Future Directions

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Abstract

Transanal total mesorectal excision (taTME) is a novel technique that has evolved over the years to address the challenges of low rectal cancer surgery by applying the principles and benefits of laparoscopic surgery to more historic transanal techniques. It has been popularized through its use in rectal cancer, but the transanal approach is slowly being expanded to tackle different clinical scenarios including benign conditions such as inflammatory bowel disease and endometriosis. For all of these new indications, it is the desire to access and begin the dissection in native tissue beyond the pathology which makes this approach applicable to other diseases where anatomy can be challenging. Training pathways to safely introduce taTME in a standardized manner are being developed and implemented in a bid to ensure adequate training to all the surgeons using this technique and thus minimize complications and patient morbidity. The future directions of this promising technique include the use of image and optical technological enhancement to aid navigation, the use of pneumorectum stabilization, and perhaps the use of fluorescence as a safety improvement. Developments have come also from the field of robotics. After a demonstration of feasibility in cadaver models, a growing experience has been gathered in the robotic approach to taTME, covered in the last part of this chapter.

Keywords

► taTME
► safety
► navigation
► fluorescence

Anatomic Extension of Transanal Dissection

General Principles in Transanal Dissection

Tissue dissection proceeds in a caudal to cranial manner, converse to the cranial to caudal approach employed in a traditional way with open or laparoscopic total mesorectal excision (TME) (►Fig. 1). Therefore, it is important to have a detailed understanding of the pelvic anatomy as this approach lends itself to unfamiliar views.1–3 In general terms, the transanal approach is most suitable for low rectal pathology, where the challenging anatomy of the deep pelvis can be visualized from a better vantage point. However, the technique is evolving fast and the transanal platform is already being used in different clinical scenarios.

While cancer resection follows the principles of TME whereby the avascular plane surrounding the mesorectum is dissected, benign pathology allows for a less stringent resection. In inflammatory bowel disease, proctectomy is often performed through a close rectal dissection which may spare the nerves supplying the bladder and sexual organs.4 The same principles of benign and cancer resection can be applied transanally. In benign disease, the surgical specimen is often described as a “poor TME” specimen.

Malignant Disease

This indication is covered extensively elsewhere, in brief, surgery in this context presents a special technical challenge to ensure a complete oncological specimen. Adding to this is the constraints of the narrow pelvis which often reduces operating space and eliminates optimal views. Low rectal tumors represent therefore one of the conditions with the highest technical complexity. This explains the interest in developing a novel technique to address these challenges.
Inflammatory Bowel Disease

Surgery for inflammatory bowel disease has also started to be approached transanally.5,6 Laparoscopic surgery is increasingly advocated as the mainstay of therapy in inflammatory bowel disease,7–9 as it is associated with benefits in the reduction of adhesions, better preserved female fecundity, and reduced incidence of hernias.7,8 However, some technical aspects of the surgery remain difficult to perform, even for experienced surgeons. The transanal approach to the distal rectum can be employed to overcome some of the unmet needs of pouch surgery: the transection of the distal rectum, the creation of the ileal pouch–anal anastomosis (IPAA), and the preservation of nervous fibers during dissection.10

The rectotomy can be performed at a level selected based on the tissue necessary for anastomosis, avoiding long rectal cuffs that could favor disease recurrence. This eliminates the challenge of rectal transection with a stapling device low in the pelvis when there can be little room to maneuver the device safely and efficiently. The anastomosis is created without tension and using a purse-string on the rectum avoids the redundant tissue in the extremities that would be created by a staple line. The inferior hypogastric plexus surrounds the mesorectum diagonally downwards from around 6 to 8 cm from the anal verge. Avoidance of this anatomical landmark is possible using the transanal approach. It is important to underscore that in the case of benign disease there is no need to respect the mesorectal plane.

There are now several promising reports on completion proctectomy with IPAA surgery using the transanal approach.5,11–15 Multiple groups have shown its feasibility5,11,13 and results with long-term follow-up are being accrued. Leo et al11 applied the transanal approach to 16 patients, achieving a conversion rate of 18.7% and a median of hospital stay of 6 days. This series recorded surgical morbidity at 37.5% with Clavien-Dindo grade I in 4 patients, grade II in 1 patient, and grade III in 1 patient. de Buck van Overstraeten et al12 have demonstrated retrospectively in a study with 216 patients that a transanal IPAA has lower morbidity on the Comprehensive Complication Index (odds ratio [OR] 0.52) when compared with open IPAA. No significant differences were found in leak rates. The published experience so far focuses on early postoperative morbidity and therefore could underestimate at present the value of a minimally invasive approach in avoiding subsequent episodes of small bowel occlusion. In severe or refractory perianal Crohn’s disease proctectomy may be necessary. This may also be accomplished via a transanal approach (transanal minimally invasive proctectomy). It was shown to be feasible in 40 patients from the international TaTME registry.16 Intraoperatively, complications in the transanal dissection were: bleeding (12.5%), incorrect plane (15%), issues with smoke extraction (12.5%), and issues with pneumopelvis maintenance (10%). This approach was safe, with 75% of patients showing no complications. Six patients had Clavien-Dindo grade II complications and one patient had a grade III complication.

**Rectovaginal Endometriosis**

Rectovaginal endometriosis presents particular difficulties in surgical access due to the obliteration of normal anatomical spaces like the pouch of Douglas.17 High perioperative morbidities (40–50%)18 are associated with colorectal resection in this context, with a high risk of damaging neighboring structures. Surgical intervention is reserved for failure of conservative management, extensive deep endometriosis in the rectum, and significant decrease in health-related quality of life. Surgery is technically very demanding, with distortion of normal anatomy and disruption of the planes the pelvic surgeon is familiar with. Although there is a move toward less radical surgery in complex rectovaginal disease, some patients will still require a formal bowel resection, and these are usually in the low pelvis. Interestingly, the tissues beyond

![Fig. 1 Rectal magnetic resonance imaging (MRI) depicting cranial to caudal approach (arrow) and the caudal to cranial approach (arrow head).](image-url)
the endometriotic nodule are usually compliant which makes a “bottom-up” approach attractive. Proposed benefits from the transanal approach in this context are avoiding damage to ureter and vagina, better nerve preservation, less conversions, and less permanent colostomies. The feasibility of this technique has already been demonstrated with early reports showing promising results. In the first published series of transanal approach to endometriosis surgery, 5 cases of transanal approach were compared with 6 cases of conventional low anterior resection. The transanal group presented no morbidity and no significant difference in terms of procedure duration. There were no conversions in the transanal group and quality of life at a mean follow-up of 13.5 months showed no significant difference. While further data are necessary, it seems the transanal approach might be a good option for the endometriosis surgeon in selected patients.

Other Indications
Indications for this approach are continuing to grow with time. The laparoscopic reversal of a Hartmann’s procedure has been demonstrated to achieve less short-term complications than open reversal in terms of overall morbidity, wound infection, and postoperative ileus. The technique for combined laparoscopic and transanal Hartmann’s reversal has been described and the first outcomes have been published recently. Ten patients were submitted to this procedure: there was no morbidity in 7 patients and only 1 Clavien-Dindo IIIA morbidity due to a parastomal abscess drained percutaneously. The mean length of hospitalization was 7.2 days. Given the considerable interest in the transanal approach, there is a very important need for useful learning guides. App-based teaching tools and online platforms have provided fundamental contributions to dissemination of knowledge about this new technique.

Technological Improvements
Navigation
The narrow confines of the pelvis increase the difficulty of dissection in this area which has often been a problem with laparoscopy using conventional straight instruments. The transanal approach offers several advantages to tackle this challenge. However, progression in the dissection still occurs through visual identification of anatomical landmarks. An interesting approach has been to use navigation technology already employed in neurosurgery and orthopedic surgery to guide the surgeon through the complex intricate anatomy of the pelvis. Initial pilot data has shown this technique to be feasible with an accuracy of ± 4 mm and achieving an R0 resection in T4 low rectal tumors. A preoperative model of the patient’s anatomy is created through imaging and is used during surgery to accurately guide dissection. This implies the use of fiducial markers in anatomical landmarks that suffer minimal movement. It is possible to base the navigation on preoperative scans or on scans obtained per-operatively with hybrid theaters. After this first description, three cases of locally advanced rectal cancers have been described with no intraoperative complications, Quirke 3 pathological specimens, and an accuracy of between ± 3.20 and ± 4.02 mm. The use of navigation for the excision of a serous cyst adenofibroma beneath the peritoneal reflection has also been reported, with an accuracy of ± 1.8 mm. The average navigation setup time was 47 minutes. Patient positioning during preoperative image acquisition and during surgery varies significantly. Wijsmuller et al. described the variation in anatomy between the supine position, reflecting the position in which preoperative image acquisition occurs; and varying degrees of lithotomy position, reflecting intraoperative positioning. The difference measured between different positions was up-to-supracentimetric and there was a significant variation in the skin fiducial positioning. The use of a 10-degree wedge under the pelvis compensated sacral tilt, significantly improving the accuracy of stereotactic navigation. There is a great interest in developing this technique but it is still in a very early phase and not available outside the scope of scientific research. Specific obstacles to be tackled in the future are the plastic deformation of soft tissue organs, real-time resynchronization of imaging to match the progress of the surgery, overall precision, and the achievement of stable landmarks.

Image Quality and Optics
These are important determinants of surgical success and continuous improvement has been occurring in the imaging platforms for endoscopic surgery that enhance the surgeon’s view. This improvement has made platforms such as 4K definition and three-dimensional imaging possible with improvements already documented in laparoscopy. These platforms have been tested in small samples so their role in improving patient outcomes is still unquantified in transanal TME (tTaM); however, they are felt to allow better tissue discrimination perhaps improving nerve and small vessel preservation.

Safety Improvements
To be advantageous, the transanal approach needs to have a favorable profile in terms of complications and the means to avoid them. Continuous advances are being made in the safety of the procedure as feared complications, such as presacral hemorrhage, urethral injury, and autonomic nervous plexus damage, provide a powerful reason for improvement. There is a current lack of standardized measures of performance and prevention of injury. As such, it is important to stress the need for a comprehensive training program to implement the technique. Some strategies have been developed: pneumorectum stabilization, identification of triangles and O’s, and finally fluorescence guidance. Evidently, no section on safety of surgical technique can be complete without addressing the learning process. Even though this topic is further discussed elsewhere (see also “Learning Transanal Total Mesorectal Excision” (pp. 168)), it is fundamental to emphasize that potentially serious morbidity may be caused by tTaM. It is therefore imperative that
standardized training pathways are created with official guidance and certification by the competent bodies.\textsuperscript{6,33,34} Also, as the uptake of taTME increases worldwide, it is important to disseminate the experience of the technique to allow a continuous improvement. The record of taTME cases in a prospective registry\textsuperscript{35} enables the early identification of trends and solutions to allow rapid dissemination.

**Pneumorectum stabilization:** TaTME has a working space gained millimeter by millimeter expanding from the rectotomy until reaching the pelvic inlet. This closed space receives CO\textsubscript{2} to expand and allow surgical manipulation. Maintenance of CO\textsubscript{2} in this cavity (pneumorectum) is therefore essential. Cyclical insufflators create an unstable pneumorectum by allowing discontinuous insufflation and accumulation of smoke from dissection. The utilization of a system for continuous insufflation, with a valveless trocar, allows these two obstacles to be overcome. With a continuous pneumorectum the structures will not collapse, and the billowing effect of the rectum will be reduced.\textsuperscript{36} Furthermore, the workflow is improved as the pauses for smoke extraction are diminished. A recent expert consensus panel has recommended initiating the transanal approach with a low pressure/low smoke evacuation level until the rectal purse-string is performed and then switching to higher CO\textsubscript{2} pressure and smoke evacuation levels.\textsuperscript{9} A word of caution on the effects of the pneumorectum, as this has been described to cause a pneumodissection along soft tissues in a robotic taTME resulting in abdominal distension with need for conversion.\textsuperscript{37} The authors hypothesized this to be the effect of prolonged operative time.

**Triangles and O’s\textsuperscript{38}:** These are concepts designed to aid in the identification of the correct plane of dissection. When adequate traction is exerted on the rectum, the mesorectal plane will produce a triangle with a base oriented outwards and a tip oriented to the correct plane of dissection. The O sign appears when cautery is used for dissection in a fascial plane. This therefore signals that the dissection is not occurring in the correct plane. On encountering this appearance, the surgeon is advised in continuing in another direction.

**Fluorescence:** The use of indocyanine green (ICG) in digestive surgery is a fast-growing field.\textsuperscript{39} When administered intravenously, ICG, the most commonly used fluorophore, binds to albumin. Blood vessels and blood flow are highlighted and therefore its most common current application is in the assessment of tissue perfusion. Local ischemia is a factor known to be associated with anastomotic leak.\textsuperscript{40,41} ICG is therefore used to evaluate the mobilized colon to ensure adequate perfusion. It may be necessary to section the colon more proximally than previously decided in the presence of low perfusion, as evidenced by a lack of fluorescence. This technique has an easy implementation in the theater workflow as it achieves results rapidly and with minimal logistic requirements. A specialized light source and receiver allow the excitation of the fluorophore and the detection of the emitted fluorescence, respectively. To date, intraoperative fluorescence has been shown to change to transection point of the proximal colon in low colorectal anastomosis in 8% of patients in the PILLAR II study, which included 147 patients submitted to left hemicolectomy or anterior resection.\textsuperscript{42} A meta-analysis has documented a significant reduction in the risk of anastomotic leak\textsuperscript{43}: an OR for leak in colorectal surgery of 0.34 and a 5.0% lower risk of leak in rectal cancer surgery, both statistically significant. Other potential use of fluorescence is to avoid urethral injuries during transanal dissection. In the taTME registry, this procedure-specific complication has been found in 12 of 1,594 cases (0.8%).\textsuperscript{44} The use of a lighted stent inserted through the urethra has been described as a mean to avoid these injuries.\textsuperscript{45} In a Thiel-embalmed cadaver, this has been described\textsuperscript{46} to help identify when dissection is occurring close to the urethra using normal intensity lighting, whereas the light must be turned off to help identify the urethra when the dissection is proceeding far from this structure. The use of the ICG\textsuperscript{47} and IRDye800BK\textsuperscript{48} fluorophores in cadavers as a means of identifying the urethra has also been described.\textsuperscript{47} The methods for fluorophore administration were either direct urethral injection or injection of a suspension of ICG or IRDye800BK into a urinary catheter. These studies have yet to be replicated in vivo.

**Robotic Approach to TaTME**

The robotic platform offers some unique advantages to taTME. The Da Vinci robotic instruments allow a higher degree of intrapelvic maneuverability through enhanced stability and the EndoWrist technology. Common surgical maneuvers are reliably performed transanally in this setting, as already documented in cadaveric experiments.\textsuperscript{49} Clinical experience has been documented in the use of a robotic approach to transanal surgery through retrospective series,\textsuperscript{37,50} comprising both benign (rectourethral fistula, anastomotic fistula, and benign neoplasms) and neoplastic disease. In this series, there was only one intraoperative complication with pneumoperitoneum requiring conversion. No major postoperative complications (Clavien-Dindo classification III or higher) occurred. The renewed interest in local excisions in the rectum may prove to be an area where the robotic approach would be best used.\textsuperscript{49} Uptake of robotic technology for the abdominal phase of taTME still has not become widespread, as shown by the negligible percentage of cases reported in a retrospective series\textsuperscript{51} and in the international TaTME registry.\textsuperscript{35}

**Conclusion**

Transanal surgery is an exciting novel technique which has expanded its role from cancer to benign disease including inflammatory bowel disease and restoration of digestive continuity after Hartmann’s procedure. Technological advances of this technique, although in its infancy, will surely provide impetus for further improvement by expanding the surgeon’s capabilities to deliver these interventions. Navigation technology seems a very promising combination with the robotic approach. Importantly, safety improvements have been a core aim of the implementation of this approach, and despite some reports of iatrogenic injury, it has been one of the most regulated procedures introduced in colorectal surgery with excellent training pathways being implemented and delivered.
Pneumorectomy stabilization, safe dissection technique, and the use of fluorescence-guided surgery have made important contributions for the benefit of the patients. In the future, data processing through machine-learning techniques will become extremely useful tools in surgery, and have the potential to drastically change the current standards. The combination of all these innovations is expected to have a big impact in patient care in the future.

Conflict of Interest
None declared.

References
1. Atallah S, Albert M, Monson JRT. Critical concepts and important anatomic landmarks encountered during transanal total mesorectal excision (taTME): toward the mastery of a new operation for rectal cancer surgery. Tech Coloproctol 2016;20(07):483–494
2. Clausen N, Wollosocheck T, Konenning MA. How to optimize autonomic nerve preservation in total mesorectal excision: clinical topography and morphology of pelvic nerves and fasciae. World J Surg 2008;32(08):1768–1775
3. Aigner F, Hörmann R, Fritsch H, et al; TAMIS TME Collaboration Group. Anatomical considerations for transanal minimal-invasive surgery: the caudal to cephalic approach. Colorectal Dis 2015;17(02):047–053
4. Bartels SAL, Gardenbroek TJ, Aarts M, et al. Short-term morbidity and quality of life from a randomized clinical trial of close rectal dissection and total mesorectal excision in ileal pouch-anal anastomosis. Br J Surg 2015;102(03):281–287
5. Carvello M, David C, Sacchi M, Di Candido F, Spinelli A. Restorative proctectomy and IPAA for right sided colonic adenocarcinoma on FAP: abdominal laparoscopic approach combined with transanal total mesorectal excision - video vignette. Color Dis 2018. Doi: 10.1111/codi.14024
6. Adamina M, Buchs NC, Penna M, Hompes R. Group on behalf of the SGCCE. St.Gallen consensus on safe implementation of transanal total mesorectal excision. Surg Endosc 2018;32(03):1091–1103
7. Øresland T, Bemelman WA, Sampietro GM, et al; European Crohn’s and Colitis Organisation (ECCO). European evidence based consensus on surgery for ulcerative colitis. J Crohn’s Colitis 2015;9(01):4–25
8. Bemelman WA, Warusavitarne J, Sampietro GM, et al. ECCO-ESCP Consensus on Surgery for Crohn’s Disease. J Crohn’s Colitis 2018;12(01):1–16
9. Maggiori L, Panis Y. Surgical management of IBD–from an open to a laparoscopic approach. Nat Rev Gastroenterol Hepatol 2013;10(05):297–306
10. Spinelli A. Transanal Pouch Surgery - AIS Channel Winter Event 2017. Published 2017. Available at: https://aischannel.com/conference/winter-event-2017-transanal-pouch-surgery/. Accessed October 9, 2019
11. Leo CA, Samaranyake S, Perry-Woodford ZL, et al. Initial experience of restorative proctocolectomy for ulcerative colitis by transanal total mesorectal excision and single-incision laparoscopic proctectomy. Colorectal Dis 2016;18(12):1162–1166
12. de Buck van Overstraeten A, Mork-Christensen A, Wasmann KA, et al. Transanal versus transabdominal minimally invasive (completion) proctectomy with ileal pouch-anal anastomosis in ulcerative colitis: a comparative study. Ann Surg 2017;266(05):878–883
13. de Buck van Overstraeten A, Woltthus AM, D’Hoore A. Transanal completion proctectomy after total colectomy and ileal pouch-anal anastomosis for ulcerative colitis: a modified single stapled technique. Colorectal Dis 2016;18(04):0141–0144
14. Tasende MM, Delgado S, Jimenez M, et al. Minimal invasive surgery: NOSE and NOTES in ulcerative colitis. Surg Endosc 2015;29(11):3313–3318
15. Liyanage C, Ramwell A, Harris GJ, Levy BF, Simson JNL. Transanal endoscopic microsurgery: a new technique for completion proctectomy. Colorectal Dis 2013;15(09):e542–7
16. Pellino G, Sahnan K, Penna M, Adegbola S. P605 Transanal minimally invasive proctectomy (TaMIP) in patients with Crohn’s disease: a cohort study from the TaTME international database. Journal of Crohn’s and Colitis 2018;12(Suppl 1):S415
17. Vlek SL, Lier MCI, Koedam TWA, et al. Transanal minimally invasive rectal resection for deep endometriosis: a promising technique. Colorectal Dis 2017;19(06):576–581
18. Meuleman C, Tomassetti C, D’Hoore A, et al. Surgical treatment of deeply infiltrating endometriosis with colorectal involvement. Hum Reprod Update 2011;17(03):311–326
19. Celentano V, Giglio MC, Bucci L. Laparoscopic versus open Hartmann’s reversal: a systematic review and meta-analysis. 2015;30(12):1603–1615
20. Bravo R, Fernández-Hevia M, Jiménez-Toscano M, et al. Transanal Hartmann reversal: a new technique. Surg Endosc 2016;30(06):2628–2631
21. Trépanier J-S, Arroyave MC, Bravo R, et al. Transanal Hartmann’s colostomy reversal assisted by laparoscopy: outcomes of the first 10 patients. Surg Endosc 2017;31(12):4981–4987
22. Atallah S, Brady RR. The iLabSurgery taTME app: a modern adjunct to the teaching of surgical techniques. Tech Coloproctol 2016;20(09):665–666
23. DeLacy FB, Nehme J, Lacy AM, Chand M. Educational technology: revolutionizing surgical education. Br J Hosp Med (Lond) 2017;78(08):426–427
24. Chand M, Heald RJ. Laparoscopic rectal cancer surgery. Br J Surg 2011;98(02):166–167
25. Chand M, Moran B, Wexner SD. Which technique to choose in the high-tech era of minimal-access rectal cancer surgery? Colorectal Dis 2016;18(09):839–841
26. Atallah S, Nassif G, Larach S. Stereotactic navigation for TAMIS-TME: opening the gateway to frameless, image-guided abdominal and pelvic surgery. Surg Endosc 2015;29(01):207–211
27. Atallah S, Martin-Perez B, Larach S. Image-guided real-time navigation for transanal total mesorectal excision: a pilot study. Tech Coloproctol 2015;19(11):679–684
28. Atallah S, Tilahun Y, Monson JRT. Real-time stereotactic navigation for the laparoscopic excision of a pelvic neoplasm. Tech Coloproctol 2016;20(08):599–600
29. Wijsmuller AR, Romagnolo LG, Aghasv, et al. Advances in stereotactic navigation for pelvic surgery. Surg Endosc 2018;32(06):2713–2720
30. Kawada K, Hasegawa S, Okada T, Hida K, Okamoto T, Sakai Y. Stereotactic navigation during laparoscopic surgery for locally recurrent rectal cancer. Tech Coloproctol 2017;21(12):977–978
31. Buchs NC, Hompes R. Stereotactic navigation and augmented reality for transanal total mesorectal excision? Colorectal Dis 2015;17(09):825–827
32. Sörensen SMD, Savran MM, Konge L, Bjerrum F. Three-dimensional versus two-dimensional vision in laparoscopy: a systematic review. Surg Endosc 2016;30(01):11–23
33. Transanal total mesorectal excision of the rectum | Guidance and guidelines | NICE. Available at: https://www.nice.org.uk/guidance/ipg514. Accessed March 4, 2018
34. McLemore EC, Harnsberger CR, Broderick RC, et al. Transanal total mesorectal excision (taTME) for rectal cancer: a training pathway. IPAP Surgery taTME app: a modern adjunct to the teaching of surgical techniques. Tech Coloproctol 2016;20(09):665–666
pneumatic insufflation encountered during transanal total mesorectal excision. Tech Coloproctol 2017;21(10):783–794
37 Atallah S, Martin-Perez B, Parra-Davila E, et al. Robotic transanal surgery for local excision of rectal neoplasia, transanal total mesorectal excision, and repair of complex fistulae: clinical experience with the first 18 cases at a single institution. Tech Coloproctol 2015;19(07):401–410
38 Bernardi MP, Bloemendaal ALA, Albert M, Whiteford M, Stevenson ARL, Hompes R. Transanal total mesorectal excision: dissection tips using ‘O’s and ‘triangles’. Tech Coloproctol 2016;20(11):775–778
39 Keller DS, Cohen R, Chand M, et al. Indocyanine green fluorescence imaging in colorectal surgery: overview, applications, and future directions. Rev Lancet Gastroenterol Hepatol 2017;2(02):757–766
40 Sheridan WG, Lowndes RH, Young HL. Tissue oxygen tension as a predictor of colonic anastomotic healing. Dis Colon Rectum 1987;30(11):867–871
41 Vignali A, Gianotti L, Braga M, Radaelli G, Malvezzi L, Di Carlo V. Altered microperfusion at the rectal stump is predictive for rectal anastomotic leak. Dis Colon Rectum 2000;43(01):76–82
42 Jafari MD, Wexner SD, Martz JE, et al. Perfusion assessment in laparoscopic left-sided/anterior resection (PILLAR II): a multi-institutional study. J Am Coll Surg 2015;220(01):82–92.e1
43 Blanco-Colino R, Espin-Basany E. Intraoperative use of ICG fluorescence imaging to reduce the risk of anastomotic leakage in colorectal surgery: a systematic review and meta-analysis. Tech Coloproctol 2018;22(01):15–23
44 Penna M, Hompes R, Arnold S, et al. Incidence and risk factors for anastomotic failure in 1594 patients treated by transanal total mesorectal excision. Ann Surg 2019;269(04):700–711
45 Atallah S, Martin-Perez B, Drake J, Stotland P, Ashamalla S, Albert M. The use of a lighted stent as a method for identifying the urethra in male patients undergoing transanal total mesorectal excision: a video demonstration. Tech Coloproctol 2015;19(06):375–375
46 Okada T, Kawada K, Nakamura T, et al. A cadaveric demonstration of visualization of the urethra using a lighted stent during transanal intersphincteric resection. Int Cancer Conf J 2018;7(03):77–80
47 Barnes TG, Penna M, Hompes R, Cunningham C. Fluorescence to highlight the urethra: a human cadaveric study. Tech Coloproctol 2017;21(06):439–444
48 Barnes TG, Volpi D, Cunningham C, Vojnovic B, Hompes R. Improved urethral fluorescence during low rectal surgery: a new dye and a new method. Tech Coloproctol 2018;22(02):115–119
49 Hompes R, Rauh SM, Hagen ME, Mortensen NJ. Preclinical cadaveric study of transanal endoscopic da Vinci® surgery. Br J Surg 2012;99(08):1144–1148
50 Atallah S, Martin-Perez B, Pinan J, et al. Robotic transanal total mesorectal excision: a pilot study. Tech Coloproctol 2014;18(11):1047–1053
51 Marks JH, Myers EA, Zeger EL, Denittis AS, Gummadi M, Marks GJ. Long-term outcomes by a transanal approach to total mesorectal excision for rectal cancer. Surg Endosc 2017;31(12):5248–5257
52 Maier-Hein L, Vedula S, Speidel S, et al. Surgical data science: enabling next-generation surgery. Nat Biomed Eng 2017. Doi: arXiv:1701.06482
53 Hashimoto DA, Rosman G, Rus D, Meireles OR. Artificial intelligence in surgery. Ann Surg 2018;268(01):70–76