] Glansplasty is the sculpting appearance of an uncircumcised tip of the phallus, allowing for a more aesthetic, 'normal-looking' penis.

There are numerous complications following RFFF phalloplasty. These can include: forearm hair causing urethral obstruction, possible tissue atrophy, urethral fistulas, persistent vaginal cavity, and urethral strictures (Nikolavsky, 2017). Urethral fistulas, persistent vaginal cavities, and strictures are the most common complications post phalloplasty due to the various vulnerability points of the procedure (Nikolavsky, 2017). According to Dr.Nikolavky, the common vulnerability points are at the anastomosis and ventral suture lines of the neophallic and neourethral anatomy. Urethral fistulas are the most common sequelae presented by phalloplasty patients with the fistula rate for RFFF phalloplasty ranging from 22-75% (Nikolavsky, 2017). They are spontaneous openings that occur between structures that, in this case, cause unwanted pathways for urine. Due to the limited vasculature of the urethral flap, as well as the possible decreased lumen, fistulas can, and often, occur at the points of anastomosis: between the *pars fixa* and native urethra, and/or between the *pars fixa* and the phallic urethra. As a result, urine streams can push their way through the suture lines. A common consequence of a fistula seen in phalloplasty patients is a persistent vaginal cavity. Distal obstructions, or possibly strictures, will cause pressurized urine to force its way through the ventral suture lines of the *pars fixa,* resulting in fistulas, and find its way into the obliterated vaginal cavity, preventing proper closure (Nikolavsky, 2017). Another common urologic sequelae are strictures, with the rate of incidence ranging from 25-58% (Nikolavsky, 2017). Strictures are unwanted closures of structures that obstruct the flow through pathways, in this case the neourethra. Although urethral strictures can occur at any point in the neourethra, they most commonly occur at the anastomosis of the *pars fixa* and phallic urethra (Nikolavsky, 2017). Other reports of the location of stricture formation stated that they occurred at the anastomosis portion of the neophallus 40.7% of presenting cases, with 28% reporting in the phallic portion, 15.3% at the meatus, 12.7% in the *pars fixa*, and 7.6% presenting in multiple portions of the neophallus (Nikolavsky, 2017). Ischemia, or lack of blood flow, is said to be the most common etiology for urethral strictures. Proper management of urethral sequelae is essential as it can have very grave consequences if left untreated, including chronic infection, sepsis, possible renal failure, and urine retention, all of which can have a great impact on the patients' overall quality of life.

Dr.Nikolavsky and team often encounter these urologic sequelae through patients complaining about the inability to urinate or other urinary complications. Careful patient evaluation is necessary to determine the extent of urologic sequelae in the patients and thus determine proper treatment, which also varies case by case. After ensuring the patient's urine is diverted properly, the team can utilize cystoscopy[9] and a retrograde urethrogram[10] to visualize the urologic sequelae within the neourethra (Nikolavsky, 2017). A "cut to the light[11]" technique is utilized to repair urethral fistulas, allowing flaps to cover the cut tissue and suture to close the fistula. Dr.Nikolavsky and team utilize a fasciocutaneous groin flap or a labial fat pad flap extracted from the previously constructed neoscrotum to cover the anastomosis of the fistula cut (Nikolavsky, 2017). Utilizing these tissue flaps can help decrease the risk of a fistula returning. Various surgical techniques are utilized to repair urethral strictures, typically grouped in single-stage or two-stage procedures. Single stage approaches to strictures can include cutting the meatus both ventrally and dorsally if the patient presents with hypospadias[12]. Other common techniques include the Heineke-Mikulicz[13] approach, and the excision and primary anastomosis (EPA)[14] approach. 2-stage approaches to urethral strictures typically involve placing a urethral graft into the incision of the stricture, allowing it to mature, typically months, and then afterwards the graft can be tubularized and the neophallus can be closed (Nikolavsky, 2017). In order for these approaches and techniques to be sufficiently understood, proper contextual information of phalloplasty and its subsequent urologic sequelae must be obtained prior to the presentation of how to utilize these approaches.

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[9] A procedure which utilizes a small camera called a cystoscope to look inside the bladder (Mayo Clinic, 2021).
[10] A diagnostic test visualizing the urethra through the use of x-ray imaging (Urology Care Foundation, 2022).
[11] Dissecting the fistula towards the light of the cystoscope.
[12] Hypospadias is an occurrence where the urethra extends past the tip of the phallus.
[13] In the Heineke-Mikulicz approach, the strictures segment is cut longitudinally, revealing a 'vertical' cut, and then sutured together transversely, resulting in a 'horizontal' suture line in order to increase the size of the urethral lumen (Nikolavsky, 2017).
[14] In the EPA approach, the structure is cut away, and the healthy tissue is then anastomosed together. This method cannot always be done due to lack of tissue mobility depending on the structure site (Nikolavsky, 2017).

THE BODY OF WORK

OVERVIEW

The work completed for this project consists of a short (3 minute) 3D animation divided into two parts: (1) ”Phalloplasty”, and (2) “Urologic Complications”. Part one depicted a detailed explanation of RFFF phalloplasty utilizing the ‘tube-within-a-tube’ technique, and part two showcased the urethral complications that arise post operation, which Dr.Nikolavsky and his team repair using various procedures in their current and ongoing research of urologic sequelae. This animation is intended to serve as a precursor to the presentation of surgical techniques utilized by Dr.Nikolavsky and his team to repair urologic sequelae; it will be linked to articles for the urology medical community and fellow colleagues, and can be used as a resource for the general public. The 3D narrated animation provided viewers with an understanding of the urologic sequelae that often arise post phalloplasty. This provides contextual information about the case-by-case repair of those sequelae as they are presented to Dr.Nikolavsky and team.

GOALS OF THE ARTWORK

1. Create – a 3D narrated animation that briefly explains the steps of radial free forearm flap phalloplasty utilizing the tube-within-a-tube technique, and the common urologic sequelae that can arise after phalloplasty.
2. Demonstrate – the process of phalloplasty, breaking down the steps needed to complete the procedure, as well as showcase the procedures that are done in tandem with phalloplasty for female-to-male transgender patients.

3. Emphasize – the common urologic sequelae that often present post phalloplasty, and demonstrate how they can arise.

ILLUSTRATION PROCESS

The illustration essential for this project was the sagittal cross section of the neophallus anatomy. The objective of this illustration was to accurately depict the anatomy of a transmale patient post phalloplasty, emphasizing the urethral reconstruction, the obliterated vaginal canal and perineum, removal of the uterus and ovaries, and the proper attachment of the neophallus to the genital area. The challenge to creating this illustration was the limited references available to accurately depict the anatomy. In a sense, the anatomy was a combination of male and female reproductive and urethral structures, yet still completely different, as the anatomy lacked many components of male anatomy, such as a corpus spongiosum. At our first meeting, Dr.Nikolavksy provided a preliminary illustration depicting the general neophallus anatomy, and provided sufficient explanation and background of the procedure that assisted in determining what was removed from the anatomy and what was added.

Thumbnail sketches were developed highlighting the neophallus anatomy with Dr.Nikolavsky's revisions of the previous illustrations, seen in Figure 1. These sketches utilized the female abdominal and pelvic cavity in a sagittal cross-section as a base reference, overlaying sketches of male genital and urologic anatomy, removing portions of the female anatomy and portions of the male anatomy, to create an accurate depiction of the neophallus and urethral reconstruction. These sketches were then imported into Procreate and later Adobe Photoshop, to be rendered and painted over. After verifying the neophallus anatomy, being sure to remove and add structures in accordance with the procedure, the initial illustration was sent to Dr.Nikolavsky. Upon approval of the neophallus anatomy after a few rounds of revisions, the illustration was utilized as a reference at the end of part one of the animation, providing the viewer with an update of the patient's anatomy following phalloplasty, as well as the still background of part two of the animation, which will be discussed later.

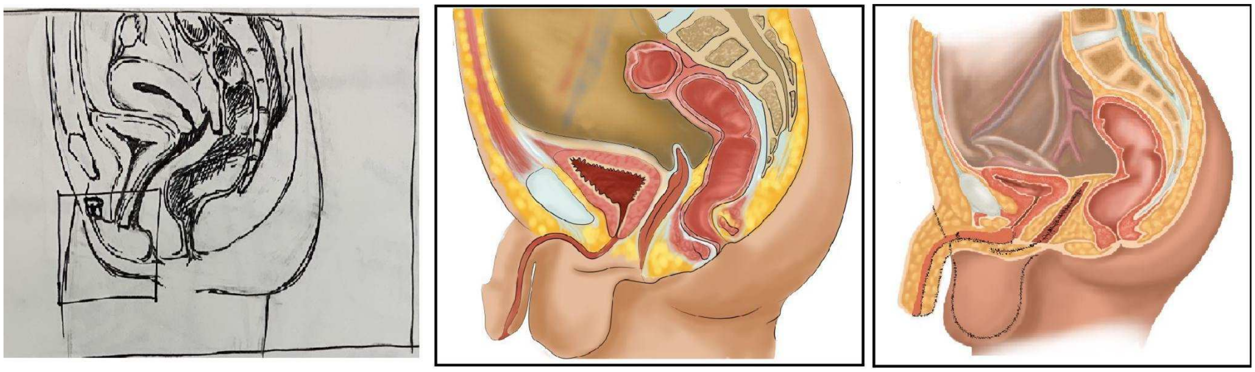

Figure 1. Side-by-side comparison of the progression of the neophallus illustration. From left to right: rough thumbnail sketch, preliminary illustration, final illustration.

ANIMATION PROCESS

It was decided that a 3D animation would better represent the surgical procedure from multiple perspectives, highlighting the neophallus anatomy both inside and outside the body. There are various points of the procedure (i.e., the creation of the neophallus utilizing the RFFF graft) that occurred away from the genital area and were done in tandem with the procedures occurring at the genital area (i.e., the urethral reconstruction). Therefore, the ability to rotate to various parts of the body, zooming in and out, helps the viewer understand that this is all occurring at once and not get confused when the camera shows a different part of the body; ultimately creating a sense of continuity. The 3D models that needed to be created for this project included: full female body, which would later be sculpted and edited to match a transman patient post 'bottom' surgery; full forms of the bladder; simplified form of female genitalia, female urethra, uterus and vaginal canal with connecting ovaries; extended neourethra, neophallus, radial skin graft; and numerous surgical instruments including a scalpel, scissor forceps, and needle and sutures. Cross-sections of the full transmale body, bladder, neourethra, and obliterated vaginal cavity also needed to be modeled.

The initial plan was to separate the fully 3D animation into multiple parts that would: (1) explain the process of RFFF phalloplasty utilizing the 'tube-within-a-tube' technique; and (2) indicate the common complications that arise following phalloplasty. Rather than utilizing 3D models for the entire animation, it was determined that for part two, it would be better to utilize the static, 2D neophallus illustration, zooming in from the full body 3D model to the static neophallus anatomy, and then overlaying the cross-section bladder, neourethra, and obliterated vaginal canal on top to showcase the various sequelae. This would focus the viewer and be able to simplify the complications, emphasizing the important structures through the use of the 3D models, while de-emphasizing the surrounding structures that remained flat from the neophallus illustration.

Timeline

Numerous deadlines were established in order to complete a majority of the animation in time for the MFA Thesis Presentation in April 2021 and to submit parts one and two of the animation by the end of February 2021 to the American Urological Association (AUA) Panurethral conference. It was important for the AUA conference to convey the various urethral sequelae which were depicted in part two of the full animation, so completion of that section was prioritized over part one edits. Virtual meetings through Zoom were planned every month, with regular communication via text, email, or phone call for edits and details to the storyboard, narration, or detailing in the animation itself. It was determined that regular check-ups with small revisions were more effective than submitting the completed section of the project. There were little details that needed to be fixed, so submitted progress portions were better for completing the little details and ensuring accuracy.

Script

Narration scripts were written for parts one and two of the storyboards to help organize the flow and movement of the animation (see Appendix). Since part one consisted of various zooming in and out of the full body, it was important to determine where it was most impactful to keep the camera stagnant and where it would be more impactful to have multiple perspectives. Since this procedure can be contextually heavy, some background information and details were reworded and shortened to allow sufficient context, but not overload the viewers with too much information, ultimately breaking away from the main points of the procedure.

In collaboration with Dr.Nikolavsky, the script wording and narration was approved. As this video was intended for the medical community as well as the lay public, the wording could not be too elaborate that the lay audience would not be able to comprehend yet could not be too simplistic that it would not justify the complexity of this procedure and its sequelae. Over-explanations were condensed into concise phrases that provided the audience with clear understanding of the steps of the procedure as well as the various complications following it.

Storyboard

The storyboard for part one explaining the steps of phalloplasty was developed towards the beginning of Fall 2020, mainly focusing on dividing the steps of phalloplasty into the elongation of the native female urethra, the creation of the neophallus, and then the combination of the two. The storyboard was completed in Adobe Illustrator, compiling the 2D preliminary illustrations of the body sketched in Adobe Photoshop which would later be modeled in Maya, as well as 2D screenshots of the preliminary 3D model of the rolled neophallus which was previously sculpted in Maya. These separate frames were then combined into Microsoft PowerPoint, to be showcased as one comprehensive draft. Each frame of the storyboard was accompanied by a description of the assets in the frame, the direction of the camera movement, and the sentence(s) of the narration script that would be overlaid during that specific scene. Initially, the progression of the procedure in the storyboard depicted the elongation of the urethra completed first, and then the creation of the neophallus completed second. However, revisions to the narration and storyboard were made to clarify that these two steps are done in tandem with each other. While one team is elongating the native female urethra, a separate team was excising the RFFF graft to construct the neophallus.

No separate storyboard was created for part two of the animation. This section remained more simplified than the first part since it was determined that it would be more beneficial to rotate the body to a sagittal view, zoom into the abdomen revealing a cross-section, then hold the camera in that stagnant zoomed position to allow the 2D neophallus anatomy cross-section to reveal 3D assets of the bladder, urethra, and obliterated vaginal cavity emerging from it. From there, strictures can be showcased within the urethra causing obstructions, and as a result of the obstruction, fistulas and persistent vaginal cavities can be shown as pressurized urine rupturing through the anastomoses. Also due to the time constraints of submitting part two to the AUA conference, it was easier to make sure the narration script was accepted by Dr.Nikolavsky, use that as an outline for the scenes, and then proceed with the creation of that section.

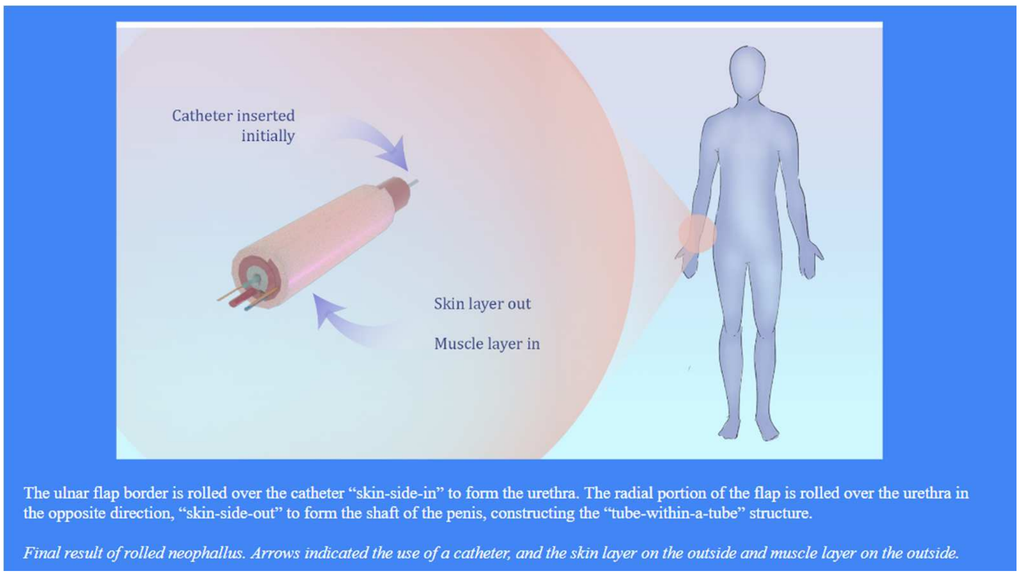

Figure 2. Storyboard frame for part one in Microsoft PowerPoint showing still-shots of the preliminary model for the rolled neophallus structure, and full body outline which would later be modeled.

Narration

The narration script was recorded and edited in Adobe Audition. No voice narration was initially created for part two of the animation; this was so that it could be voiced over separately by Dr. Nikolavky and incorporated into his presentation for the AUA conference. Voice narration was added later, after the AUA submission, so that the two sections of the animation could be combined into one cohesive piece. Recording was completed frame by frame in accordance with the initial scripts/storyboard. This was done in order to prevent long pauses or stutters and help to ensure that each frame was paced correctly.

Removal of static and random background noise was achieved in Adobe Audition to ensure the isolation of the narration voice. Further splicing and time adjustments were later made in Adobe After Effects.

Models and Development of Assets

3D Models

The 3D models of the female urogenital system (bladder, kidneys, ureters), female genitalia, neophallus, neourethra, cross-sections of those structures, and various flaps were modeled primarily in Autodesk Maya, with the exception of the full female body, the uterus, and ovaries whose simplified base meshes were purchased from Turbosquid, imported into Autodesk Maya, and reconstructed and edited to fit the needs of the project. Arnold shaders were applied to all models. Specified structures, such as the bladder and uterus, received texture maps created in Autodesk Mudbox to achieve a more realistic look, as these two structures would be focused on in detail. UV maps of the two structures were exported from Autodesk Maya, and then taken into Autodesk Mudbox to provide the base for sculpting. These texture layers were then exported as displacement maps which could in turn be imported back into Autodesk Maya and set as a bump map.

It was important to maintain a transparency to the skin of the full body in order to be able to see within. To achieve this, the Arnold shader for the full body had the Opaque setting disabled and the transmission weight set to one, giving it a transparent look at the center of the model, while still being able to see the outlines around it. A second full body with normal opaque skin was also rendered, and the two were then combined and overlaid on top of each other in Adobe After Effects, utilizing the opaque skin near the surgical site, and transitioning it to the transparent full body further up the abdomen. Combining the two allows the viewer to see the surgical site on the surface of the body while simultaneously showcasing the internal anatomy being put into place inside the body. An example of this can be seen in Figure 3 below.

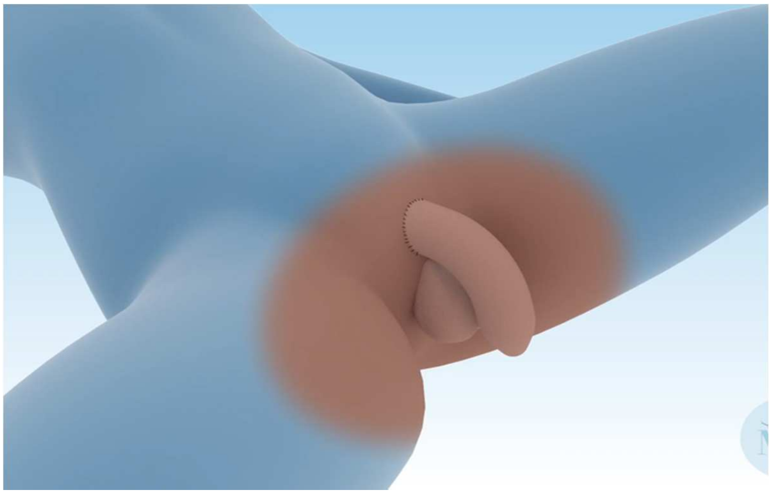

Figure 3. Still-image of part one of the animation showcasing the combination of transparent and opaque Arnold shaders on the full body to achieve multiple perspectives.

The combination of these shaders and perspectives allow the viewer to see the surgical viewpoint and internal viewpoint of the procedure, something that is often not possible with standard surgical recordings. Creation of the surgical instruments was completed in Maxon Cinema 4D. Reference images of the instruments were imported in the plane maps, and could be utilized as guides. After the instruments were rounded and structurally accurate, the 3D assets were imported back into Maya, where they were assigned Arnold shaders with metallic properties, giving them a reflective look (Figure 4).

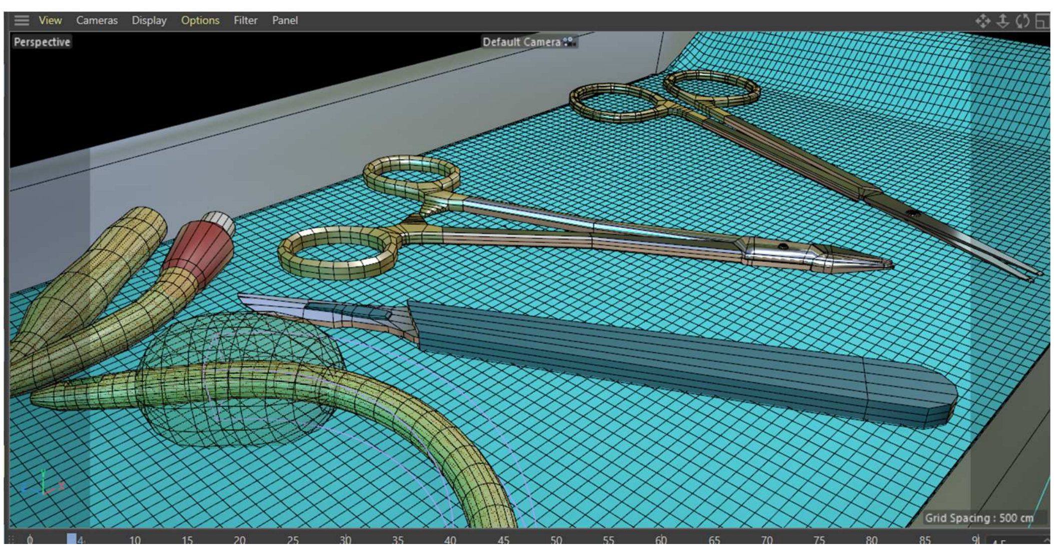

Figure 4. Screenshot of the surgical instrument utilized in the procedure modeled in Cinema 4D showcasing the polygon structuring to the models.

Creation and manipulation of the neophallus was the most challenging part of the animation process. One of the main points in the animation was to depict the 'tube-within-a-tube' technique, which involved rolling a single graft partially in one direction, and then the remaining portion in the opposite direction. The deformation of the graft along a motion path curve with a lattice was originally suggested, however it yielded limited results, ultimately only allowing a single direction roll formation instead of the multiple directions needed (Figure 5).

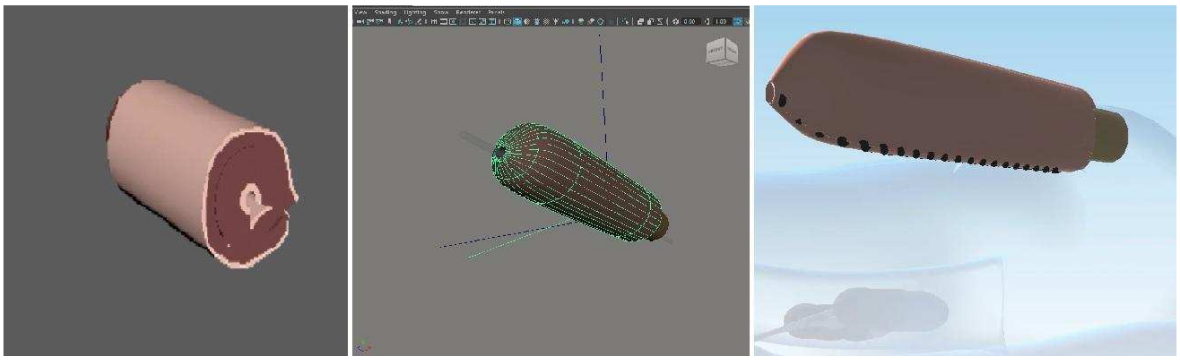

Figure 5. Screenshots of rolled neophallus. Left image shows the initial roll using the motion path curve technique, Middle image shows the final neophallus in Autodesk Maya, and Right image is a still-shot of the neophallus in the final animation.

The neophallus had sharp kinking in the rolled form and was unable to close into the meatus, ultimately just looking like a rolled cylinder. After much experimentation, it was determined that a simpler approach yielded better results. The initial singular graft was separated into the radial and ulnar parts and kept next to each other to imitate a singularly connected graft. A bend deformer was added to the longer ulnar portion to roll it in towards the radial portion. Another bend deformer was added to the radial portion, and as the bend progressed, the radial section of the graft was slowly rotated and shifted using key framing, to achieve the rolled-over look of the tube-within-a-tube. Below is an example of the created neophallus in the animation.

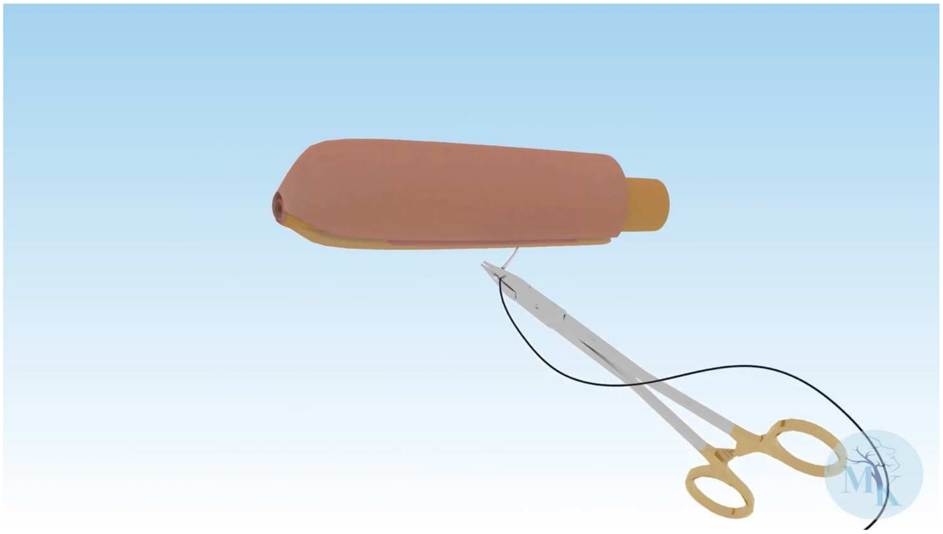

Figure 6. Still-shot of part one animation showcasing the final rolled neophallus about to be sutured together on the dorsal side.

Bend deformers and assigning objects onto a path were combined and utilized for numerous structures and scenes. Rigging the full body model was necessary to showcase the position of the patient during the procedure as well as the manipulation of the left arm to extract the RFFF graft. The body was rigged in Maya using the Auto-Rig function, and then manipulated per scene using key framing.

Part two needed to showcase pressurized urine filling into the cross-section of the bladder and then forcing its way through the strictured urethra, breaking the suture lines, and forcing its way into the obliterated vaginal cavity. To achieve this, a nucleus emitter was created using the FX function in Maya. A volume axis field was created along a curve and placed near the emitter to manipulate the nParticles to flow within the axis field. Liquid simulation was added to the nParticles along with adjustments to size, bounce, and collision of the particles. An Arnold shader was applied to the nParticles, and when rendered, the nParticles took on the form of overflowing urine traveling through the urinary tract (Figure 7).

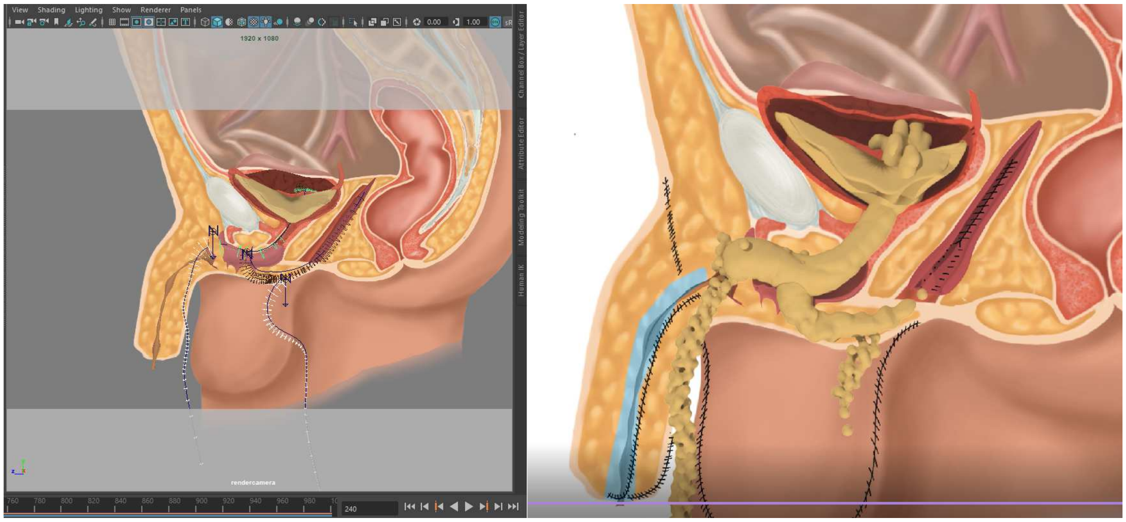

Figure 7. Comparison of the before and after rendering of the nParticles along the axis fields to mimic the appearance of flowing urine. Left image shows the nParticle flow in Maya, while the right image shows nParticle flow when it is fully rendered.

Illustration Assets

The main 2D asset utilized in the animation was the sagittal cross-section of the neophallus anatomy. As previously mentioned, this was created in Procreate and Adobe Photoshop and can be seen throughout the animation, particularly in part two. Below are examples of this illustration, utilized in various forms (Figures 8 and 9).

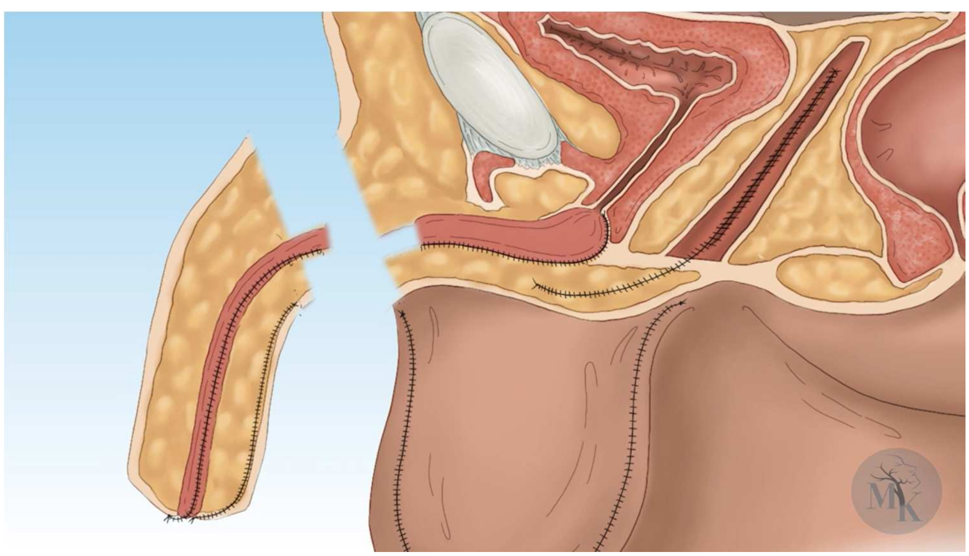

Figure 8. Still-shot of part one animation showing the neophallus and subsequent penile urethra attaching to the *pars fixa* to create an anastomosis.

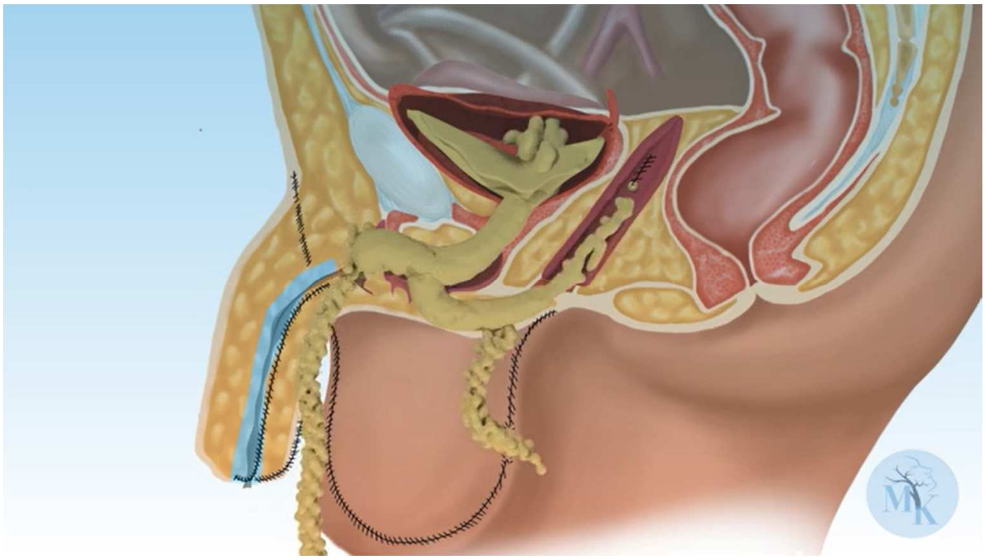

Figure 9. Still-shot of part two animation showcasing the inevitable rupture of the pressurized urine making its way through the ventral suture lines and into the obliterated vaginal cavity.

Other 2D assets such as labels or the vasculature of the RFFF graft were created in Adobe After Effects and overlaid with varying opacity depending on the asset. For part two, the sutures were created in Adobe Photoshop separately from the neophallus anatomy illustration, and then overlaid over the original image to allow manipulation of the sutures in Adobe After Effects as the pressurized urine breaks through them.

Animation

The animation process was broken down into the two separate sections, however the process remained ultimately the same. Utilizing the key framing in Maya, initial playblasts were shared with Dr.Nikolavsky to evaluate the camera movement and flow of the scene. Playblasts were utilized to limit the number of times the scenes would be rendered. As previously mentioned, it was important in part one to show the camera zooming in and out of the full body, so that the viewers would recognize that all of the procedures were taking place on the same patient at the same time. Since there were overlays utilized for certain assets, such as the full body, and multiple perspectives, some scenes needed to be rendered multiple times; each time something would be altered whether it was the Arnold shader of a structure, or the camera angle. For part two, it was easier to render since there were limited camera variations, allowing the render time to decrease.

Once all the scenes were rendered, they were imported into Adobe After Effects to create the full compilation. Initially the two sections were composed separately in Adobe After Effects, and later combined into one full animation with transition labels in between. Each section had numerous layers including labels, line paths, audio layers, etc., so organizing layers according to the narration section helped to break up the massive clutter of layers. Part one utilized transitional breaks in the animation to emphasize to the audience the main points of the procedure. Rendered scenes were transitioned in and out of the compilation as the camera zoomed to simulate seeing inside the body and the structures. Utilizing the multiple renders of the same scene and overlaying them on top of each other, some structures, such as the uterus and ovaries, can gradually disappear in the scene while keeping the rest of the structures intact, providing a seamless transition. The same procedure was utilized later in part two to showcase the transparent and opaque sections of the body. In part two, the original neophallus anatomy and cross-section 3D asset of the human body were color altered to blue to blend more into the background, and then fully colorized in certain sections to highlight those important structures, as seen when highlighting the anastomosis of the urethra. Later once the illustration was fully colorized, a blue highlight was utilized to showcase the urethral stricture. Examples of this can be seen in Figures 10 and 11 below.

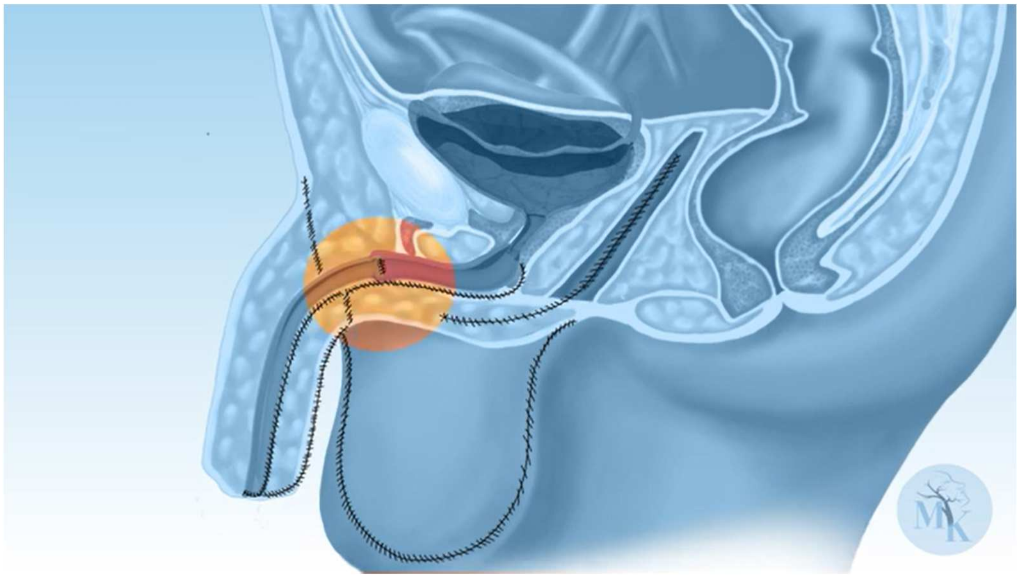

Figure 10. Still-shot of part 2 of the animation pointing out the vulnerability points at the anastomosis.

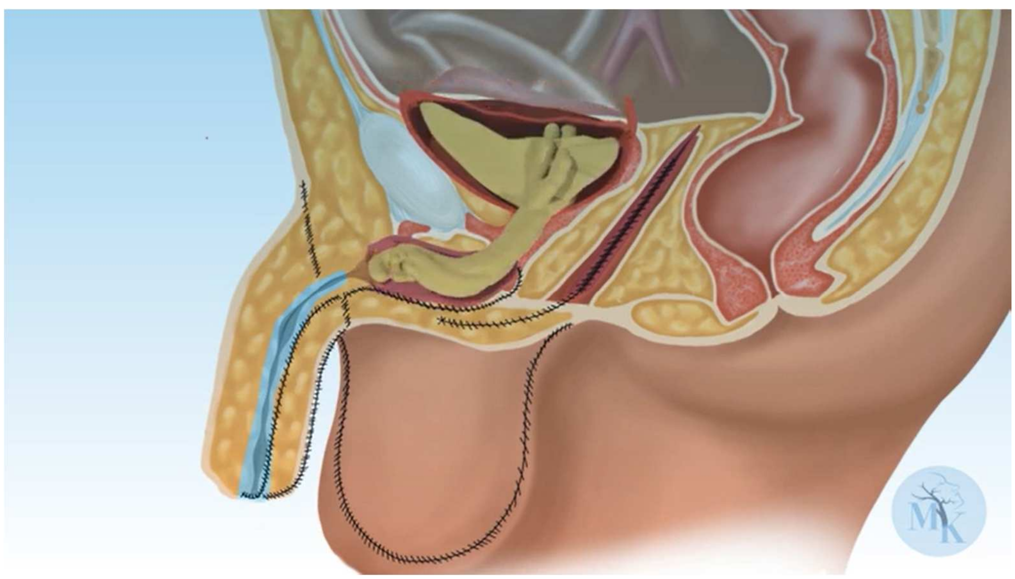

Figure 11. Still-shot of part two animation highlighting the urethral strictures causing obstruction, leading to pressurized urine buildup in the *pars fixa* section of the urethra.

Once the two sections were compiled individually they were combined together and exported as an AVI and imported into Adobe Media Encoder to convert it to an MP4 file and decrease the overall file size. More examples of parts one and two of the animation can be seen below.

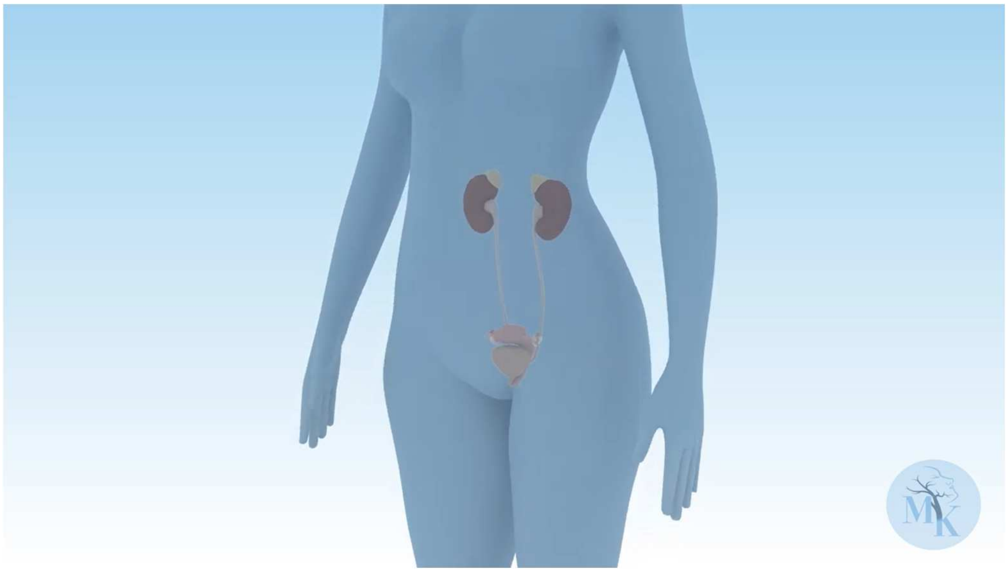

Figure 12. Still-shot of part one animation showcasing the zoomed out torso with the urogenital organs involved with the procedure.

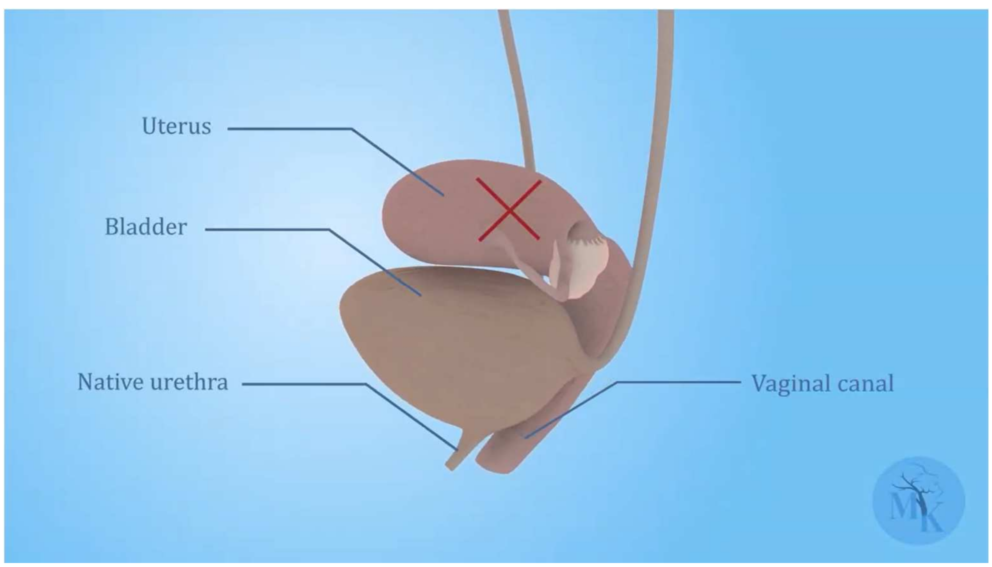

Figure 13. Still-shot of part one animation showcasing native urogenital systems. It is explained that before phalloplasty, a vaginectomy is performed.

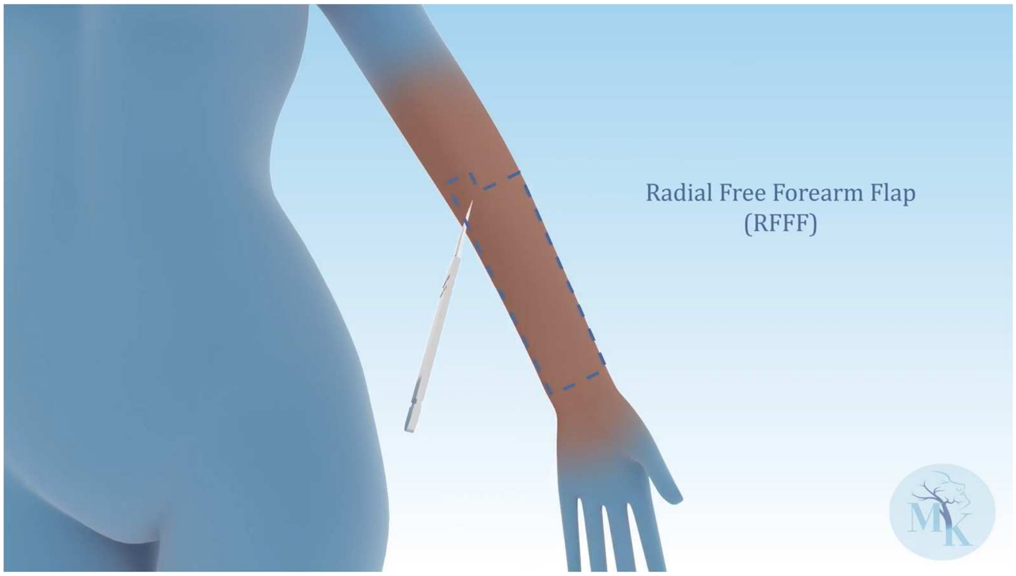

Figure 14. Still-shot of part one animation showcasing the outline of the RFFF graft to be excised and harvested for the procedure.

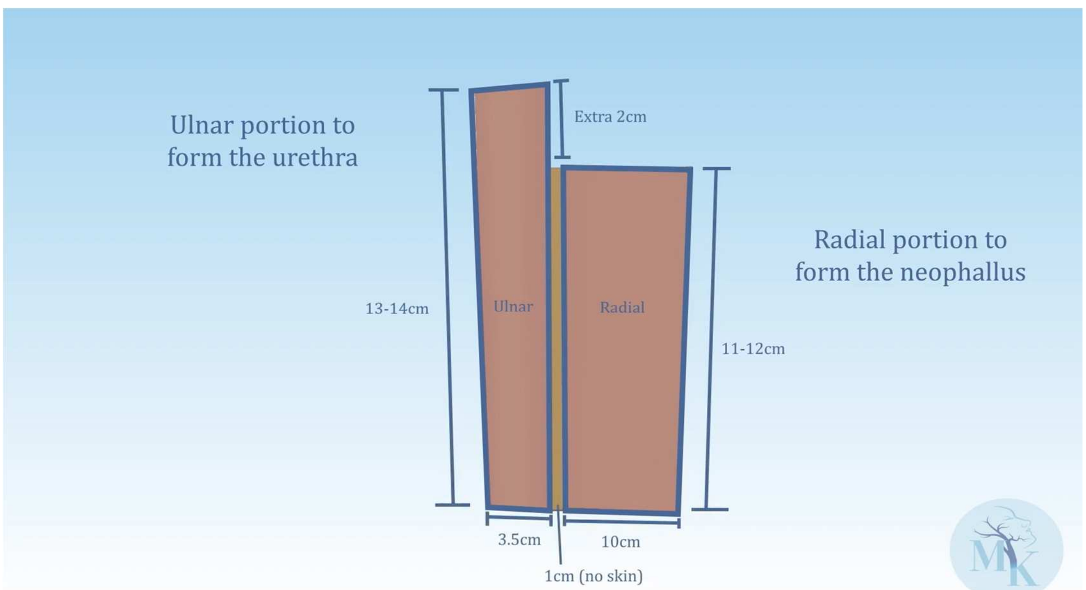

Figure 15. Still shot of part one animation. The graft is zoomed in and labeled with the dimensions typically needed. It also showcases that the ulnar portion is longer than the radial portion.

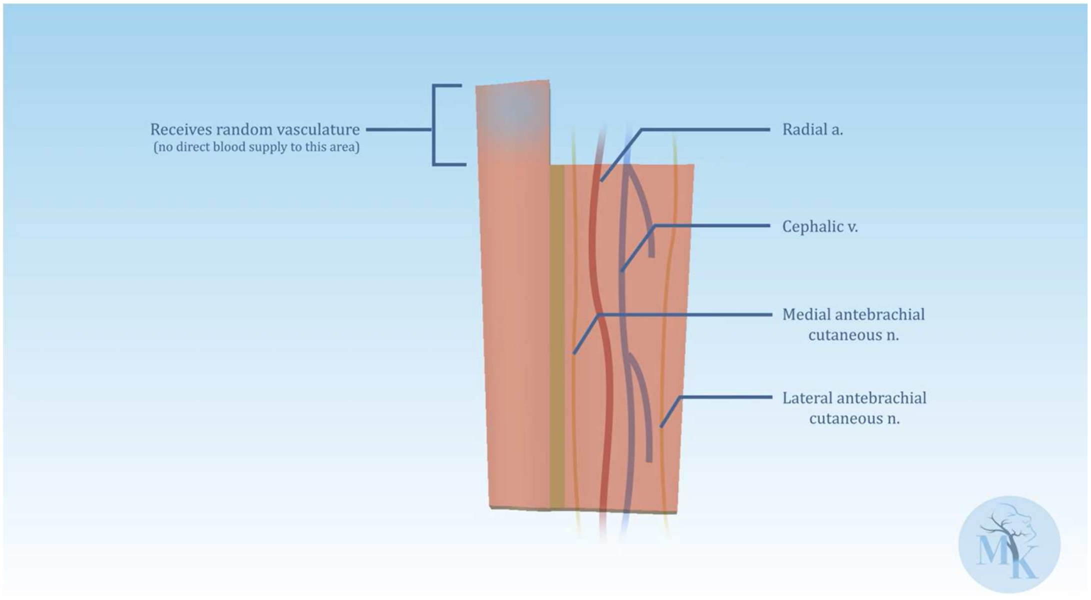

Figure 16. Still-shot of part one animation showcasing the internal anatomy of the RFFF graft that is kept intact and harvested to later be anastomosed to the surrounding genital tissue.

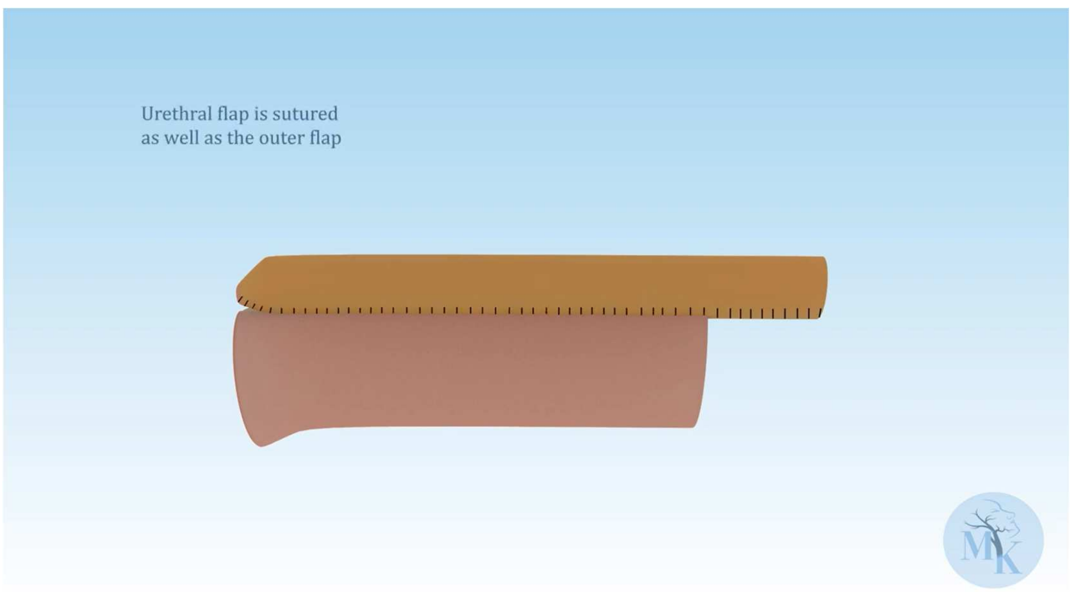

Figure 17. Still-shot of part one animation showcasing the beginning step of the “tube-within-a-tube” technique. The longer ulnar portion is rolled over towards the center first and sutured together.

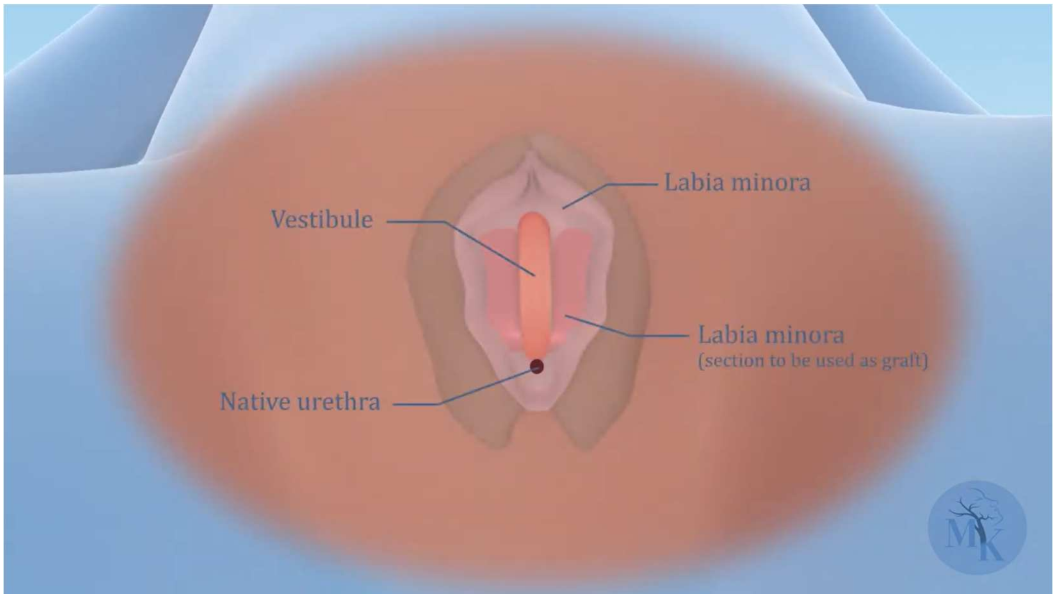

Figure 18. Still-shot of part one animation showing the anatomy involved with the creation of the *pars fixa.*

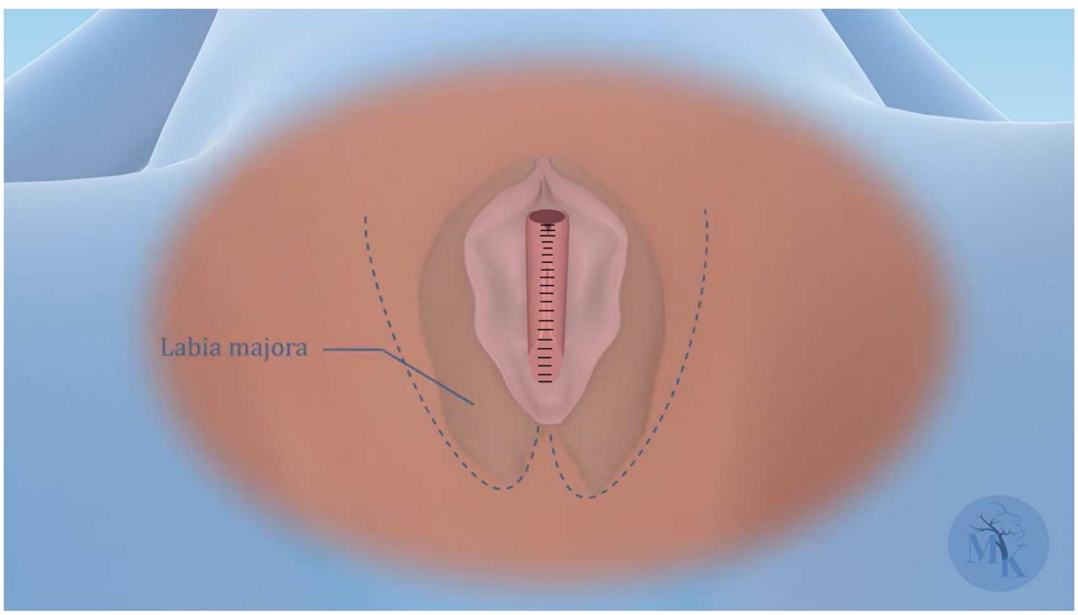

Figure 19. Still-shot of part one animation showcasing the neoscrotum being created and sutured together by the labia majora.

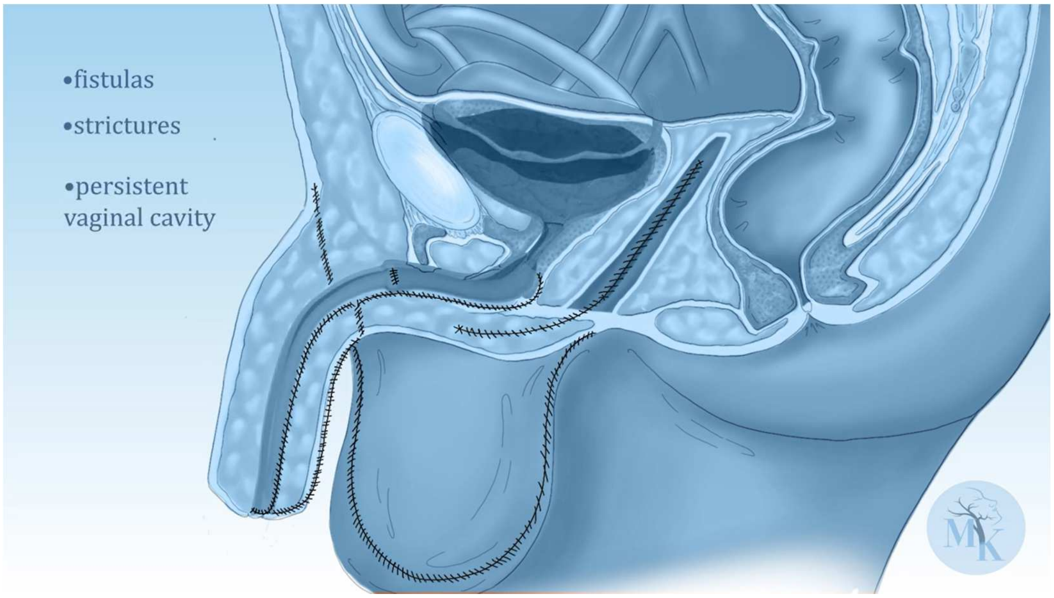

Figure 20. Still-shot of part two of animation showing the illustration of the neophallus anatomy with the common urologic sequelae.

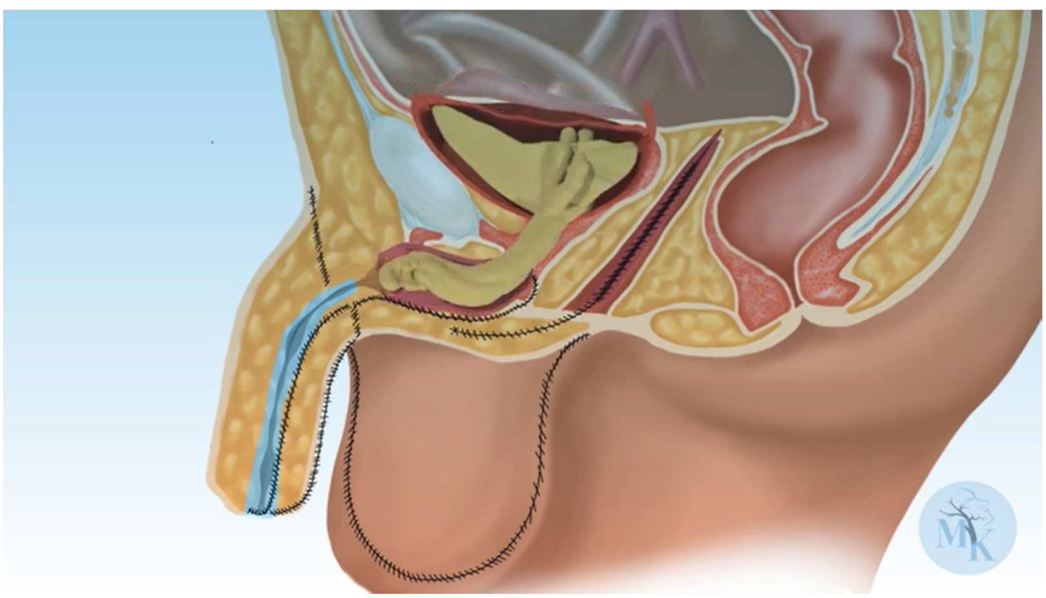

Figure 21. Still-shot of part two animation highlighting the urethral strictures causing obstruction, leading to pressurized urine buildup in the *pars fixa* section of the urethra.

CONCLUSION

Recent advances in technology as well as increased social acceptance has allowed for surgical procedures such as gender affirmation surgery to be a growing practice among the US population as a remedy for gender dysphoria. While not all transmen seek out 'bottom' surgery, those who do are offered multiple options for genital reconstruction. With RFFF phalloplasty remaining one of the most common procedures for female-to-male transgender patients, it is important for the medical community to be aware of common urologic sequelae that often arise within the first few months.

The objectives of this project were to create a short 3D animation that would summarize the process of RFFF phalloplasty utilizing the 'tube-with-a-tube' technique, and showcase the three urologic sequelae that commonly arise within the first few months after phalloplasty: fistulas, strictures, and persistent vaginal cavities. This animation would serve as a contextual precursor to Dr.Nikolavsky's presentation of repairing urologic sequelae post phalloplasty, providing fellow urologists in the medical community as well as the lay public the necessary background understanding of the procedure. The combined animation has since been submitted as a link in an article to the journal *Urology*[15].

The project not only provided educational understanding of numerous software programs such as Autodesk Maya, Maxon Cinema4D, Adobe After Effects, etc., it also provided beneficial insight to research collaboration working with Dr.Nikolavsky. This project opened the opportunity to produce a similar (30 second) animation on the use of a buccal mucosal graft to treat penile adhesions, which was submitted as a link in an article to the journal *BJU International*[16]. Maintaining constant communication throughout the project allowed for adjustments to be made so that the animation could be interpreted the best way possible. Possible steps to further this animation could include a third section animating the

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[15] Schardein, J., Beamer, M., Kittleman, M.A., Nikolavsky, D. (2022). Staged Urethroplasty for Reconstruction of Long Complex Pendulous Strictures of a Neophallic Urethra. *Urology, 164,* e309-e311. https://doi.org/10.1016/j.urology.2021.12.029

[16] Beamer, M. R., Angulo, J. C., Capiel, L., Lopez-Alvarado, D., Ramirez, E. A., Satyagraha, P., Zaccarini, D., Kittleman, M. A., Nikolavksy, D. (2021, Dec., 8). A Buccal Mucosal Graft Sub-Coronal Resurfacing to Treat Recurrent Penile Adhesions: The Buccal Belt. *BJU International, 129* (3): 406-408. https://doi.org/10.1111/bju.15670

surgical techniques utilized by Dr.Nikolavsky and his team. Adding a third part could further assist in the explanation of repairing urologic sequelae, however, at this time the animation remains a precursor to Dr.Nikolavsky's larger presentation for urethral reconstruction.

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APPENDIX

Script Narration

Phalloplasty, is a complex reconstruction procedure part of transmasculine genital affirmation surgery. Commonly, the early steps of phalloplasty involve vaginectomy, the construction of the neophallus, and urethroplasty. Typically, vaginectomy is performed at the time of phalloplasty. Various techniques exist to obliterate the vaginal canal. While this is being done, a separate team is creating the neophallus using a tube-within-a-tube technique. In this example, a Radial Free Forearm Flap (RFFF) is utilized through the use of the tube-within-a-tube technique to construct the penile urethra and the neophallus. The ulnar portion of the graft is longer than the radial portion to allow a single-stage restoration of urethral continuity. The radial artery, cephalic vein, and medial and lateral antebrachial cutaneous nerves are kept intact. The urethral portion of the graft does not receive a direct blood supply, and instead, receives random vasculature perfused from the main portion of the flap. The least perfused area is the area of future anastomoses. The ulnar flap border is rolled over the catheter 'skin-side-in' and anastomosed and sutured together to form the urethra. The radial portion of the flap is rolled over the urethra 'skin-side-out' to form the shaft of the penis, constructing the tube-within-a-tube structure. Local tissue flaps from the labia minora are used for the construction of the *pars fixa*. The *pars fixa* is a structure analogous to the bulbar urethra. This will later be anastomosed to the penile urethra. Note the ventral suture lines used during the tubularization of the *pars fixa*. These will later be an important factor in urologic complications. Tissue flaps from the labia majora are used to create the neoscrotum. These flaps are used in conjunction with the urethroplasty to construct the various portions of the male urethra. Various procedures are done in tandem with the construction of the neophallus, resulting in the desired anatomy for upright voiding and sexual sensation.

Management of the neourethra is important, as various complications arise due to the vulnerability points of the procedure. Fistulas, strictures, and persistent vaginal cavities are the most common complications. Common vulnerability points are at the anastomosis of the *pars fix,* and the suture lines of the neophallus and neourethra anatomy. Strictures due to ischemia can form at the anastomosis of the *pars fixa,* the meatus of the neophallus, or along the entire length of the penile urethra. Once there is a stricture causing distal obstruction, pressurized urine may break through the ventral suture lines causing urethral cutaneous fistulas and may even find its way into the obliterated vaginal cavity. Failure to manage urologic sequelae of phalloplasty can lead to urinary obstruction, painful urination, recurrent urinary tract infections, perineal abscess cavities, sepsis, and overall decrease quality of life.