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Review

Transanal total mesorectal excision for rectal cancer:

The journey towards a new technique and its current status

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Abstract

Introduction: The surgical approach to total mesorectal excision (TME) for rectal cancer has undergone a substantial evolution with the adoption of more minimally invasive procedures. Transanal TME (taTME) is the latest advanced technique pioneered to tackle difficult pelvic dissections.

Areas covered: The evolution of TME surgery from open to laparoscopic, robotic and transanal techniques was explored in this review. The outcomes to date on the latest approach, taTME, are reviewed and the future direction of rectal cancer surgery proposed. A literature search was performed using Embase, Medline, Web of Science and Cochrane databases for articles published between January 2005 to May 2016 using the keywords “transanal”, “TME”, “laparoscopy”, “robotics”, “minimally invasive”, “outcomes” and “training”.

Expert Commentary: Surgical experience in taTME is growing and randomised controlled trials have been planned and initiated worldwide. However, the learning curve for this procedure remains to be established and a structured training programme is necessary to ensure safe introduction and dissemination of the technique in the clinical setting. Further innovation including stereotactic navigation and more specialised transanal equipment are currently being explored and are likely to enhance the technique further.

Keywords

Transanal, TME, bottom up, laparoscopy, robotics, evolution, training, outcomes, future direction.

1. Introduction

With an estimated 1.36 million new cases diagnosed annually, colorectal cancer remains the third most common cancer worldwide [1]. The treatment and management of rectal cancer in particular have greatly evolved over the last few decades with increased use of neoadjuvant chemoradiotherapy, adoption of more minimally invasive surgical approaches and even a ‘watch and wait’ strategy in selected cases. The gold standard approach to rectal cancer surgery, however, has remained the same; a complete total mesorectal excision (TME) as described by Professor Heald in 1979 [2]. Clear distal (DRM) and circumferential resection margins (CRM) together with high quality TME are paramount for optimal oncological outcomes with reduced locoregional recurrence rates and improved cancer-free survival [3-5]. A number of tumor and patient related factors can pose significant challenges to the surgical resection with a subsequent increased risk of obtaining a poor TME specimen and positive margins. The strive to overcome these technical difficulties has led to the development and implementation of more advanced surgical techniques including laparoscopic, robotic and transanal approaches.

Transanal TME (taTME), also known as ‘bottom up TME’, hybrid natural orifice transluminal endoscopic surgery (NOTES) and transanal minimally invasive surgery (TAMIS) TME, is the latest technique designed to tackle difficult pelvic dissections. Although primarily pioneered for rectal cancer, the approach has also been adopted for benign conditions such as Familial Adenomatous Polyposis, inflammatory bowel

disease, deep pelvic endometriosis and difficult recto-vaginal fistula. The evolution of taTME is a great example of the process and steps required to develop and safely introduce a new surgical technique into practice, as outlined by the IDEAL (Innovation, Development, Exploration, Assessment, Long-term study) framework [6]. This article explores the evolution of TME surgery, current published outcomes and future work and direction.

2. Material and Methods

Literature

A literature search was performed using Embase, Medline, Web of Science and Cochrane (2014 Issue 3) databases for articles published between January 2005 to May 2016. The keywords searched included “transanal”, “TME”, “laparoscopy”, “robotics”, “minimally invasive”, “outcomes” and “training” in combination with the Boolean operators AND or OR. Only English articles describing techniques performed for TME surgery were included; reports of local excision were excluded. The details of each operative procedure were reviewed and discussed.

3. Evolution of TME

The practice of colorectal surgery has undergone significant changes over the last 30 years. Following extensive development and implementation programs, minimally invasive approaches, particularly laparoscopic surgery, are now established standard of care in many colorectal units. The adoption of laparoscopic surgery has been a long process due to initial scepticism regarding the new technique and its steep learning curve. With time, multiple studies demonstrated numerous short term advantages of the laparoscopic approach over open abdominal surgery, including less postoperative

pain, fewer wound infections and shorter hospital stay [7]. Consequently, laparoscopic practice has continued to increase over the years. In the PROCARE rectal cancer registry, which collects data from 82 Belgian hospitals, the use of laparoscopy for rectal cancer resections increased from 22% to 38% between 2006 and 2011 [8]. In the United Kingdom (UK), a national training programme for laparoscopic colorectal surgery (LAPCO), funded by the British government, was established in 2008 after acknowledging the benefits of this less invasive technique and the need for structured supervised training [9]. Thanks to the national training program, Hospital Episodes Statistics (HES) data have shown an impressive rise in laparoscopic colorectal activity in England from less than 5% in 2005 to 40% in 2012; a world-leading figure of implementation [10].

Despite the increase in laparoscopic training and the benefits seen in colonic surgery, the evidence so far has not convincingly shown laparoscopy to be superior to the open approach in studies for rectal cancer [11,12]. This is clearly a reflection that rectal cancer surgery is one of the most difficult colorectal operations, posing unique challenges to the surgeon.

3.1 Challenges of rectal cancer surgery

Cecil et al. [13], subdivided features that affect the suitability for laparoscopic TME as surgeon, patient and tumor related factors based on a literature review and personal experience. Male, obese patients with a narrow pelvis and previous abdominal surgery together with a fixed, bulky and low rectal tumor pose the greatest level of difficulty with a higher risk of intra-operative complications and poor histological outcomes. These features present technical challenges during both laparoscopic and open surgery, i.e. a “top-down” approach, due to the limited operating space encountered

from above that leads to inadequate visualisation and poor exposure of the mesorectal plane. This poses a risk not only to the mesorectum and rectal tube but also to the nearby nerves that control bowel, urinary and sexual function. The fixed bony structure of the pelvis can also impede the introduction of instruments down a narrow area resulting in insufficient angulation of the tip of the instruments and thus rendering accurate dissection more difficult. For similar reasons, distal rectal transection using the current laparoscopic stapling devices can also be a challenge in low tumors. As demonstrated by augmented reality reconstruction, a stapler inclination of at least 65° is required to enable optimal, perpendicular firing [14]. A less acute angle will lead to multiple firings in a “zigzag” manner in order to complete the full rectal transection. Ito et al demonstrated that the risk of anastomotic leak increases five-fold if more than two firings are required [15]. Furthermore, operating in a deep pelvis for long hours standing can place significant strain on both the surgeon and surgical assistants leading to musculoskeletal pain (especially of the back and shoulders), visual strain and varicose veins.

3.2 Laparoscopic versus Open TME surgery

The Colorectal Cancer Laparoscopic or Open Resection (COLOR) II trial reported on the short-term outcomes between laparoscopic and open surgery in 1103 patients operated on at 30 centres in eight countries [16]. Patients in the laparoscopic arm had significantly less blood loss, earlier return of bowel function and shorter hospital stay. However, the operative time for this group was longer compared to the open arm and both overall morbidity and mortality within 28 days were similar. The short-term oncological end points did show non-inferiority for laparoscopy with an overall positive CRM rate of 10% in each group and similar rates of completeness of the

TME specimen (88% vs. 92% for laparoscopic vs. open; $p=0.250$). Importantly, CRM involvement reached as much as 22% in open low rectal cancer cases. Positive CRM rates of 16% were found in the earlier Medical Research Council (MRC) CLASICC trial [17], but short-term oncological outcomes did not reach statistical significance. Long-term results of the CLASICC trial reported a slightly better median overall survival in the laparoscopic group (82.7 vs. 78.3 months), but found no difference in recurrence rate or disease-free survival, and once again results were not statistically different between the two groups [18]. Long-term 3-year rates of cancer recurrence, disease-free survival and overall survival from the COLOR II trial also did not find any statistically significant difference between open and laparoscopic surgery in rectal cancer patients [19].

Two more recent randomized controlled trials (RCT), ACOSOG Z6051 [11] and ALaCaRT [12], were unable to demonstrate non-inferiority of laparoscopic TME to open TME for histopathological outcomes and morbidity in stage II and stage III rectal cancer patients. The positive CRM rate for laparoscopic versus open TME surgery in these trials was 12.1% vs. 7% and 7.7 vs. 3%, respectively. High conversion rates from laparoscopic to open surgery, which is known to increase postoperative morbidity and lead to a poorer oncological outcome [16,17], have also been reported in the COLOR II [16] and ACOSOG Z6051 [11] trials, 16% and 11.3% respectively. Furthermore, an interesting study by Bondeven et al. [20] performed magnetic resonance imaging (MRI) before and after surgery on 136 patients who had undergone rectal cancer operations and correlated the scan findings to the corresponding resected TME specimens. Results showed that almost 40% of patients still had residual mesorectum even after “TME” surgery, posing an increased risk of local tumor recurrence in these patients.

A recent observational study by Askari et al. analyzed the national administrative data set (HES database) including all elective hospital admissions in England between 2001 and 2011 [21]. A total of 141,692 patients underwent elective surgery for colorectal cancer, of which 71,645 (51%) were rectal operations and 29,550 (20.9%) of all procedures were performed laparoscopically. The median survival in the open and laparoscopic groups was 36.1 months versus 64.1 months respectively ($p < 0.001$). Patients who underwent laparoscopic resection were 18% less likely to die than patients who had open surgery at 10 years, and the survival benefit was irrespective of age and administration of adjuvant chemotherapy. Cox survival analyses showed laparoscopy to be an independent predictor of survival. On the other hand, the latest Cochrane review comparing laparoscopic versus open TME for only rectal cancer cases included 14 studies with a total of 3528 patients, and found moderate quality evidence that laparoscopy lead to better short-term post-surgical outcomes in terms of recovery for non-locally advanced rectal cancer, but similar effects to open TME on long term survival and recurrences [22].

3.3 Hand-assisted and Robotic approaches

Two main approaches were developed to try to overcome the challenges of rectal surgery including hand-assisted surgery and robotic surgery [23]. Although hand-assisted surgery can reduce operative time and facilitate exposure and visualisation of the dissection plane, the larger incision may obviate certain benefits of laparoscopic surgery such as wound infection rates and post-operative pain. Smaller laparoscopic-sized incisions can be maintained using the robot, although at least two additional trocars are usually required. The advantages of the robotic system are its excellent 3-dimensional images, higher degree of dexterity, dual-console trainer for teaching that

can reduce the learning curve, no hand tremor as well as surgeon comfort sitting at the console with less physical strain. However, the initial enthusiasm over the application of the robot to TME surgery is slowly dissipating, as study results so far have not been able to demonstrate a significant advantage of the robotic approach over laparoscopic TME surgery. One of the largest comparative studies in over 130 patients assessing long-term oncologic outcomes of robotic low anterior resection for rectal cancer versus laparoscopic surgery found no statistically significant difference in peri-operative clinicopathological outcome as well as overall five-year survival, disease-free survival and local recurrence rates [24]. A previous meta-analysis comparing the two techniques had also concluded equivalence with respect to distal resection margin, mesorectal completeness and complications [25].

Recent findings from the ROLARR (Robotic versus Laparoscopic Resection for Rectal Cancer) trial [26] did not show robotic TME to be superior to laparoscopic TME surgery. The CRM involvement in the laparoscopic and robotic groups was similar with 6.3% and 5.1% (Odds ratio, OR, 0.79, CI 0.35–1.76). The conversion rate in the robotic arm was slightly lower at 8.1% compared to 12.2% in the laparoscopic group but this did not reach statistical significance (OR 0.61, CI 0.31–1.21, $p=0.158$). Although conversion rates tended to be lower in the robotic arm, on subgroup analysis rates still reached as high as 18.9% in obese patients and were never lower than 7% in any subgroup. Furthermore, the substantial cost of the robot needs to be taken into account. The initial capital required for the robotic system has been quoted between \$1.75 to \$2.25 million with an additional annual service contract and up to \$3000 more per procedure to cover the cost of disposable instruments [27]. Therefore, more impressive results from robotic TME surgery are required in order to justify its high cost.

3.4 Transanal TME approach and its indications

The quest for the optimal surgical technique to tackle difficult TME dissections now brings us to the most recent surgical innovation that has attracted much attention and is currently under the spotlight: transanal total mesorectal excision (taTME). The transanal approach to pelvic dissection was pioneered to overcome the inherent shortcomings of abdominal (“top-down”) dissection. Enthusiasts of this “bottom up” approach state that the technique offers clearer visualisation of the dissection plane even in a narrow pelvis, avoids excessive manipulation of the specimen to obtain exposure thus allowing a more precise and trauma-free dissection. This in turn has the potential to facilitate superior oncological resections as well as preserving the pelvic autonomic nerves with subsequent preserved bowel, urinary and sexual function. TaTME is not a completely new concept but rather, it was inspired and created from a combination of other techniques, namely transanal endoscopic microsurgery (TEM) [28], transanal transabdominal approach (TATA) [29], NOTES [30,31] and TAMIS [32].

Clear indications for the taTME approach have yet to be firmly established and varying opinion exists among surgeons performing this operation. An international group of surgeons with experience and expertise in taTME surgery published consensus statements following the second international taTME conference in 2014 [33]. They recommended that patient selection should include both benign and malignant conditions that require accurate pelvic dissection. Further, patient and tumor-related features that could benefit from the transanal approach include: (i) male

gender, (ii) narrow and/or deep pelvis, (iii) visceral obesity and/or a body mass index (BMI) $>30 \text{ kg/m}^2$, (iv) prostatic hypertrophy, (v) a tumour height of less than 12 cm from the anal verge, (vi) tumour diameter $>4 \text{ cm}$, (vii) distorted tissue planes due to neoadjuvant radiotherapy, and (viii) impalpable, low primary tumour requiring accurate placement of the distal resection margin. Contraindications to taTME were advised to included T4 tumors, obstructing masses and emergency rectal surgery. Results from randomised controlled trials will hopefully confirm the true benefits of the approach and help to confirm the indications and contraindications of taTME.

3.5 Initial TaTME studies

Extensive preliminary work in animal laboratories [34,35] and on human cadavers [31,36] was performed in order to demonstrate feasibility of the concept and establish the critical steps of the operation. Whiteford et al. [31] were the first in 2007 to describe the feasibility of a NOTES radical sigmoidectomy using the rigid TEM platform in human cadavers. More recently, the same authors published a comparative study calling for further surgical innovation for instrument design as they found conventional rigid TEM instrumentation to be inadequate for colonic mobilization [37]. Sylla et al. [34] was able to perform a more extensive left colonic mobilization by combining the NOTES transanal rectosigmoid resection with transgastric endoscopic assistance. These initial studies suggested the use of a hybrid transanal approach with laparoscopic assistance in order to permit more efficient splenic flexure mobilization and secure proximal vascular control. Subsequently, in 2010, Sylla et al reported the first human clinical case [38], calling the procedure 'NOTES transanal rectal cancer resection using trans-anal endoscopic microsurgery and laparoscopic assistance'. The following year, Gaujoux et al. [39] reported the first two cases of

proctectomy with TME and intersphincteric resection using only two ports (single port access at the stoma site and TEM rectoscope transanally), reporting excellent post-operative clinical and histological outcomes. The interest and adoption of taTME has grown ever since and evidence in the literature is expanding on this novel technique.

3.6 Current TaTME results

Since the initial reports of live taTME in 2010, the number of studies published by early expert adopters has rapidly increased describing their surgical technique and short-term oncological and clinical results. Rouanet et al [40] published one of the first larger prospective cohort series on transanal endoscopic proctectomy in 2013. Thirty men with advanced or recurrent low rectal tumors underwent a sphincter-sparing transanal endoscopic proctectomy. Although the mesorectal specimen was graded as good in all patients, R0 resection was achieved in 87% and conversion rates intra-operatively reached 6% and an overall morbidity rate of 30%. Importantly, two urethral injuries occurred in two patients at the beginning of the surgeons' experience. The authors commented that, although trained surgeons performed the transanal proctectomy, relatively poor early outcomes occurred including urethral injuries, which are virtually never seen with laparoscopic TME. However, it is important to note that exclusively high-risk patients were selected in this cohort with unfavourable anatomy and/or tumor characteristics, which also pose a significant challenge to the 'top-down' approach, particularly early in the surgeons' learning curve.

To date, Dr Antonio Lacy in Barcelona, who pioneered the technique and performed the first case with Dr Patricia Sylla in 2009, has the greatest experience with taTME and recently reported the largest series of 140 patients [41]. In this series, the mean

operative time was 166 minutes with no conversions and no serious intra-operative adverse events. The TME specimen was complete in over 97.1% of cases with a positive CRM rate of 6.4% and early local recurrence rate of less than 3% (mean follow up of 15 months). The authors recommended the two-team approach, an abdominal and a perineal team, as they can work together guiding each other during the pelvic dissection and shorten operative time.

A number of systematic reviews have also been published, such as that by Similis et al [42], including 36 studies (eight case reports, 24 case series, four comparative studies) with a total of 510 patients who underwent taTME for mostly rectal cancer except 16 cases of benign disease. Pure transanal TME (without laparoscopic assistance) was performed in 18 reported cases, whilst the hybrid approach mostly involved laparoscopic surgery. Several authors have evaluated robotic surgery for transanal rectal dissection [43-45], showing that the procedure, coined RATS-TME (Robotic Assisted Transanal Surgery for TME), is feasible. However, the potentially long set up and docking time and high financial burden remain a limitation. Results from Similis's systematic review appear very promising with overall morbidity and mortality rates comparable to those for laparoscopic TME surgery at 35% and 0.2% respectively [42]. Twelve conversions from laparoscopic or transanal to open surgery were reported. Reasons for these conversions included posterior fixity of the tumor, intra-abdominal adhesions after previous laparotomy, a bulky high tumor, a urethral injury, and technical difficulties in two obese patients. Urethral injury is a serious adverse event that is rarely seen in abdominoperineal resections and almost never with abdominal anterior resections. The occurrence of such a complication calls for caution in performing taTME in the clinical setting without adequate training, preceptorship and proctorship for initial cases.

Anastomotic leakage occurred in 6.1% (n=26) and the re-operation rate was 3.7% (n=14). More hand-sewn coloanal anastomoses were performed at a ratio of 2:1 to stapled anastomoses, for tumors found at a mean height ranging from 4 to 9.7 cm from the anal verge. The mean operation time ranged from 143 to 450 minutes with a mean blood loss of less than 230 mL. From an oncological point of view, the positive CRM rate was 5% and DRM rate only 0.3%, whilst a good TME specimen without major defects was obtained in 94%. The mean length of hospital stay ranged from 4.3 to 16.6 days.

A more recent systematic review published this year by Arunachalam *et al.* [46] included larger cohorts of patients such as 140 cases by Lacy *et al* [41] and 80 cases by Velthuis Helbach *et al.* [47] (table 1). Fifteen predominantly retrospective studies, with a total of 449 patients were included in the review. The mean distance of the tumor from the anal verge was 5.6 cm and 72% of patients received neo-adjuvant chemotherapy or chemoradiotherapy. The operative time varied greatly from 91 to 495 minutes with a median time of 254 minutes. Predictably, the operative time was longer for a sequential approach (267 minutes) compared to a synchronous two-team approach (236 minutes). Around 90% of cases required splenic flexure mobilisation, whilst 98% had a defunctioning stoma. Similar cumulative morbidity and mortality rates of 35.5% and 0.4% respectively were found. However the anastomotic leak and re-operation rates were higher at 9.1% each. In terms of oncological endpoints, the CRM was negative in 98% of cases with mean distal and CRMs of 2.5 and 1.1 cm respectively. Thirteen percent of TME specimens were graded as incomplete with major defects in the mesorectum down to the rectal tube, as described by Quirke *et al* [48]. The median follow up was 4.5 months, with two studies reporting three local recurrences (2.5) after 30 months and three studies found 10 patients (7.9%) with

distal metastasis after more than 23 months of surveillance [41,49,50]. A further study from two centres in the UK followed 40 patients for a median follow up of 10.7 months, and reported no local recurrences but six (15%) developed distant metastases [51]. Due to the relatively short practice of taTME 5-year oncological data is currently lacking. Likewise, long-term functional outcomes are also pending with only a few studies so far reporting on their early functional results [45,52,53]. The most recent published results on functional outcome are from a French-randomized trial by Pontallier *et al.* [54], conducted between 2008 and 2012 and followed up for more than twelve months. They randomized 100 patients with low rectal cancer and suitable for sphincter-saving resection to either transanal or laparoscopic low rectal dissection. Bowel and urinary function were similar between the two groups based on LARS (Low anterior resection syndrome score), Wexner continence scores and IPSS (International Prostate Symptom Score). However, significantly more patients in the transanal group who were sexually active before surgery maintained an activity following surgery compared to the laparoscopic group (71% vs. 39%, $p=0.02$). Also, erectile function was better in men after the transanal approach, although this did not reach statistical significance (IIEF, International Index of Erectile Function, scores 17 versus 7, $p=0.119$).

4. Conclusion

Exciting and innovative changes are impacting the way in which rectal cancer surgery is practiced, with the prospect of potentially improving both oncological and functional outcomes. TaTME is the latest novel technique that, in experienced hands, has the potential to give promising results in difficult pelvic dissections. As technology continues to advance, we are likely to see more sophisticated and clever

surgical devices and equipment. However, these new devices do not substitute the technical skills of a trained surgeon or the wishes and best interest of the patient.

5. Expert Commentary

The current level of evidence on taTME in the published literature is level 2 with prospective comparative studies [55-58]. A number of randomized controlled trials have been planned and initiated around the world. In Europe, a national multicentre open-label randomized study in France, based on oncological non-inferiority, and comparing endoscopic transanal proctectomy to standard transabdominal laparoscopic proctectomy for low lying rectal cancer (ETAP-GRECCAR 11) started patient recruitment in January 2016 [59]. This trial only includes female patients and low non-metastatic T3 tumours justifying a manual coloanal anastomosis. Some may argue that the ETAP-GRECCAR 11 trial is not capturing cases for which the transanal approach was pioneered for and for which it is believed to have the most significant benefits, i.e., in difficult low rectal cancer cases in male patients with a narrow pelvis and bulky tumour. Also, possible advantages of stapled over handsewn anastomosis will not be evaluated. However, many surgeons may still be at the early stages of their learning curve for taTME and cases can be more easily matched if kept to the same gender and all manual coloanal anastomoses. The COLOR III trial [60] is an international randomized trial due to start soon and has kept broader inclusion criteria with recruitment of both gender and left the stapled or handsewn anastomosis up to the surgeon. However, short- and long-term results from these trials will not be available for at least a few years.

In the meantime, the largest cohort of taTME cases is prospectively collected on both national and international databases. The largest taTME registry was developed in the UK; launched in July 2014 and funded by the Pelican Cancer Foundation [61]. To date this registry has 166 registered centres from 32 different countries worldwide. The initial 720 cases have been analyzed and results are eagerly awaited.

It is important to keep in mind that, although the transanal technique was pioneered to overcome challenges encountered in difficult pelvic dissections, i.e. obese males with bulky tumors, the mean BMI in most studies is around 23 kg/m² with approximately 64% males and some studies excluding patients with higher ASA grades of III or IV. However, it is also true that surgeons are at the beginning of their learning curve for taTME and so starting with more straightforward cases until more experienced is a sensible approach. Other considerations including advantages and disadvantages of taTME are outlined in table 2. Arunachalam *et al* [46] also comment that any surgical unit intending to perform taTME should have a high volume of lower third rectal cancers in order to ensure that both surgeons and theatre staff maintain their level of competence and expertise in the procedure. The learning curve for transanal TME has not been established yet and so actual numbers of how many cases surgeons should aim to do per year are not yet known.

6. 5-year view

Rectal cancer surgery has undergone significant advances over the last few decades with surgical innovation and technology paying particular attention to this field. As surgeons' experience in taTME grows, they will be able to advise and liaise with industry to develop more tailored transanal instruments and devices, such as longer articulating instruments, adjustable access platforms and adapted transanal stapling

devices. Such modifications may render a full NOTES recto-sigmoidectomy easier and possible for such cases to be performed. Surgeons are already expanding the indications for which they utilised the transanal approach other than anterior resections, such as its application in extralevator abdominoperineal excision [62], and therefore even more specialised equipment may be required. These advanced technologies could potentially also permit resection via the transanal route of more locally advanced T4 tumors.

With the addition of stereotactic navigation and augmented reality [63,64], clearer delineation of the anatomy and mesorectal plane could be accomplished to guide a more accurate dissection. Atallah et al [63], reported the first frameless stereotactic navigation for rectal surgery using intra-operative CT guided navigation to complete transanal TME using TAMIS on a difficult case with locally advanced, distal rectal cancer abutting the prostate post-radiation. They successfully achieved an R0 resection with an accuracy of $\pm 4\text{mm}$ demonstrating feasibility of the technique. The addition of the robot to image-guided navigation may even further improve the precision of dissection, but this remains to be explored. Furthermore, as highlighted by Buchs et al [64], several technical problems involving soft-tissue organs remain to be resolved, including stable landmarks, plastic deformation and real-time resynchronization.

Regardless of how sophisticated the instruments and devices may be, as recently stated, it is important to remember that “Laparoscopes and robots do not operate, surgeons do!” [65]. It is therefore essential that surgeons who intend to perform taTME or any new technique must undergo appropriate training; ideally to include formal perceptorship and proctorship during their initial live cases. In an era following extensive simulated teaching and availability of cadaveric courses, it is no

longer acceptable for surgeons to 'try' new procedures on patients without adequate training. The need for a structured educational programme with the aim to ensure the safe introduction of taTME into clinical practice was acknowledged and formalised at the first international taTME educational group meeting in the UK in October 2015 [66]. A group of twelve international surgeons with experience in taTME and specialist interest in education as well as the President and Chair of the Education and Training committee of the Association of Coloproctology of Great Britain and Ireland (ACPGBI) discussed the need for a taTME educational collaborative. The educational group would guide training by establishing a structured curriculum and promote effective networking and communication amongst surgeons worldwide allowing surgeons to share their experience and collaborate on research studies. The structured curriculum will consist of initial online modules, followed by simulated purse-string bench top modules to cadaveric courses and formal proctorship of the trainee's initial live cases. An interactive online website for the International taTME Educational Collaborative (www.tatme.com) was launched at the European Association for Endoscopic Surgery congress in June 2016 and provides essential educational material with animated videos as well as published literature and access to the taTME registry [61,67]. The iLappSurgery Foundation has also designed an excellent App to deliver extensive educational modules in a clear modern and user-friendly way [68]. The Advances In Surgery (AIS) channel also provides up-to-date information not only on taTME but all minimally advanced general surgical procedures access to live congress talks and operative cases [69]. Further work is ongoing to develop and deliver the structured taTME training curriculum. McLemore *et al* [70] in the United States of America (USA) also described their experience with cadaveric training suggesting a similar pathway. They also outlined six key elements that should be

acknowledged and emphasized in the process of taTME training and implementation of the technique into surgical practice: (1) expertise in TME for rectal cancer, (2) expertise in minimally invasive TME from the abdominal approach (laparoscopic and/or robotic), (3) expertise in transanal endoscopic surgery, (4) experience in intersphincteric dissection for very low rectal invasive neoplasms, (5) practice in taTME techniques in human cadaver models, and (6) institutional review board approved data collection with publication of outcomes and participation in a clinical registry.

The next five years are therefore likely to see the establishment of a formal taTME training programme and important results from randomised controlled trials to help confirm the true benefits and risks of this procedure.

7. Key issues

- Total mesorectal excision is the gold standard approach to rectal cancer surgery.
- Low rectal cancer poses a unique set of challenges and are at risk of obtaining poorer oncological outcomes.
- Surgical innovation and advanced technologies have led to the development of less invasive surgical techniques including laparoscopy, robotics and transanal approaches.
- Extensive preliminary animal and cadaveric lab work was conducted in order to develop the taTME concept and assess its feasibility.
- Initial taTME series and cohorts show promising results with high levels of TME specimen completeness, negative CRM and comparable morbidity/mortality rates.

- Unforeseen adverse events have however been encountered with taTME specifically urethral injury.
- Structured supervised education and training in taTME should be followed in order to ensure the safe practice.
- Further advances in technology and improved instrumentation specifically designed for the transanal approach are in the process of being designed with the aim to further facilitate this technique.
- Results from randomized controlled trials and long-term oncological and functional outcomes are awaited to assess the true benefits and drawbacks of taTME.

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Table 1. Comparison of clinical and histological outcomes from published studies with the largest cohorts of patients undergoing transanal total mesorectal excision (taTME).

	Buchs et al. 2015 [51]	Burke et al. 2015 [71]	Tuech et al. 2015 [49]	Veltcamp Helbach et al. 2015 [47]	Lacy et al. 2015 [41]
Number of patients	40	50	56	80	140
Median Body Mass Index, BMI (kg/m ²)	27.4	26	27	27.5	25.2
Length of hospital stay (days)	7.5	4.5	10	8	6
Median operative time (min)	360	267	270	204	166
Median tumour height from anal verge (cm)	5	4.4	4	5.3	7.6
Positive Circumferential resection margin, %	5.0	4.0	5.3	2.5	6.4
Incomplete TME specimen, %	2.5	2.0	0.0	3.0	0.7
Number of harvested lymph nodes	20	18	12	14	14.7

Table 2. Advantages and disadvantages of transanal total mesorectal excision (taTME).

	TaTME ADVANTAGES	TaTME DISADVANTAGES
ANATOMY	<ul style="list-style-type: none"> Improved view of the low pelvic dissection plane that is not restricted by a narrow pelvis, bulky tumour or excess adiposity. Adequate exposure requiring less manipulation of tumour and surrounding tissue Distal margin determined at start of procedure under direct vision 	<p>Different view point compared to the “top-down” approach requiring specific appreciation and review of the anatomy to avoid intra-operative injuries to surrounding structures.</p>
TECHNICAL SKILL	<ul style="list-style-type: none"> Amalgamation of minimally invasive abdominal and transanal techniques, further refining a surgeon’s skill. Potential for further surgical innovation and development. 	<ul style="list-style-type: none"> Complex operation requiring advanced technical skills and preferably previous experience in minimally invasive techniques. Learning curve remains to be established.
INTRA-OPERATIVE EVENTS	<ul style="list-style-type: none"> Avoids difficulties with multiple cross stapling of the rectum. Potentially shorter operative time and extra guidance if abdominal and transanal teams are operating synchronously. Low conversion rates, even for difficult cases. 	<ul style="list-style-type: none"> Unexpected intra-operative adverse events, especially urethral injury reported. Longer operating time if only one team operating. Specialist equipment required including transanal platform and insufflation system.
CLINICAL OUTCOMES	<ul style="list-style-type: none"> Overall morbidity of ~32% and low mortality comparable to laparoscopic TME results. Potential for lower anastomotic leak rate with double pursestring anastomosis 	<p>Randomized controlled trial results not yet available.</p>
HISTOLOGICAL/ ONCOLOGICAL OUTCOMES	<ul style="list-style-type: none"> Distal margin determined at start of procedure under direct vision Very promising low positive CRM rates (<7%) and complete TME specimens. 	<p>Randomized controlled trial and longer-term oncological results not yet available.</p>
QUALITY OF LIFE AND FUNCTIONAL OUTCOMES	<ul style="list-style-type: none"> Similar bowel and urinary functional outcomes between transanal and laparoscopic TME reported so far. Sexual function potentially better in the transanal group. 	<p>Randomized controlled trial and longer-term results not yet available.</p>
	<ul style="list-style-type: none"> Cadaveric workshops in place and 	<ul style="list-style-type: none"> Cadaveric workshops are expensive

TaTME TRAINING	<p>online taTME education website and app available.</p> <ul style="list-style-type: none"> • Structured taTME training curriculum currently under development in the UK. 	<p>and not available in every country.</p> <ul style="list-style-type: none"> • Currently no simulated model available. • Proctorship of initial live cases recommended but logistically and financially can be difficult.
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CRM: Circumferential resection margin; TME: Total mesorectal excision.