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ENDOLUMINAL SURGERY

Robotic transanal minimally invasive rectal mucosa harvest

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Abstract

Introduction Buccal mucosal grafts (BMG) are traditionally used in urethral reconstruction. There may be insufficient BMG for applications requiring large grafts, such as urethral stricture after gender-affirming phalloplasty. Rectal mucosa in lieu of BMG avoids oral impairment, while potentially affording less postoperative pain and larger graft dimensions. Transanal minimally invasive surgery (TAMIS) using laparoscopic instruments has been described. Due to technical challenges of harvesting a sizable graft within the rectal lumen, we adopted a new robotic approach. We demonstrate the feasibility and safety of a novel technique of Robotic TAMIS (R-TAMIS) in the harvest of rectal mucosa for the purpose of onlay graft urethroplasty.

Methods Six patients (ages 28–60) presenting with urethral stricture and one vaginal stricture underwent robotic rectal mucosal harvest. The procedure, which was first studied on an inanimate bovine colon model, was performed under general anesthesia in lithotomy position using the GelPOINT^{TM} Path Transanal Access. Mucosa was harvested robotically after submucosal hydrodissection. Graft size harvested correlated with surface area needed for urethral or vaginal reconstruction. Following specimen retrieval, flexible sigmoidoscopy confirmed hemostasis. The graft was placed as an onlay for urethroplasty.

Results There were no intraoperative or postoperative complications. Mean graft size was 11.4 × 3.0 cm. All reconstructions had excellent graft take. All patients recovered without morbidity or mortality. They reported minimal postoperative pain and all regained bowel function on postoperative day one. Patients with prior BMG harvests subjectively self-reported less postoperative pain and greater quality of life. There have been no long-term complications at a median follow-up of 17 months.

Conclusions To our knowledge, this is the first use of R-TAMIS for rectal mucosa harvest. Our preliminary series indicates this approach is feasible and safe, constituting a promising minimally invasive technique for urethral reconstruction. Prospective studies evaluating graft outcomes and donor site morbidity with more long-term follow-up are needed.

Keywords TAMIS · Robotic surgery · Transanal surgery · Rectal mucosa · Urethroplasty · Transgender surgery

Buccal mucosa graft (BMG) was first examined for treatment of bulbar urethral stricture in adults in the 1990s, and has since become the gold standard due to its thick epithelium, accessibility, and relatively strong performance in studies of long-term outcome [1–4]. Lingual graft reports are also described in literature; however, both oral sources are associated with severe postoperative pain, impairment in eating and speaking, and limitations of dimension. Furthermore, candidacy is limited by variables such as prior BMG and use of tobacco products or other oral disease [5–8]. Sigmoid mucosal grafts avoid oral discomfort and provide excellent length, but are not easily accessible as they require resection of bowel at the donor site with the risk of more serious complications. Thus, we describe the use of rectal mucosa graft (RMG) harvest by minimally invasive means, advancing technical surgical ease and efficiency while minimizing morbidity and postoperative discomfort [9–11]. Our goal is to demonstrate the feasibility and safety, and to describe our initial experience of a novel operative technique of Robotic

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TAMIS (R-TAMIS) RMG harvest for the purpose of onlay graft urethroplasty.

Onlay graft urethroplasty addresses recalcitrant stricture disease resulting from trauma, congenital anomaly, iatrogenic injury, and lichen planus. In the search for an autologous graft source that is both easily perfused and suitable to conditions of the urinary tract, surgeons have attempted the use of penile, colonic, oral, bladder, and rectal tissue [12]. Small intestine submucosa (SIS) has been transferred as a scaffolding for epithelialization in the prostatic or membranous urethra, and current animal model studies are exploring the possibility of seeding SIS with urine-derived stem cells meant to differentiate into urothelial and smooth muscle cells [13–17]. These numerous substitutions have varying reports of success seemingly impacted by stricture length and complexity, vascularity of the target site, and specific defect location (i.e., urethral segment and anterior vs. posterior) [18]. RMG is described here as it is a good option which can be harvested in relatively large size, with good accessibility, and we hypothesize with minimal morbidity.

The treatment of resection for rectal pathology has benefitted from a minimally invasive approach with the advent of transanal minimally invasive surgery (TAMIS), first described in 2010 [19]. The single-port transanal platform using laparoscopic instruments allows for resection of benign and malignant lesions with great efficacy and minimal morbidity, as well as for total mesorectal excision (TME) in cancer [20–26]. First reported in 2012, robotic instrumentation has been successfully applied to TAMIS (R-TAMIS) for excision of benign and malignant rectal masses, and performing transanal TME, with technical precision [22, 27–30]. The robotic approach has been shown (in small, experimental series) to be safe and feasible with minimal morbidity and no known mortalities. Here, we detail our results of a novel operation using a technique developed employing R-TAMIS in the harvest of rectal mucosa graft for use in urethral reconstruction.

Of importance, multidisciplinary development of improved tactics within the niche of urethral reconstruction addresses a growing need among female-to-male (FTM) transgender patients [31]. Phalloplasty is offered to those who desire an aesthetic phallus, the ability to urinate while standing, and the capacity to perform insertive intercourse. It is most often accomplished using a radial forearm-free flap (RFFF) and frequently necessitates revision operations due to high rates of urethral complications—namely, stricture and fistula. The neourethra is considerably vulnerable at the anastomosis of the pars fixa and pars pendulans. Despite prelamination of the neourethra with mucosa (buccal, uterine, or vaginal), multiple reconstructions are not uncommon due to graft contracture and recurrent disruption of continuity [32–34]. With an increasing number of this operation being performed, there is an increased need for urethral reconstruction. The transgender population is, therefore, inclusive of many requiring alternatives to the currently available BMG measures. Here, we present our initial experience of a novel operative technique: Robotic TAMIS (R-TAMIS) rectal mucosal graft (RMG) harvest for the purpose of onlay graft urethroplasty.

Materials and methods

IRB approval was obtained. Patients were made aware that this was a novel procedure in both rectal mucosa graft use and robotic transanal technique. The procedure was first performed on an inanimate model with bovine colon to determine feasibility and work flow. Prior to performing this robotically, the operating colorectal surgeon had performed RMG harvest via TAMIS and the procedure in a bovine model.

Patient selection

The patients identified as candidates for R-TAMIS rectal mucosa harvest were adults requiring urethroplasty due to strictures where BMG was contraindicated. This specific population included FTM transgender adults requiring urethral reconstruction after previous gender-affirming radial forearm-free flap (RFFF) phalloplasty and bilateral BMG harvest. Six patients (age range: 28–60 years) were identified and included. Five patients presented with urethral stricture necessitating onlay graft urethroplasty, one of which had previously undergone a successful rectal mucosal graft harvested by TAMIS with laparoscopic instruments. R-TAMIS rectal mucosa harvest was additionally performed on one male-to-female (MTF) adult for the purpose of vaginoplasty revision.

Procedure description

Both mechanical and antibiotic (NuLYTELY®, neomycin, and metronidazole) bowel preparation is administered preoperatively, and subcutaneous heparin and intravenous antibiotics are administered per protocol. Following administration of general endotracheal anesthesia, with complete paralysis maintained throughout the case, the patient is placed in the lithotomy position. A local anal block with 10 cc of 1.0% lidocaine and 0.25% bupivacaine (1:1) is injected into the intersphincteric space in all four quadrants. Note that the maximum dose of lidocaine should be calculated so as not to exceed this in the course of the resection. All patients had pre-existing suprapubic catheters in place.

The GelPOINT™ Path Transanal Access Platform is used. It accommodates five to six ports and its access channel offers 360° visualization. The trocars are inserted

through the Gel Cap prior to placement in the anal canal (Fig. 1). A 150-mm (bariatric length) cannula for the da Vinci Xi® Robotic 8 mm 30° scope is positioned at 12 o'clock. This minimizes collisions. The SurgiQuest AirSeal® 5 mm port is inserted directly through the gel at approximately the 7 o'clock position. An assistant 5-mm port is placed at the 5 o'clock position. Two robotic ports are placed laterally at approximately 3 and 9 o'clock.

The GelPOINT™ platform's introducer is used to gently dilate the rectum, and the TAMIS access channel is advanced into the anal canal, with the aid of large Kelly clamp if necessary. Four 0–0 silk anal everting sutures can be used. The channel is affixed with silk sutures, after which the GelSeal cap can be secured in place. We suggest rotating the channel so it is fastened to the skin at 1:30 and 7:30 for optimal orientation of the ports once the cap is attached, so the clip mechanism can be placed at 12 o'clock. The AirSeal port is used to insufflate to a pressure of 12–15 mmHg.

The da Vinci Xi® Surgical System is then docked at an angle toward the patient's right leg, at approximately 45° to the midline; alternatively, it can be docked between the patient's legs. Arm#1 of the surgical system is not used and may be undocked and moved out of the way. The boom is rotated while docking, and care is taken to avoid collision with the patient's legs, which should be positioned near the chest to avoid interference with the robotic arms and maximize assistant access. The assistant is standing or seated between the robotic base and the patient. Once confirming the position and intraluminal exposure with the camera, the instruments are inserted. The right robot arm employs the Monopolar Curved Scissors and Large Needle Driver, while the left arm instrument uses the Long Bipolar Grasper. The assistant uses a fenestrated grasper and laparoscopic injector needle (25GA).

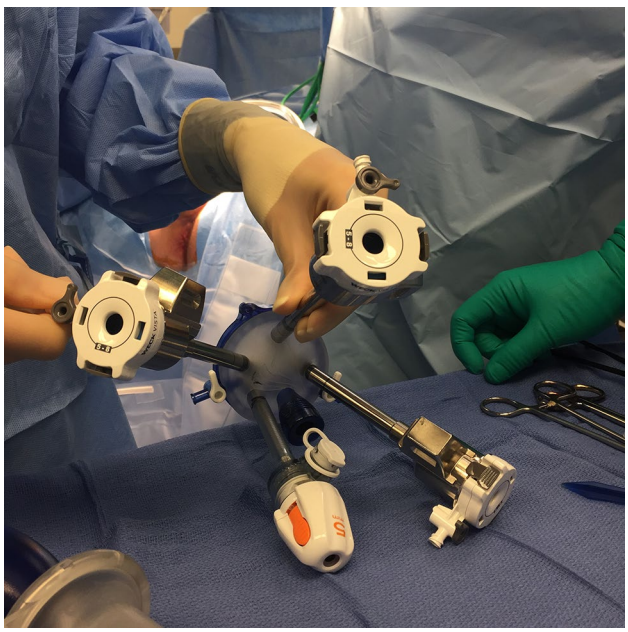

Fig. 1 Trocar placement through GelPOINT™ Path Transanal Access Platform prior to insertion into the anal canal

Once setup is complete, the surgeon's scope view is adjusted between 30° up and 30° down to obtain ideal visualization and determine if posterior versus anterior harvest will allow larger graft size based on anatomy and rectal valve location, and potential pitfalls need to be kept in mind. A posterior harvest is generally simplest if possible with less risk of inadvertent peritoneal entry. Because a long strip of mucosa is needed (up to 15 cm), the location with the widest site uninterrupted by valves is usually selected. FTM transgender patients after previous RFFF phalloplasty have had prior resection of vaginal mucosa and the anterior area closed. Rectal-neovaginal fistula is a potential complication in MTF patients, as they have had a vaginal cavity dissected between the prostate and the rectum for vaginoplasty. As the harvest is limited to the mucosa only, it minimizes the risk of perforation or peritoneal entry, although these complications are possible, and discussed with patients prior to the procedure. Prior rectal mucosal graft harvests and prior anal or rectal surgery must also be taken into account.

As the view is magnified, it is important to have a good sense of dimension. A small ruler (cut the standard ruler length wise) is passed via the assistant port, and is used to measure the area of desired harvest (Fig. 2A). Generally, 3 cm width by 10–15 cm length is required and harvested. The monopolar scissors are used to score the planned area of mucosal resection (Fig. 2B). If scoring the proximal edge of the desired area of harvest is postponed until later in the harvest, the length harvested can be adjusted based on intraoperative accessibility, and often more than initially appears feasible can be taken.

The harvest proceeds from approximately 2 cm proximal to the dentate line in a distal-to-proximal fashion. 0.5% lidocaine with epinephrine solution is injected at intervals by the assistant, guided by the surgeon, to raise and hydrodissect the mucosal plane and minimize bleeding. Epinephrine alone with saline can be used if there is concern for approaching toxic doses of lidocaine. Dissection through the mucosa with the monopolar scissors first reveals the submucosal plane, and gentle blunt dissection with the long bipolar grasper is used in combination with short burst of cautery from the scissors to elevate the flap of mucosa. Once the proper plane is identified from the edge, the dissection is continued in the injected area; when it no longer is visible, the injection is repeated. The surgeon may find it helpful to cross instrument arms as they manipulate the mucosal flap to better access lateral areas (Fig. 2C–F).

The assistant may help with retraction by using the laparoscopic fenestrated grasper or with a suture. The latter is accomplished by using the robotic needle driver to

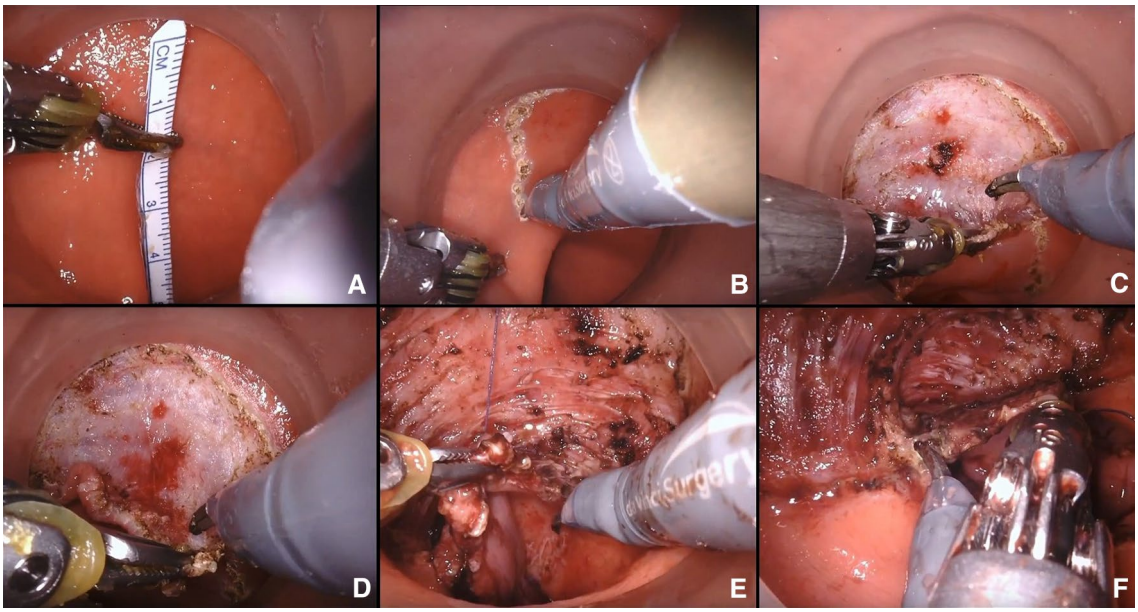

Fig. 2 **A** Measurement of mucosa prior to initiation of harvest. **B** Scoring the proposed area of harvest with bursts of cautery. **C–D** Blunt dissection following lift with lidocaine/epinephrine injection. **E** Continued dissection using suture for retraction of the graft. **F** Crossing instrument arms to effectively dissect contralateral edge

place (dyed 4-0 Vicryl) suture through the flap. To facilitate efficiency and avoid knot tying in a restricted space, the end of the suture can be fastened with a LAPRA-TY® or by pre-knotting the end of suture and applying a Weck® polymer clip. The assistant can then grasp the suture and manipulate the tissue with minimal tension.

The smoke is well managed by the SurgiQuest AirSeal® System. In our experience, minimizing the passage of instruments though the AirSeal® port allows for the most optimal insufflation and feedback, which avoids frustrating pitfalls such as a billowing effect or the chance of the assistant inadvertently removing the port through the gel, which then results in complete loss of insufflation and luminal collapse. A remotely operated suction irrigation (ROSI) system is also of use, as it is flexible, non-obstructive, easily maneuverable robotically by the operating surgeon, and has a long, adjustable reach. If not available, one could improvise with pediatric nasogastric tubing connected to suction.

Once the dissection is complete, to avoid damage to the delicate graft, the specimen is not retrieved through a port, but is extracted with removal of the gel cap. Immediate graft removal is recommended to avoid displacement into proximal colon from insufflation. The harvest site and proximal and distal lumen are inspected to confirm hemostasis. The mucosal defect is left open to heal, hoping to reduce the likelihood of stricture. The robot is undocked, the cap and channel removed, and flexible sigmoidoscopy is performed for final inspection, to ensure hemostasis without maximal insufflation, and to inspect for injury. The graft is then soaked in saline and prepared for onlay (Fig. 3).

Results

There were $N=6$ patients who underwent robotic rectal mucosal harvest. All operations were completed as planned. There were no intraoperative complications. There were no postoperative rectal complications including bleeding, perforation, abscess, or obstruction. Average graft length was 11.4 cm (Range: 7.5–15.0 cm), and widths were consistently 3 cm. All were sufficient size for urethral reconstruction.

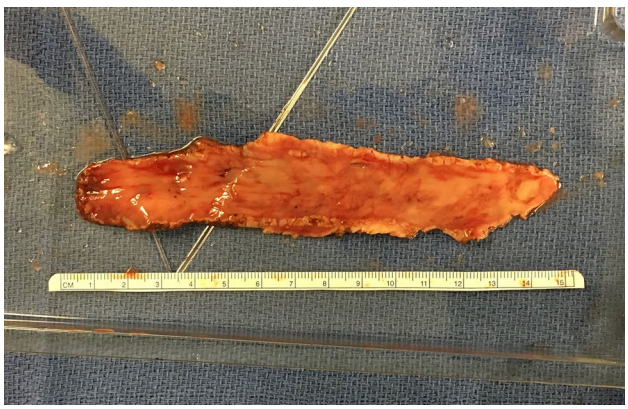

Fig. 3 Harvested graft before placement as onlay graft

There were no major morbidities or mortalities. All patients were observed in the hospital overnight and then discharged based on the urologic clinical situation. Patients with prior BMG harvests subjectively self-reported less postoperative pain and greater quality of life. All patients tolerated a regular diet and regained bowel function within 12–24 h after surgery.

Patients were evaluated postoperatively by both the urologist and colorectal surgeon at separate outpatient visits. The colorectal surgeon who performed the RMG harvest saw patients at a median follow-up of 2 months (range: 0.5–3 months), and the urologist at approximately 1–2 weeks postoperatively with regular follow-up thereafter. All reconstructions had excellent graft take.

The median long-term follow-up time was 17 months. There have been no long-term complications reported. There were no bowel-related complications. All patients (100%) had successful graft take. Two patients (33%) developed stenosis or a stricture recurrence, including one FTM patient requiring surgical revision of the neourethra and the single vaginoplasty patient requiring vaginal dilation and botulinum toxin injection.

Discussion

To our knowledge, this is the first use of R-TAMIS technique for harvest of rectal mucosa graft. This novel technique allows for a technically feasible harvest with access to large graft size, with minimal to no morbidity. The robotic approach with wristed instruments affords the benefit of technical ease of operation within a confined space such as the rectum. Single-site surgery using the robotic platform has been previously described; however, this has traditionally been used for single-lesion excisions [27, 28, 30, 35]. The operating surgeon in this case is faced with the additional challenge of harvesting a large (usually 15 cm) graft and maintaining the submucosal plane within the narrow rectal lumen transanally. This procedure was previously performed by the author via TAMIS with laparoscopic instruments in one patient, and then the robotic approach was adapted as it was felt dexterity provided by robotic instruments, due to the da Vinci EndoWrist® technology, facilitated the ability to do submucosal dissection, harvesting a long (15-cm) strip in a confined space via a single-site approach. Simultaneously, customization of the transanal ports allows assistant access for effective retraction, injection, and suction. This study shows that R-TAMIS RMG harvest for the repair of long segment urethral strictures is a safe and feasible technique with large available graft size.

In our series of six patients on whom we have performed this operation thus far, none have had intraoperative or postoperative rectal complications. In this study, we had sufficient graft size and good quality for each. All patients have recovered well from the rectal mucosa harvest without complaints, morbidity, or mortality. They subjectively self-reported having less postoperative pain and better quality of life with this operation in comparison to their BMG harvests. Demonstrated feasibility with no morbidity or mortality, and possible avoidance of the negative sequelae associated with BMG harvest, warrants the continued application and evaluation of the R-TAMIS technique, and determination of its long-term results.

Limitations of this study include its small sample size and single surgeon (both colorectal surgeon and urologist) experience at a single institution. In addition, unfortunately, operative times specific to this aspect of the procedure were not available, as the operative times recorded included all aspects of the case (urologic and plastics teams' dissection, graft implantation, and reconstruction).

Because of its promising results and the ability to be completed at any robotic center, we hope this technique can be employed on a more widespread basis in the future at reconstructive urology centers, and thus, prospective multicenter studies with long-term follow-up data can confirm our favorable results. Future prospective studies are needed to provide long-term results and comparisons between buccal and rectal graft outcomes (including graft success, donor site morbidity, patient experience, postoperative pain), and between TAMIS with laparoscopic instruments and robotic TAMIS harvest methods.

Conclusion

To our knowledge, this is the first use of R-TAMIS for rectal mucosa harvest. Our preliminary series indicates this approach is feasible and safe, constituting a promising technique for urethral reconstruction in both transgender and cisgender patients. Prospective studies evaluating graft outcomes and donor site morbidity with more long-term follow-up are needed.

Compliance with ethical standards

Disclosures Drs. Zhao, Weinberg, Granieri, Bernstein, Grucela, and Ms. Howard have no conflicts of interest or financial ties to disclose.

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