Transanal total mesorectal excision

From inception to implementation

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Publication date
2019

Document Version
Final published version

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Citation for published version (APA):
Hompes, R. (2019). *Transanal total mesorectal excision: From inception to implementation*.

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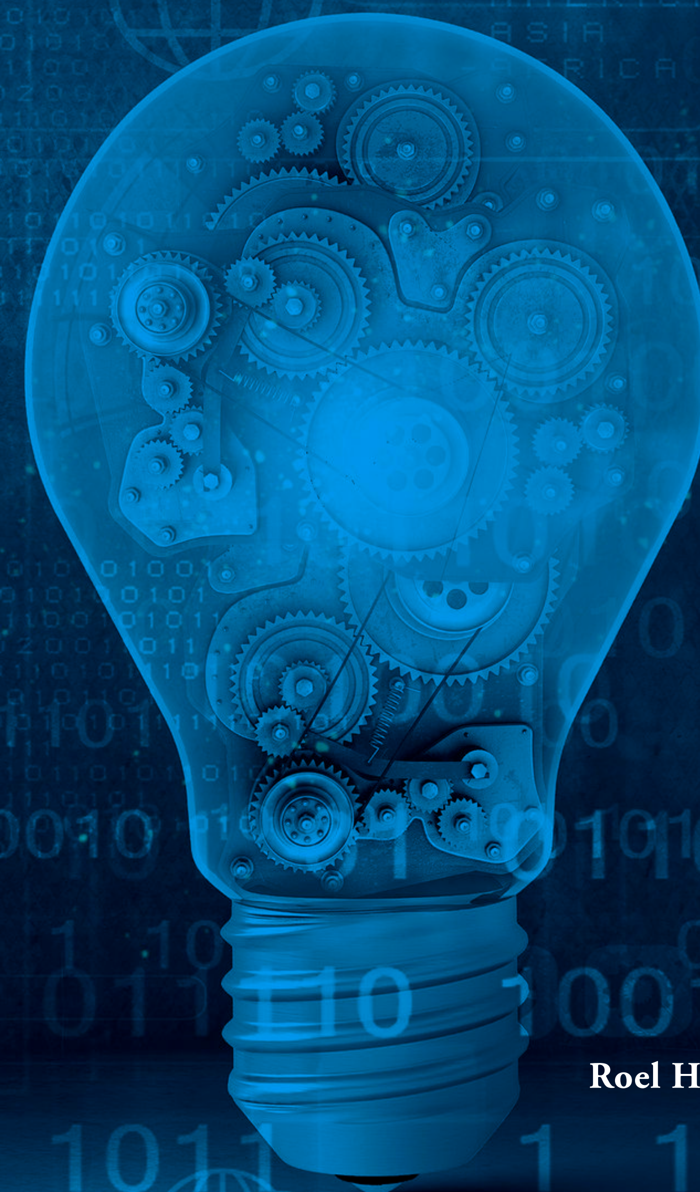

Roel Hompes

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ISBN/EAN: 978-94-6380-366-3

Cover design:
Lay-out: ProefschriftMaken || www.proefschriftmaken.nl
Printed: ProefschriftMaken || www.proefschriftmaken.nl

Financial support for the printing of this thesis was kindly provided by : Wetenschappelijk fonds chirurgie AUMC.

Transanal Total Mesorectal Excision:

from inception to implementation

ACADEMISCH PROEFSCHRIFT
ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. ir. K.I.J. Maex
ten overstaan van een door het College voor Promoties ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op vrijdag 14 juni 2019, te 12.00 uur

door
Roel Hompes
geboren te Bree

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Faculteit der Geneeskunde

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PART III – EXPLORATION

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General introduction and outline of the thesis

General introduction and outline of the thesis

Rectal Cancer Surgery

Surgeons throughout history have conceptualized and implemented approaches from both the abdominal and perineal perspective in an attempt to improve outcomes for patients with rectal cancer. Surgical pioneers like Lisfranc, Kraske and Miles led the innovative movement, making significant technical advances for approaching rectal tumors, but their early advancements were unfortunately fraught with high risk of postoperative morbidity and mortality, and unacceptably high local recurrence rates.[1, 2] A big step toward improved outcomes with fewer morbidities and improved quality of life after surgery came when Dixon introduced the anterior resection as a sphincter saving technique. [3] However, it was not until 1982, when Heald popularized the technique of total mesorectal excision (TME), that we witnessed a true revolution in the management of rectal cancer.[4] The concept of dissecting along embryological, avascular planes improved peri-operative outcomes and more importantly significantly reduced local recurrence rates, particularly in combination with multimodal therapy and extended TME surgery in locally advanced cases. [5]

The introduction of a minimally invasive approach to rectal cancer with laparoscopy has not garnered the same success as that for colon cancer. The limited operative field within the bony confines of the pelvis, imperfect retraction with straight instruments, and reduced visibility compound an already technically difficult dissection. [6] Furthermore, other than possible improved short-term perioperative outcomes, the true benefits, with particular focus on oncological outcomes remain uncertain. The recent randomized controlled trials have further fueled this uncertainty as laparoscopy failed to meet noninferiority criteria compared with open surgery in curative rectal cancer resections, feeling more like a step backward than a leap forward with minimally invasive approaches. [7-9] It is therefore not surprising that there has been an exceedingly slow adoption rate and underutilization of laparoscopy for rectal cancer. In fact, its implementation into routine colorectal practice could be labelled as a failure. While the robotic approach addresses some of the aforementioned technical limitations related to visualization and retraction, it has not delivered on the expectations highlighted by its proponents.[10] Without any tangible advantages over standard laparoscopy, the operational cost and access remain critical limitations, particularly in the modern era with significant constraints on healthcare budgets. The desire to continue in a minimally invasive fashion, despite the subjective perception of a laborious and often unsatisfactory pelvic dissection, has triggered surgeons to continue the quest for novel surgical approaches.

Transanal Total Mesorectal Excision (TaTME) is perceived as the latest innovative procedure with the potential to overcome the technical challenges posed by utilizing a minimally invasive approach within the anatomical constraints of a bony pelvis, confounded further by challenging tumour specific characteristics.[11] Particularly suited for this technique are tumours within the distal part of the rectum, especially in the most challenging patients (i.e. male and/or obese) as the pathology is approached from below. [12] This ensures immediate control of the distal margin and allows for a meticulous TME dissection under direct vision without any of the constraints and limited visualization experienced by a pure anterior approach. Even though TaTME is based on well established surgical concepts (TME, Transabdominal Transanal Surgery, Transanal Endoscopic Microsurgery/TransAnal Minimal Invasive Surgery), it remains a challenging procedure with many pitfalls and potential for severe complications. [13-16] Therefore, as for any new procedure, its implementation and adoption should be careful and thoughtful in accordance to the recently popularized IDEAL framework for surgical innovation. [17, 18]

Innovation in Surgery and the IDEAL principle

The advancement of surgery for rectal cancer over the last 2 to 3 decades has been fueled by technology-based innovation. And while not intentional, the advancement of surgical techniques are often associated with a degree of increased patient morbidity and mortality early on.[19-21] This underscores the clear need to find the appropriate balance between allowing acceptable morbidity as the "art" of surgery progresses and the potential long term gains of an improved treatment approach. While encouraging and fostering an evolution toward superior techniques, we must ensure that the periods of transition in surgical practice are safe and maintain, or ideally exceed, the established standard of care. Contrary to the development of a new pharmaceutical, there was up to recently, no international consensus pathway for the robust evaluation of safety, efficacy and effectiveness with a new surgical technique. This has fortunately changed with the introduction of the IDEAL framework, which describes the five stages for evaluating and reporting surgical innovation: Idea, Development, Exploration, Assessment and Long-term (as shown in figure below).[17, 18, 22] Following these steps should allow for a safe, efficient and reproducible introduction of new technology and technique into clinical practice.

	1 Idea	2a Development	2b Exploration	3 Assessment	4 Long-term study
Purpose	Proof of concept	Development	Learning	Assessment	Surveillance
Number and types of patients	Single digit; highly selected	Few; selected	Many; may expand to mixed; broadening indication	Many; expanded indications (well defined)	All eligible
Number and types of surgeons	Very few; innovators	Few; innovators and some early adopters	Many; innovators, early adopters, early majority	Many; early majority	All eligible
Output	Description	Description	Measurement; comparison	Comparison; complete information for non-RCT participants	Description; audit, regional variation; quality assurance; risk adjustment
Intervention	Evolving; procedure inception	Evolving; procedure development	Evolving; procedure refinement; community learning	Stable	Stable
Method	Structured case reports	Prospective development studies	Research database; explanatory or feasibility RCT (efficacy trial); diseased based (diagnostic)	RCT with or without additions/ modifications; alternative designs	Registry; routine database (eg, SCOAP, STS, NSQIP); rare-case reports
Outcomes	Proof of concept; technical achievement; disasters; dramatic successes	Mainly safety; technical and procedural success	Safety; clinical outcomes (specific and graded); short-term outcomes; patient-centred (reported) outcomes; feasibility outcomes	Clinical outcomes (specific and graded); middle-term and long-term outcomes; patient-centred (reported) outcomes; cost-effectiveness	Rare events; long-term outcomes; quality assurance
Ethical approval	Sometimes	Yes	Yes	Yes	No
Examples	NOTES video[6]	Tissue engineered vessels[7]	Italian D2 gastrectomy study[8]	Swedish obese patients study[9]	UK national adult cardiac surgical database[10]

RCT=randomised controlled trial. SCOAP=Surgical Clinical Outcomes Assessment Programme. STS=Society of Thoracic Surgeons. NSQIP=National Surgical Quality Improvement Program. NOTES=natural orifice translumenal endoscopic surgery.

***Table:* Stages of surgical innovation**

Outline of the thesis

The objective of this thesis is to present how Transanal Total Mesorectal Excision (TaTME) has evolved since its inception in alignment with the steps of the IDEAL framework for surgical innovation. First there is an *Idea or Innovation*, which then undergoes *Development* and *Exploration*, and is subsequently evaluated through *Assessment* and *Long-term Studies*. The recently added pre-IDEAL preclinical phase is not presented here since we introduced the technique as early adopters rather than the true innovators of TaTME. Furthermore, the adoption has only very recently shifted toward the assessment phase, where the main safety and efficacy aspects of TaTME are now being compared to the best current treatment practices (COLOR 3 and GRECCAR11 randomized controlled trials). [23, 24] Therefore, the primary focus of this thesis will be stage 1 (Idea), stage 2a (Development) and stage 2b (Exploration).

While viewed as an innovative surgical technique, TaTME is actually based on three well established surgical concepts: Total Mesorectal Excision (TME), Transabdominal Transanal Surgery (TATA) and Transanal Endoscopic Microsurgery (TEM). [4, 25, 26] But the true catalyst for the development of TaTME as we know it today was the inception of Transanal Minimal Invasive Surgery (TAMIS) - laparoscopic trained surgeons felt less restricted in their ability to work within a confined space and the versatility of the flexible platforms triggered surgeons to explore beyond the standard indication of local excision for rectal neoplasms.[27, 28] Herein, chapters 1-5 provide an overview of how the colorectal department in Oxford applied the idea of a surgical glove port for Single Incision laparoscopic Surgery (SILS) to a transanal platform for (Robotic) TAMIS and finally TaTME. In chapters 6-10, elements from the Development phase of IDEAL are presented. The focus shifts to the technical changes, procedural standardization and feasibility of TaTME in initial small and highly selected cohorts of patients. Our own early experience with TaTME in 20 patients is presented in Chapter 6. Chapter 7-9 goes on to present some of the technical modifications and changes made to the necessary equipment as we gained further experience and insight from our own experience performing TaTME. While our own small case series established TaTME to be feasible, we investigated feasibility in a larger sample of collective case reports and case series from the early adopters, the results of which are presented in the first systematic review on the topic in Chapter 10.

In the final chapters, the focus shifts from the technical development of TaTME to the Exploration phase of IDEAL, where attention is given to defining the appropriate indications for TaTME, and better understanding its potential harms and benefits. The development of a registry, as described in Chapter 11, was crucial for the prospective data collection of safety and surgical outcomes across multiple international surgical units. Short-term clinical and oncological outcomes are presented in Chapter 14, and anastomotic leak and anastomoic failure rates following TaTME are reported in Chapter 15. As TaTME continues to gain traction, it is being utilized by a wider and potentially less experienced group of surgeons.

Therefore, guidance toward effective training and optimal clinical practice are required and essential before widespread adoption of this innovative technique. The creation of a structured training framework specifically for TaTME and consensus statements for its ue in clinical practice are discussed in Chapter 12 and 13 respectively.

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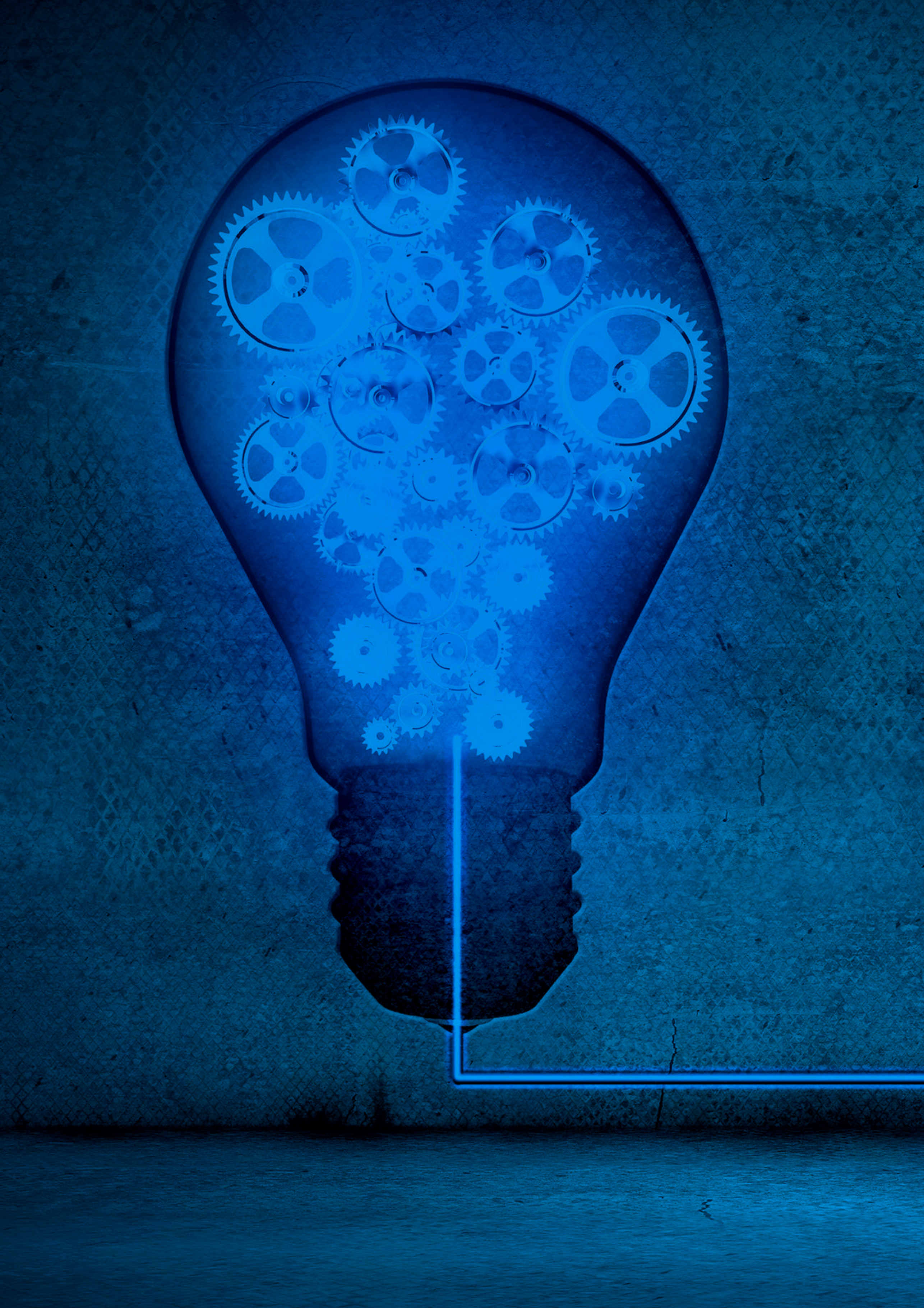
PART I
IDEA



Chapter 1

Step-wise integration of single-port laparoscopic surgery into routine colorectal surgical practice by use of a surgical glove port

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Tech Coloproctol. 2011 Jun;15(2):165-71.

Abstract

Introduction

The cost associated with single-port laparoscopic access devices may limit utilisation of single-port laparoscopic surgery by colorectal surgeons. This paper describes a simple and cheap access modality that has facilitated the widespread adoption of single-port technology in our practice both as a stand-alone procedure and as a useful adjunct to traditional multiport techniques.

Methods

A surgical glove port is constructed by applying a standard glove onto the rim of the wound protector/ retractor used during laparoscopic resectional colorectal surgery. To illustrate its usefulness, we present our total experience to date and highlight a selection of patients presenting for a range of elective colorectal surgery procedures.

Results

The surgical glove port allowed successful completion of 25 single-port laparoscopic procedures (including laparoscopic adhesiolysis, ileo-rectal anastomosis, right hemicolectomy, total colectomy and low anterior resection) and has been used as an adjunct in over 80 additional multiport procedures (including refashioning of a colorectal anastomosis made after specimen extraction during a standard multiport laparoscopic anterior resection).

Conclusions

This simple, efficient device can allow use of single-port laparoscopy in a broader spectrum of patients either in isolation or in combination with multiport surgery than may be otherwise possible for economic reasons. By separating issues of cost from utility, the usefulness of the technical advance inherent within single-port laparoscopy for colorectal surgery can be better appreciated. We endorse the creative innovation inherent in this approach as surgical practice continues to evolve for ever greater patient benefit.

Introduction

In the last 2 years there has been a steady increase in reports on single-port laparoscopic surgery for a wide variety of indications [1–7]. In comparison with more conventional multiport laparoscopic approaches, this modality minimises the surgical trauma even further to facilitate improved cosmesis as well as reduced likelihood of trocar wound complications and incisional pain [8]. Although to date, attention has been primarily directed at focussed operative targets such as gall bladder and renal intervention, colorectal surgery and surgeons seem likely to have the most to gain from the inclusion of this advanced operative technique into standard practice. This is because often operations in this speciality already require several trocar accesses as well as a wound for specimen extraction or stoma formation that is equivalent to that needed for single incision devices. Therefore, the potential for markedly reducing the number of ports used in standard practice is perhaps greatest in this speciality. In addition, in many further cases, a single port-type device could be used to restore working trocar capacity after specimen extraction has been performed via a trocar access site.

However, if expensive disposable equipment is required for this technique, the potential advance inherent in such operative facility will be limited. This is particularly the case since the benefits of single-port laparoscopic surgery over standard laparoscopy are as yet unproven. This may frustrate procurement of the devices and hence integration of the technique into routine colorectal practice. Therefore, in order to extend the principle and practice of single-port laparoscopy beyond niche indication for either highly selected patients or in exceptional units, issues of costs need to be divorced from considerations of patient benefit. A simple, cheap and reliable access device would better allow the incorporation of this modality into routine practice than any other advanced operative instrumentation and allow clinicians to distinguish practical advantage from theoretical supposition. Here, we describe how a surgical glove can be utilised with a conventional wound protector (used in nearly every colorectal case involving resection) to allow units to embrace single-port laparoscopy throughout the spectrum of their clinical case-load ranging from introductory level to complex intervention. In addition to presenting our total experience to date, we highlight selected cases to detail the techniques used and hence the usefulness of the approach.

Materials and methods

Surgical glove port construct (see Fig. 1)

The access device construct proposed here comprises the standard wound protector/retractor in use in our department (ALEXIS wound retractor S (small size) or XS (extra small size); Applied Medical, CA, USA) along with a size 6, latex or non-latex sterile surgical glove (in our unit Ansell, Brussells, Belgium). Once the wound protector/retractor is inserted in the standard fashion (open cut-down technique) and snugged into place by twisting the outer ring down to skin level, the cuff of the surgical glove is snapped onto the external ring. Latex-free gloves are preferred as in general these are thicker and more robust than their latex counterpart. Standard laparoscopic ports (1x12mm; 2x5mm) are then inserted through the fingers and an airtight seal around the ports achieved with either sutures or (preferably) latex strips cut from another glove. These ports provide a conduit for instruments that need exchanging during the case (e.g. camera, graspers, hook dissector etc.). Reuseable ports are preferred to disposable ports for reasons of cost but also because of the narrower atrium profile reducing instrument clutter and clash. Instruments that are only used for a short period of time such as a laparoscopic stapler or clip applicator can be introduced directly through a separate finger (without the use of a trocar sleeve) when needed. Curved instruments, if desired, can also be inserted directly into the glove fingers (i.e. without using standard trocars as a sheath). Their insertion point can then be tied off after the use and exit of the instrument. For cases where larger specimens are being removed, we utilise the small (3 cm diameter) size wound protector and at the commencement of the operation place it at the site intended for specimen extraction. For cases where we intend to operate through a prior or intended stoma site [9], an extra-small wound retractor is used. In our unit, the LigaSure V (Covidien, Valleylab, Norwalk, CT, USA) is used for the majority of intra-abdominal dissection although on occasion the harmonic scalpel (Ethicon Endosurgery, Ohio, USA) is preferred

Patient selection and pre-operative care

Departmental approval for this operative approach was obtained prior to commencement of this experience and all surgeons had prior experience with single-port operating for colorectal disease. The series was performed on consecutive patients on days where our most experienced single-port surgeons (RAC and RH) were available and the patients were those in whom no undue intraoperative difficulty was predicted. Patients were fully consented for the approach as well as for standard potential intraoperative complications and were assured that there was a low threshold for conversion to standard laparoscopy if any procedural concern or deviation occurred.

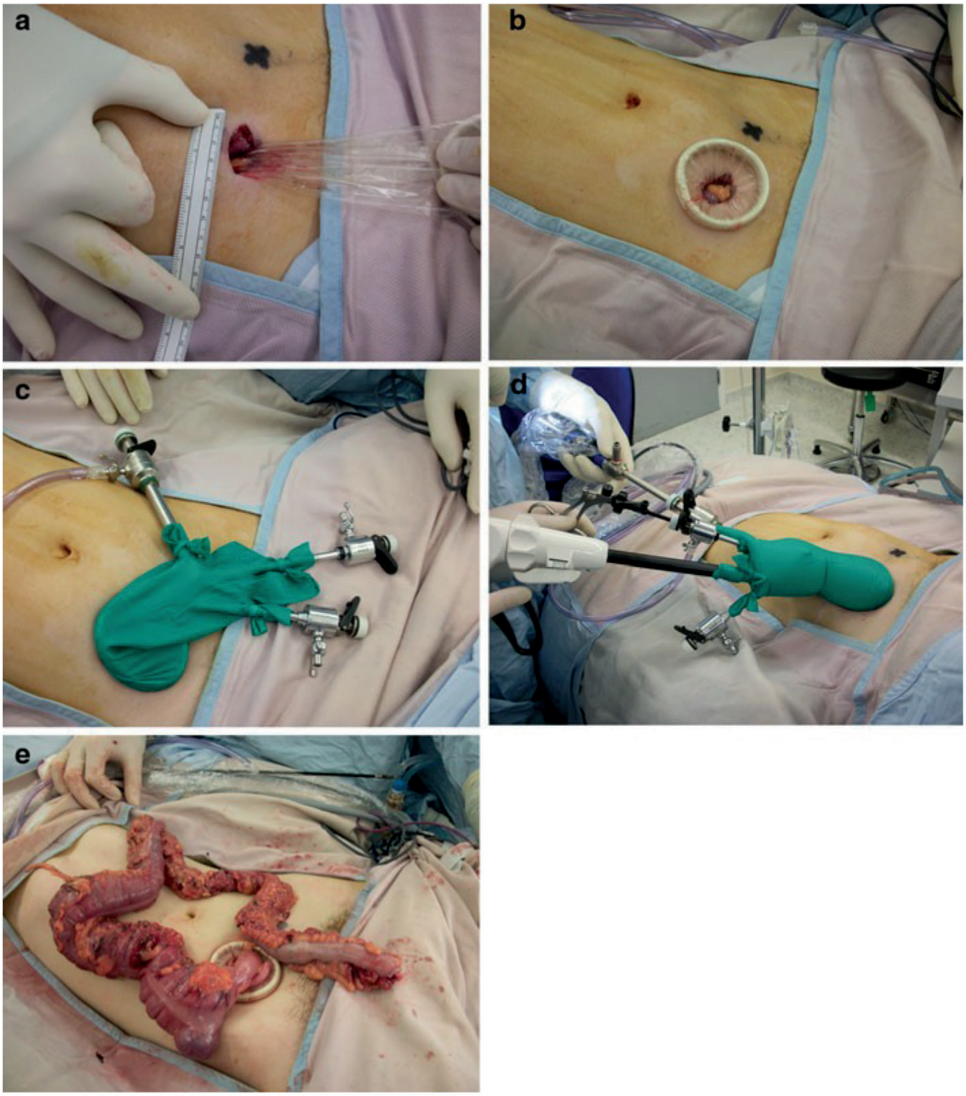

Fig. 1. Operative photographs detailing the construction and use of surgical glove port for a patient undergoing single-port laparoscopic total colectomy with end ileostomy. a The initial incision as indicated for either specimen extraction or stoma creation is made by an open technique at the commencement of the operation (here it is at the site intended ultimately for the stoma). b A wound protector/ retractor is inserted into the incision. c The cuff of a sterile surgical glove is then snapped onto the external ring of the wound protector/ retractor and trocars are inserted into the tips of three fingers and secured with latex strips cut from another glove or vicryl ties. d After attachment of the sufflation tube to a trocar, a pneumoperitoneum is established and the glove distends in concert allowing laparoscopic instruments to be worked via the trocars (or indeed through any of the additional glove fingers) e The entire colectomy specimen still in continuity with the terminal ileum is delivered through the wound protector component of the Surgical Glove Port. After its resection, the end ileostomy is fashioned in this site as the sole abdominal wall access site

Results

In total, we have now used the surgical glove port in over 100 cases (see Table 1). In 25, this device was the sole operative access used to complete the procedure. In an additional 84 cases, we used the construct to recapture full laparoscopic working capacity after specimen extraction or stoma takedown (*n* = 5) during a standard multiport laparoscopic case. Below, we highlight six cases delineating the spectrum of utility of this approach.

The first illustrative case is a 89-year-old man (BMI 23.8 kg/m^2) who was diagnosed with caecal cancer suitable for laparoscopic-assisted right hemicolectomy. The procedure began with creation of a 3-cm transumbilical incision to act as the site of both the surgical glove port (as sole operative access) and specimen extraction. The operative approach was identical to our standard oncologic multiport approach and involved a medial to lateral approach with intra-abdominal ligation of the ileo-colic vessels. The anastomosis was fashioned extracorporeally. The total operative time was 95 min, with minimal blood loss (<100 ml). The pathology revealed a 31 cm long resection specimen with 22 lymph nodes (Dukes B cancer). The second illustrative case is a 47-year-old woman who had a prior laparoscopic total colectomy with loop ileostomy followed by intermittent episodes of obstructive symptoms. At her operation for elective stoma closure, her ileostomy was mobilised and closed in the usual fashion and the ileal loop returned to the peritoneum. Placement of an extra-small Alexis wound protector into the stoma site then allowed construction of the surgical glove port followed by full laparoscopy through this incision site to allow complete inspection of the peritoneal cavity and adhesiolysis. The fascia was closed and the operation completed. The patient has remained well without further abdominal pain for the past 3 months.

The third patient presented here is a 24-year-old man (BMI 23.5 kg/m^2) undergoing take-down of his end ileostomy and formation of an ileo-rectal anastomosis by a single-port approach after a prior urgent total colectomy for Crohn's colitis. After initial mobilisation of the stoma, the anvil of the stapler for the re-anastomosis was inserted into the free end of the ileum and dropped back into the peritoneal cavity. Using the surgical glove port at the stoma site, the rectal stump was dissected laparoscopically and refashioned using a 60-mm Endo GIA (Covidien, Autos ture, Endo GIA Universal Roticulator, Norwalk, CT, USA). The orientation of the small bowel was fully checked with great care for any twists before the anastomosis was created end-to-end using a circular EEA 28-mm stapler (Covidien, Norwalk, Connecticut, USA). Donuts were complete and air test was satisfactory. Operating time was 55 min. Oral intake was tolerated on postoperative day one and the patient was discharged on postoperative day four.

Table 1. Total number of colorectal procedures in our department in which the surgical glove port construct has been utilised

Single-port procedures (i.e. Surgical Glove port used as sole operative access) (n = 25)			
Laparoscopic appendicectomy	1	Laparoscopic formation of stoma (colostomy or ileostomy)	6
Laparoscopic reversal of ileorectal anastomosis	2	Laparoscopic adhesiolysis with reversal of stoma	2
Laparoscopic-assisted right hemicolectomy or ileo-caecal resection	8 (including one for caecal volvulus)	Laparoscopic sigmoidectomy for volvulus	2
Laparoscopic total colectomy with end ileostomy	2	Laparoscopic anterior resection	2 (1 low anterior resection)
Use as adjunct in standard multiport cases (n = 84)			
Sealing of specimen extraction site in standard multiport laparoscopy (by restoring full port capacity this facilitates haemostasis and anastomotic checking as well as any further dissection to ensure absolutely tension-free lie).	Laparoscopic anterior resection	46 (in two cases used to assist in complete revision of the colorectal anastomosis).	
	Laparoscopic-assisted Right hemicolectomy	33	
	Laparoscopic reversal of hartman's procedure	5	

The fourth patient in this series was a 70-year-old man (BMI 27.8 kg/m^2) undergoing a standard multiport laparoscopic high anterior resection (with splenic flexure mobilisation) for a proximal sigmoid cancer. The specimen was extracted through a 4-cm peri-umbilical incision with extra corporeal preparation of the descending colon with anvil insertion (EEA, 28 mm Covidien). The surgical glove port was used to restore the pneumoperitoneum as well as full laparoscopic access working capacity. Once the anastomosis was fashioned, there was a small segment of ischaemic colon (±2 cm) just proximal to the stapler line. The anastomosis was taken down and refashioned without the need for conversion or placement of any additional ports. Total operative time was 220 min.

The fifth illustrative case is a 18-year-old man (BMI 19.5 kg/m^2) with medically refractory ulcerative colitis requiring urgent operation. As previously described [9], our technique for single-port laparoscopic total colectomy involves placement of the single-port device at the site intended for the end ileostomy, and early distal sigmoid transection, followed by caudad to cephalad mesenteric dissection in a close pericolonic plane. The dissected specimen is withdrawn via the stoma site/port wound and the ileostomy fashioned within this space. The total operating time was 210 min. The final patient was a 70-year-old woman (BMI kg/m^2) who was diagnosed with a circumferential, upper rectal cancer and planned for primary resectional surgery. The sole entry access point for the surgery and specimen extraction was a 3-cm intra-umbilical vertical skin and rectus fascia incision. The operative approach using the surgical glove port was identical to our standard oncologic multiport laparoscopic low anterior and involved a medial to lateral 'inferior mesenteric artery first' technique. Afterwards TME dissection was performed and the rectum transected 5 cm distal to the lower border of the tumour by a single fire of a 60-mm Endo GIA stapler. After specimen extraction, preparation of the descending colon for re-anastomosis was completed extracorporeally. After replacement of the glove onto the wound retractor/protector, a conventional end-to-end circular anastomosis was formed (Coviden EEA stapler) and checked by air-testing. Operating time was 190 min. The surgical specimen was 30 cm in length, with adequate margins and 19 harvested lymph nodes.

Discussion

Natural orifice transluminal endoscopic surgery (NOTES) and single-port laparoscopic procedures are being proposed, explored and developed in an effort to further reduce parietal trauma and 'perfect' operative practice for patient benefit [10]. The wide range of devices becoming available for these techniques is an indication of the rapid developments occurring in engineering in this field [11]. Although we began our own single-port experience and expertise with trials of commercially supplied ports, we found the expense of the systems in association with the current lack of justification in terms of proof of patient benefit frustrating for our procurement efforts. While the expense of the single-port devices available may be expected to decrease with uptake and with the advent of reusable and reposable components, the limited number of ports available to us conferred a 'precious' status to the ports, meaning that we moved to employing the approach for only the most rarefied operative circumstances. This approach, however, is of obvious concern not only because expertise develops and is maintained by frequency of experience but also, and perhaps more importantly, because advances in operative technique should represent a level rise in standards for all patients and for all interested surgeons not only those who are economically fortunate.

The use of the 'glove-port' has been reported previously in both in this [12–14] and other specialities and in such allied fields it is moving beyond single case descriptions to case series [15, 16]. In our department, we started using this technique in standard multiport laparoscopic anterior resection during the formation of the colorectal anastomosis after specimen extraction through the umbilicus (also our preferred location for siting a 10 mm camera during the laparoscopic mobilisation stage of the proc dure). Thereafter, we gradually implemented it in other multiport procedures as well as specific pure single-port laparoscopic cases and our experience with this approach now exceeds our series with commercial equivalents. We can now propose that surgeons considering this approach begin their experience with entry level procedures and progress along a graded scale of technical complexity (see Table 2).

Table 2. Table describing a putative grading of colorectal procedures according to level of likely technical complexity

Suggested scale of procedures by level of associated technical difficulty	
'Entry Level' Procedures	Check of anastomosis lie and haemostasis after right hemicolectomy Observation of formation of colorectal anastomosis, anastomotic air-leak test and suctioning of pelvic fluid after anterior resection when specimen has been extracted through an extension of the 12 mm camera port (whether at umbilicus or iliac fossa)
'Intermediate Level' Procedures	Laparoscopic appendicectomy
	Laparoscopic-assisted right hemicolectomy
	Laparoscopic-assisted ileo-rectal anastomosis after subtotal colectomy with end ileostomy
	Adjunct to complicated laparoscopic anterior resection after point of specimen extraction and return of proximal colon to peritoneum after placement of circular stapler anvil:
	(a)Refashioning of rectal stump in cases where it is found that endoanal stapler head will not easily reach end of rectal stump after transsection for high anterior
	(b)Revision of colorectal anastomosis after anterior resection (positive air test or signs of inadequate vascularisation after formation of initial anastomosis)
	(c)Performance or completion of splenic flexure mobilisation to ensure tension-free anastomosis when surgeon/unit performance is selective performance of this step
	Laparoscopic stoma formation (port placed at site of intended stoma formation)
'Advanced Level' Procedures	Pure single incision laparoscopic anterior resection (High/Low)
	Pure single incision laparoscopic total colectomy

With its use, we have found the 'glove-port' to have multiple advantages over and above comparative price (see Table 3). It is easy to use and mostly provides well for a robust and tight air seal, even in longer cases. Given the characteristics of conventional wound protector/ retractors, the port can accommodate variable thickness of the abdominal wall and can be inserted at any site (including potentially transanally). In addition to the reports above, we have, for example, used the 'glove-port' to construct a loop ileostomy in a super obese patient (BMI 56 kg/m^2). Furthermore, most single incision ports only have 3 or 4 ports to accommodate instruments whereas the glove port allows up to five instruments to be used simultaneously without restrictions regarding the size of the instruments. This allows the surgeon to easily deviate from the intended operative plan in the case of unexpected or changed intraoperative circumstances (e.g. unusual anatomy or intraoperative complications such as haemorrhage). Furthermore, the economic attractiveness of this device means also that a surgeon need have no hesitation in commencing the case with this access and then utilising additional ports as may be helpful.

Table 3. List prices of component pieces of laparoscopic approaches for colorectal procedures as supplied to our unit by device manufacturers

Operative Access	Component costs	Total cost	
		GBP	EURO
Standard Multiport laparoscopic case (five trocar approach)	Hassan port - £52.67 Additional 12 mm port - £20.55 5 mm port with trocar - £40.55 5 mm sleeves (no trocar) - £44.76 Alexis Wound retractor - £25.00	£183.53	€210.41
Glove port	Glove £0.80 Alexis (very small) small (£20) £25	£25.80	€29.60
	With disposable ports: 12 mm sleeve port for camera £20.55 (no Hassan port needed) 3 x 5 mm sleeve (without trocar) - £44.76 12 mm x 1 (optional as finger alone without port can be used for stapler, clip applier etc if needed)	£65.31 + £20.55 = £85.66/£106.41	€73.39 + €23.56 = €96.95/ €119.57
	With re-useable ports, cost per case after purchase	£20.80/£25.80	€23.85/€29.58
SILS Port (Covidien)	SILS port with one 12 mm cannula and 3 x 5 mm cannulae - £296 Alexis small £25	£321	€368.01
LESS Port (Olympus)	Quadport £460 (Alexis small £25)	£460 (485)	€527.37 (556.03)
Gelport (Applied medical)	Gelport £460 Alexis small £25	£485	€556.03

The surgical glove port also has attractive technical features. There is a wide axis of movement possible with the glove port being positioned outside the abdomen which allows for the instruments inside the abdomen to be either used more widely apart or, conversely, easily crossed or rotated as the operative situation requires. Indeed, as the surgeon is focussed on the laparoscopic screen, the vertical, horizontal and rotational freedom inherent in the glove port provides unrestricted instrument manoeuvring albeit within the confines of the size of the incision (this latter point of course means normal degrees of triangulation of instruments possible in conventional laparoscopy cannot be matched). In addition, the instruments can be easily held at different heights in the wound reducing the tendency for instrument clutter (this is further aided by choosing ports with narrow profile heads). Obviously as the trocars are placed into the glove space and not actually into the patient, most unsophisticated reusable or cheap early generation ports (at least in terms of blade shielding/retraction) can be used without undue concern regarding intraabdominal organ injury (or indeed blade resharpening in the case of reusable trocars). The profile of the wound protector flush with both aspects of the abdominal wall allows a wide degree of freedom of instrument movement. Finally, and in fact still only theoretically, the lack of trocar-induced friction (due to the arc of movement of instruments worked through them) at the actual level of the abdominal wall may cause less parietal trauma and thus less pain. However, we have as yet no formal objective data to support this contention although a prospective study is underway.

The use of a glove for this purpose is by no means ideal. Its main disadvantage relates to the large artificial 'hernia' created by the distended glove's palm and wrist components above the wound protector/retractor and the fact that the glove fingers are not in an optimal arrangement for this purpose. Because the trocar atria are at some distance from the entry point into the peritoneum at the level of the abdominal wall, instrument changes can be a nuisance and it can be frustrating to disrupt the operative flow by having to break off to find the correct path of the instrument into the abdomen. This can be especially difficult if, due to manipulation, a twist in the glove occurs and is also compounded by the opaque nature of the glove's material. Another downside is that misdirection of the instrument tips within the glove can lead to tears in the glove and loss of pneumoperitoneum, which may result in a need to replace the glove and ports. Additionally, the glove may slip off the wound protector/retractor, especially during extremes of instrument positioning, leading to immediate loss of pneumoperitoneum. The two final points are of course that the glove is not certified for this use and that, especially when the approach is solely a single-port intervention, this approach needs to be considered an advanced operative technique. The use of the surgical glove construct obviates issues of device cost but of course not operative expertise.

Conclusion

The glove port is a cheap, useful and readily available tool to regain access to the abdomen in multiport cases while in fully single incision laparoscopic cases it provides the same access as the other expensive commercially provided equivalents. The choice of a low cost equivalent allows greater and more flexible employment of single-port surgery in routine colorectal specialist practice and provides an entry level for this technique that is accessible for every surgeon in every department.

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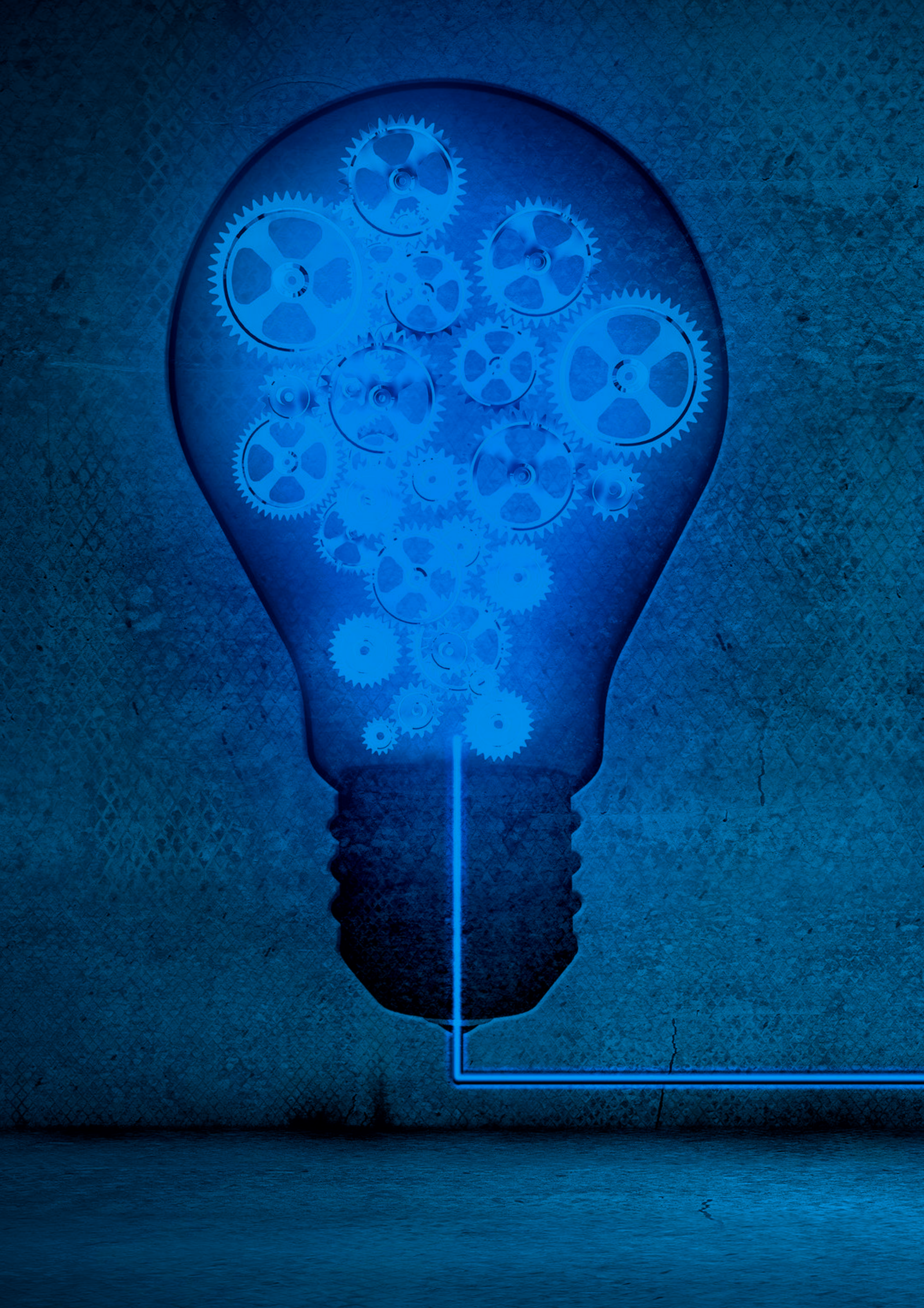

Chapter 2

Sealed Orifice Laparoscopic or Endoscopic (SOLE) Surgery: technology and technique convergence for next-step colorectal surgery

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C. Cunningham
N.J. Mortensen

Colorectal Dis. 2011 Nov;13 Suppl 7:3-7.

Abstract

The new avenue of minimally invasive surgery, referred to as single-incision/access laparoscopy, is often presented as an alternative to standard multiport approaches, whereas in fact it is more usefully perceived as a complementary modality. The emergence of the technique can be of greater use both to patients and to the colorectal specialty if its principles can be merged into next-stage evolution by synergy with more conventional practice. In particular, rather than device specificity, what is needed is convergence of capability that can be applied by the same surgeon in differing scenarios depending on the individualized patient and disease characteristics. We detail here the global applicability of a simple access device construct that allows the provision of simple and complex single-port laparoscopy as well as contributing to multiport laparoscopic and transanal resections in a manner that is reliable, reproducible, ergonomical and economical.

Introduction

The recent enthusiasm for single-access laparoscopy (or any other similar term) has focused surgeons on developing skill sets that have been familiar to proponents of Transanal Endoscopic Microsurgery (TEM) for many years. An increased facility for operating instruments in parallel with each other and with limited scope for triangulation and abduction / adduction within a confined access site across the colorectal specialty should allow maximum usefulness to be gleaned from any potential entry site (whether a surgically created transparietal incision or a natural orifice such as the anus for intraluminal or even transluminal surgery) for any particular disease process and hence prime surgeons for further evolution in minimally invasive surgery. Laparoscopic colorectal surgery inherently demands incisions in excess of standard trocar diameters for the purposes of specimen resection and stoma construction / reversal and often needs to address pathology in proximity to a natural orifice (specifically the anus). In addition, colorectal surgeons as a specialty tend already to be facile with flexible and rigid endoscopic platforms and possess a deep appreciation of operative as well as immunological and oncological principles of abdominopelvic pathology and its therapy. Therefore, rather than supraspecialization by operative access or platform (and hence unlike the fields of gastroenterology and cardiology), the next stage in laparoendoscopy is likely to be a move towards convergence of technique and technology. This will allow disease-specialty surgeons to employ the optimum modality for the exact pathology at the time of presentation in any individual patient and retain an ability to adapt or switch approach, depending on the conditions and / or problems encountered (including those induced iatrogenically, such as haemorrhage or inadvertent, uncontrolled intestinal perforation). In the case of single-incision laparoscopic access devices, the access modality should also support multiport laparoscopy as well as facilitate transanal working and natural orifice specimen extraction (and thereafter potentially transluminal surgery). In this way, technical skills and instrumentation can overlap between approaches in order to obviate parallel learning-curve requirements and simplify economics.

Single access laparoscopy / endoscopy

The current generation of commercially available single ports are all designed for transabdominal surgery and hence have focused predominantly on relatively straightforward, single-quadrant operations such as cholecystectomy. In addition they have centered their fixation mechanisms on use via a surgical incision (i.e. 'singleincision laparoscopy'). When adapting for larger resectional procedures, such as those encountered in colorectal surgery, the companies have considered increased portals to be necessary and have often increased the overall size of the access device. In addition, reticulating or fixed rigid double-curved instruments have been advocated to help the majority surmount the added constraints of confined-access surgery. In fact, however, these tendencies have so far only really added complexity and specificity to the devices and their use. As many surgeons choose to perform laparoscopic-assisted rather than purely intracorporeal operations for right-side (ileo)colonic resections (and therefore need only a camera and two working instruments, including an energy dissector/sealer), simpler devices are in fact are better suited for this category of procedure (see Fig. 1).

This is also the case even for more extensive procedures, such as total colectomy with either end-ileostomy or ileorectal anastomosis (see Fig. 2), as these procedures require the single use of a laparoscopic stapler for only a few minutes of one part of the operation [1].

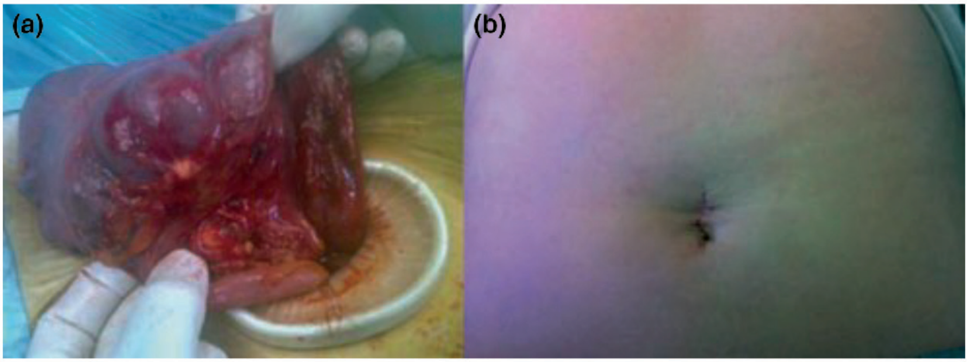

Figure 1. Photographs of a patient undergoing a single-incision laparoscopic-assisted right hemicolectomy. (a) All intracorporeal dissection was performed via a single-port access device until the point of specimen extraction (seen here), through the transumbilical incision as the sole abdominal wall incision. (b) The cosmetic appearance in the same patient [body mass index (BMI) = 28 kg/m2] 6 weeks postoperatively.

Figure 2. Photographs taken of a patient undergoing single-port laparoscopic total colectomy with ileorectal anastomosis for attenuated familial adenomatous polyposis showing (a) the specimen removed via the transumbilical single-access incision and (b) the closed incision immediately postoperatively.

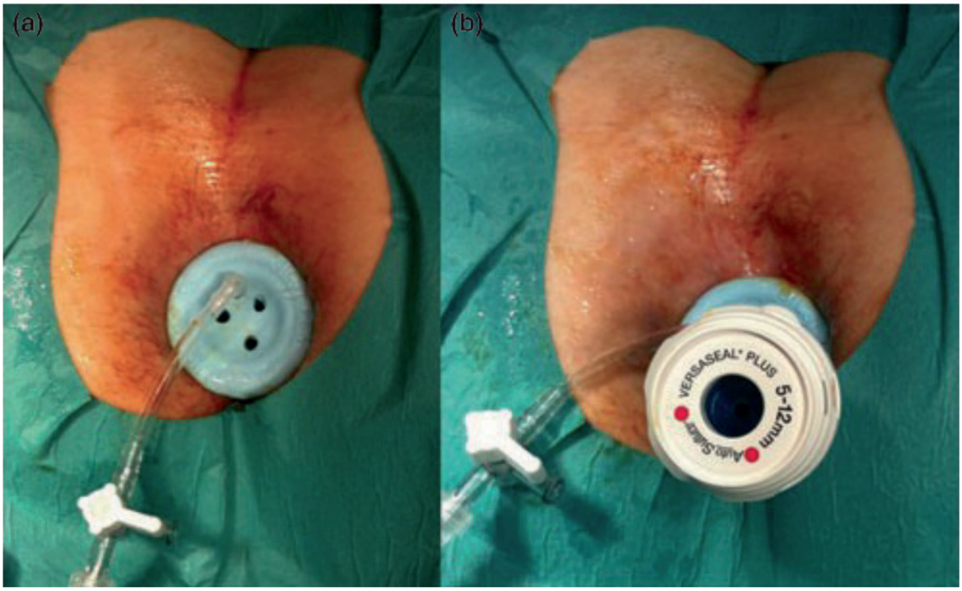

Figure 3. A commercially available singleport device (SILS, Covidien) placed transanally to allow performance of an intraluminal endoscopic resection. The offset air-sufflation channel is an advantage; however, the lack of fixation (although the device can be sutured in situ) and the bulk of the trocar heads can interrupt fluency of operative flow.

In reality the practical trend in multiport surgery has been, and still is, towards simplicity and 'sameness' (informal communication, M. Whiteford) with surgeon instrument-sets becoming more basic, and multi-use instruments such as sealer-dividers being favored. This is both for the purpose of standardization as well as to reduce costs associated with use and resterilization, and to reduce both disruption of operative fluency and the potential for iatrogenic injury during instrument exchanges. In conjunction with this, there has been an increased focus on cost-effectiveness, and the current single-port devices are primarily positioned in the market to be used in place of, instead of alongside, standard laparoscopic trocars. This mitigates against surgeons adding trocars with low discrimination during single-port cases and, more importantly perhaps for the evolution of colorectal surgery, incorporation of these devices during a multiport procedure to recapture a specimen extraction site or more fully utilize an intended or existing stoma site. Furthermore, in parallel to advances in transabdominal laparoscopy, the recent past has seen great interest in Natural Orifice Transluminal Endoscopic Surgery (NOTES). While some of the fervency surrounding the topic has diminished, the exploration of this concept has encouraged greater consideration of the use of natural accesses for more than just endoluminal procedures. In the simplest form this may involve intraluminal retractional assistance for colorectal surgery, whether by intelligent use of a flexible endoscope positioned in the left colon [2] or, more elegantly (in theory at least), intraluminal magnetic capture and release systems with one pole being placed in the colon and another on the abdominal wall [3]. More advanced, while still being credibly close to mainstream practice, is the idea of natural orifice specimen extraction in order to utilize fully the access already created by nature in both genders and to remove the resectional specimen transanally in order to obviate the need for any abdominal incision in excess of a standard trocar diameter [4]. Once this practice becomes validated and simplified, undoubtedly the next step will be use of transanal transrectal instrumentation to perform parts of the intrabdominal procedure as has already been the case for transvaginal [5] and (highly selectively) transrectal access [6]. While TEM and its variants, such as Transanal Endoscopic Operation, are currently the most likely platforms to advance this concept, they are not widespread in either their availability or in their expert use. Clearly, however, the mode of working and even the device configuration of single-access laparoscopy more than just resembles such established transanal devices and should enable their crossover from abdominal wall access to natural orifice (see Fig. 3). However, the specific nature of current commercial devices (in particular their requirement to catch against the flush inside the abdominal wall and the cylindrical nature of their internal channels and construction that prevents short fulcrum working for nearby targets) makes them difficult to use transanally for rectal pathology.

Sealed Orifice Laparoscopic or Endoscopic (SOLE) Surgery

From the experience of most colorectal surgeons, it should be clear that the most useful and most needed single-access device would possess the characteristics of widespread utility in a variety of settings and applicability to many, if not all, potential access modalities, while being simple, unfussy and inexpensive (or better yet cheap). The ideal apparatus should not overly complicate the procedure either in its planning or performance and should allow the surgeon to concentrate on the intra-abdominal component of the operation (which for the laparoscopist means enabling full focus on the screen). The apparatus should therefore be stable in its fixation, regardless of where it is placed, and should complement and facilitate all standard equipment in regular, routine use without demanding specific 'device' expertise in its set-up. Simply, the device should never be a conspicuous barrier to operative performance. In addition, it should be available for all surgeons rather than those in selected centres only, as in this way all patients can benefit and all users can contribute to its evolution.

At present, in our view, the access device that best fits these criteria is the Surgical Glove Port (see Fig. 4) [7]. While not in itself ideal in every aspect, it allows us use the device with sufficient frequency for all surgical and nursing staff to become readily familiar with its set-up and use, and lends itself easily to application in differing, allied scenarios whether via a surgical incision or a natural orifice. In doing so, it points the way towards the next likely step-change in laparoscopic colorectal surgery – the concept of sealed access or orifice laparoscopy or endoscopy, either alone ('single port') or in combination with standard laparoscopic techniques, and either transabdominal or transanal (possibly also transrectal). With some reconfiguration, it should be possible to retain the principal benefits of this device and to eliminate the drawbacks (especially the dimensions and arrangement of the 'cuff' and digits along with the tendency of the wrist to slip off the outer cuff or twist 360°).

Figure 4. Construction and use of a surgical "glove port" in a patient who had previously undergone an urgent total colectomy with end ileostomy for Crohn's colitis and who is undergoing ileorectal anastomosis for the restoration of intestinal continuity. (a) After full mobilization of the end ileostomy, the anvil of the stapler that will be used to form the ileorectal anastomosis is placed in the end ileum. (b) The end of the ileum is returned into the abdomen and then a small-size wound protector-retractor (ALEXIS XS; Applied Medical) is placed into the stoma site. (c) The wrist of a standard sterile surgical glove is snapped onto the outer ring of the wound protector-retractor. (d) Three standard trocars are placed into the cut fingertips of the glove. An air-seal can be ensured by tying the fingertips around the trocar sleeves with either suture material or elastic (cut from the other glove in the pair). (Further details can be found in Ref 7) Gas sufflation is carried out via the taps on the standard trocars.

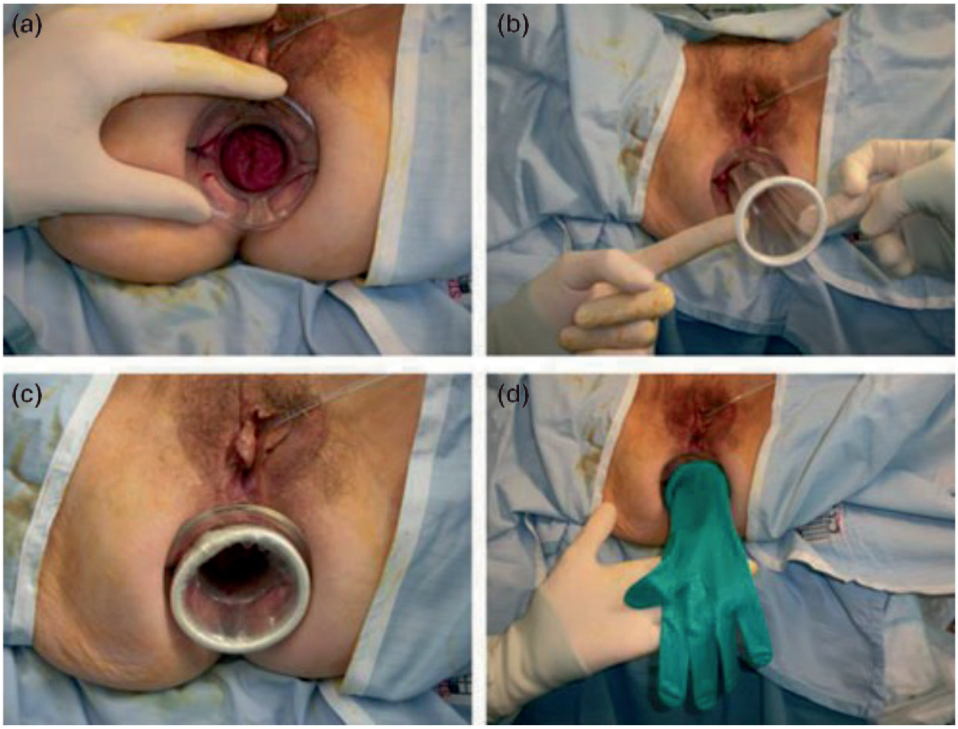

Figure 5. Construction of a surgical 'glove port' for the purposes of a transanal excision of a rectal lesion. (a) A circular anal dilator (CAD) device is sutured in situ transanally and (b) a small-wound protector-retractor is placed through this and snugged into position (c). (d) A sterile surgical glove can then be placed onto the outer ring of the wound protector and the set-up continued as in Fig. 4d.

As it is, this access device allows (re)capture of any incision made in the abdominal wall (because of the adaptability of the wound protector-retractor) in any size of patient. In the most common instance, this allows use of the extraction site as a laparoscopic port following specimen exteriorization in laparoscopic anterior resection and segmental colectomy, such as right or left hemicolectomy, and so allows for easier visual control of intracorporeal anastomosis formation and increased facility for haemostasis checking and security, along with fluid suctioning (the latter being ideal for 'entry level' singleport skill acquisition). Its positioning at the site intended for stoma formation allows single-port loop ileostomy and colostomy as well as urgent total colectomy for colitis failing medical therapy. We have also used it as a means of adding operating instrument capability via the site intended for the end colostomy (whether for splenic flexure mobilization, proximal colonic transection by stapling or added instrument retraction) in a morbidly obese patient undergoing laparoscopic abdominoperineal resection (and so avoiding any other trocar > 5 mm). This latter instance raises the possibility of bringing a second surgeon into the operation for the purposes of pelvic peritoneal retraction and/or assisting dissection as well as the ability to move camera position in order to obtain different views and perspectives even with the more standard 10mm size optic. Its placement at the site of a pre-existing stoma at the time of stoma reversal allows for check laparoscopy after closure of a loop defunctioning stoma. Furthermore, it may allow performance of the entire operation where an ileostomy is being internalized to form an ileorectal anastomosis or a colostomy is being changed to a colorectal anastomosis (i.e. reversal of Hartmann's procedure). Finally, we have also utilized this access device with some simple modification as a means of performing transanal excision of small benign and even malignant tumours (see Fig. 5).

Conclusion

While surgical technological innovation is often considered to involve the development of high-specification, sophisticated instruments, in fact what is sometimes needed more and is of greater use are broadly accessible 'low tech' devices which can synergise with evolving technique development. This is perhaps essential in the early stages of development of novel operative opportunities when is it unclear what specifically is needed by the 'target market'. Often the initial focus is on creating additional devices when what already adept surgeons need is the time and opportunity to work through their own learning curve in a way that is not financially or cognitively imposing. By broadening the field of opportunity, the level of reciprocal feedback then allowed can more markedly advance the field than any number of 'ivory tower' pronouncements.

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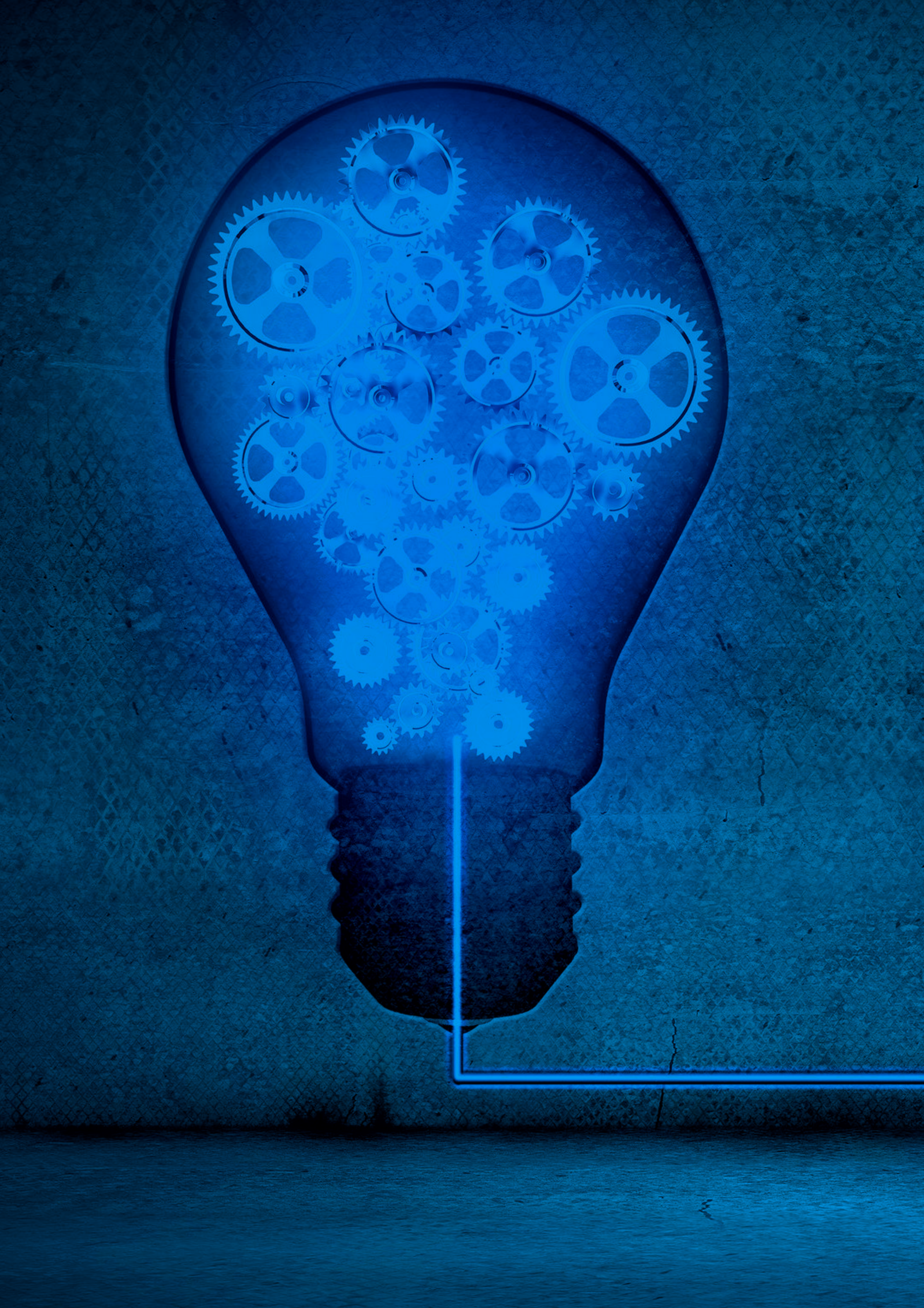

Chapter 3

Preclinical cadaveric study of transanal endoscopic da Vinci® surgery

R.Hompes
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E. Hagen
N.J. Mortensen

Br J Surg. 2012 Aug;99(8):1144-8.

Abstract

Introduction

Single-port platforms are increasingly being used for transanal surgery and may be associated with a shorter learning curve than transanal endoscopic microsurgery. However, these procedures remain technically challenging, and robotic technology could overcome some of the limitations and increase intraluminal manoeuvrability. An initial experimental experience with transanal endoscopic da Vinci® surgery (TEdS) using a glove port on human cadavers is reported.

Methods

After initial dry laboratory experiments, the feasibility of TEdS and ideal set-up were further evaluated in human cadavers. For transanal access a glove port was constructed on-table by using a circular anal dilator, a standard wound retractor and a surgical glove. A da Vinci® Si HD system was used in combination with the glove port for transanal endoscopic resections.

Results

It was possible to perform all necessary tasks to complete a full-thickness excision and closure of the rectal wall, with cadavers in both prone and supine positions. The stable magnified view, combined with the EndoWrist® technology of the robotic instruments, made every task straightforward. Intraluminal manoeuvrability could be improved further by intersecting the robotic instruments. The glove port proved to be very reliable and the inherent flexibility of the glove facilitated docking of the robotic arms in a narrow confined space.

Conclusions

Using a reliable and universally available glove port, TEdS was feasible and a preferred set-up was determined. Further clinical trials will be necessary to assess the safety and efficacy of this technique.

Introduction

Since its introduction in the early 1980s, transanal endoscopic microsurgery (TEM) has proved to be the technique of choice for surgical resection of benign rectal adenomas and is increasingly being considered for early rectal cancers[1–5]. The magnified and clear visualization of the rectal lesion within a stable pneumorectum allows more precise dissection and resection with clear surgical margins, translating into superior clinical results. Nonetheless, the uptake of TEM has been relatively slow owing to the cost of highly specialized instrumentation and inherently complex learning curve[6,7]. Particularly nowadays with the competing role of endoscopic submucosal dissection and endoscopic mucosal resection, cases presented to surgeons are more challenging and complex, making it even more difficult to reach proficiency.

The evolving place of local excision in rectal cancer treatment, not only in early rectal cancer but also in more advanced rectal cancers after a (near-)complete clinical response to neoadjuvant treatment, has led to a resurgence of TEM. Furthermore, the development in natural orifice transluminal endoscopic surgery, for which TEM offers a stable platform, and the boom in singleport surgery has contributed to an increased interest in transanal approaches[8–11]. New access devices/platforms have been developed for single-port surgery that are transferable to transanal work[12]. The configuration of most ports also provides access to the rectal vault and allows precise intraluminal surgery which seems more intuitive than TEM to surgeons with laparoscopic experience.

In the Department of Colorectal Surgery at Churchill Hospital in Oxford, the 'glove port' is used predominantly as a single-port platform, and this technique was adapted to allow transanal work[13,14]. Although safe, reliable and effective, the 'glove TEM port' has some drawbacks, as also reported for other devices[10,12]. The main disadvantage is that the single-port platform used for transanal work is a less stable platform than TEM, and assistance from an experienced camera operator (usually a second surgeon) is needed to achieve good views in the more technically challenging cases. To overcome these problems, it makes sense to combine a transanal platform with robotic technology; a single-surgeon stable platform is again created with improved intraluminal manoeuvrability and excellent three-dimensional imaging. To translate it into clinical practice, various challenges need to be addressed. The purpose of this study was to evaluate the glove TEM port in combination with the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, California, USA), aiming to define the best set-up for a feasibility study in patients. This technique is referred to as transanal endoscopic da Vinci® surgery (TEdS).

Methods

Dry Laboratory

In preparation for the cadaveric experiments, inanimate experiments were performed by one of the authors to ascertain the feasibility of TEdS. Initially a crude model was derived from a plastic abdominal training model and this was later replaced by an improved rectal model.

Cadaveric Study

On 2 consecutive days, the feasibility of TEdS and an ideal set-up were investigated in two human cadavers; one male (body mass index 23 kg/m^2) and one female (41 kg/m^2). A four-arm da Vinci® Si HD system (Intuitive Surgical) was used in combination with a glove TEM port for all experiments. The glove port was constructed on-table by using a circular anal dilator (CAD) (Frankenman International, Sheung Wan, Hong Kong, China), a standard wound retractor (Alexis® wound retractor XS; Applied Medical, Rancho Santa Margarita, California, USA) and a surgical glove. Details of the set-up were reported previously[14] and copied for the cadaveric experiments. Briefly, the CAD was inserted and fixed in position with perianal retaining sutures. The wound retractor was inserted through the aperture of the CAD, and the internal ring anchored itself above the anorectal ring. The outer ring of the wound retractor was rolled down to the level of the CAD and the cuff of a surgical glove snapped on, creating an airtight and easily accessible conduit. A standard 12mm laparoscopic port for the camera and the robotic trocars were inserted through the fingers of the glove and connected to the robotic arms (*Fig. 1*). A stable pneumorectum was obtained after expansion of the rectum by carbon dioxide insufflation to an intrarectal pressure of 10–15 mmHg.

The feasibility and ease of resecting 'pseudolesions' created in the rectum and suturing of the defects were assessed by all surgeons. Two of the surgeons were experienced in TEM (approximately 50 procedures per year) and were qualified to perform da Vinci® surgery, whereas the third surgeon had significantly more experience with robotic colorectal surgery (approximately 75 procedures per year). Different port positions and various instruments for dissection (different types and diameters) were tried. Experiments were done with the cadaver in the prone and dorsal decubitus positions. Lateral decubitus was not assessed because the operating table did not allow this set-up. With the patient in various positions, two different positions of the robotic cart were assessed: parallel docking of the cart or at an angle of 30–40° on the right side of the cadaver.

Fig. 1. Glove port in situ: a 12-mm camera port and two 8-mm da Vinci® cannulas are inserted into the tips of three fingers, and secured with latex strips cut from another glove to create an airtight seal. After docking of the da Vinci® system pneumorectum is established; the glove and rectum distend in concert, allowing robotic instruments to be worked via the trocars

Results

Glove Port

Access to the rectum was achieved successfully using the glove port in both cadavers in various positions. All surgeons were able to construct the glove port, insert the ports and dock the robotic arms in less than 10 min.

Patient position

The prone position avoided any collisions of the robotic arms with the thighs and legs of both cadavers. In the prone position both robotic arm 2 (set-up shown in *Fig. 2*) or arm 3 could be used in combination with arm 1. The dorsal lithotomy position was not feasible, as it was not possible to clear both legs.

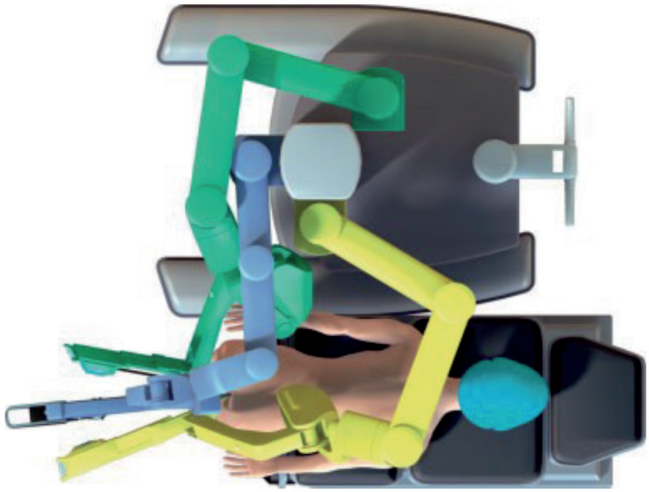

Fig. 2. Overhead view of docked patient cart (side-docking), illustrating camera position (blue), arm 1 (yellow) and arm 2 (green)

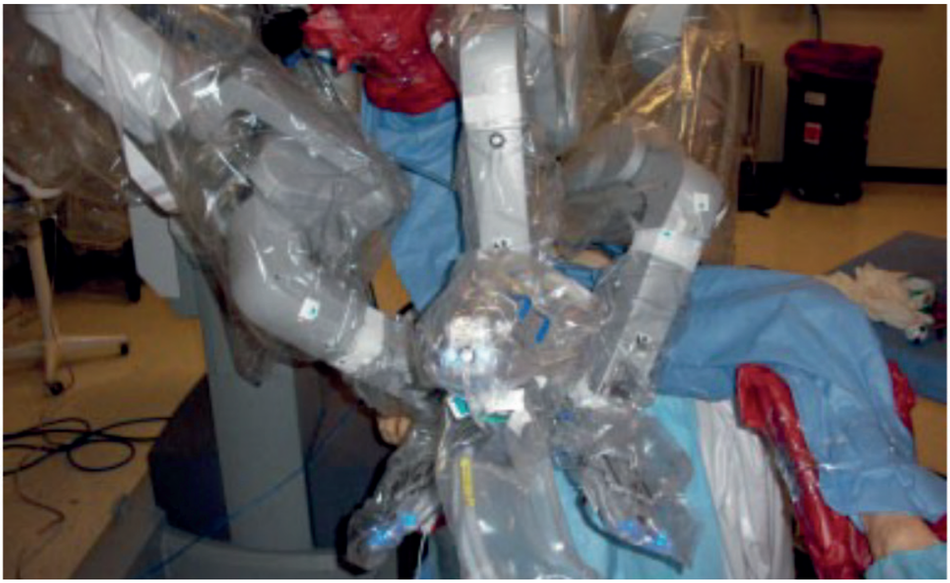

Fig. 3. The da Vinci® Si HD system side-docked with intersected robotic arms and the patient in a modified lithotomy position; the left leg is slightly extended and the hip abducted (low lithotomy), whereas the right leg is flexed at the level of the knee and hip (high lithotomy)

However, the lithotomy position could be achieved with one leg in high lithotomy (right leg) and the other in low lithotomy (left leg) position. With the cadaver in this position, it was possible to bring robotic arm 1 over the left leg and robotic arm 2 under the right leg, thereby clearing both legs (*Fig. 3*). Although robotic arm 3 cleared the right leg with greater ease, it clashed significantly with the camera and could not therefore be used.

Robotic docking, robotic arms and instruments

The dry laboratory experiments were performed with the robot docked on the right side of the model, with an angle of 30– 40°. However, during the cadaveric experiments it became apparent that side-docking the robot provided additional manoeuvrability and less collision of the robotic arms (particularly with the patient in the lithotomy position). For side-docking, the robotic cart was positioned in parallel on the right side of the patient, and for the ideal depth the forks of the robotic cart needed to line up with the caudal base of the table (*Fig. 2*).

Both 8-mm and 5-mm instruments were evaluated; 8mm instruments were ideal for intrarectal access and work. Although the 8-mm instruments might be more bulky, the 5-mm instruments lack the EndoWrist® technology (Intuitive Surgical) and needed to be inserted further into the rectum to clear the joint, limiting their use. All surgery was performed using EndoWrist® instrumentation (permanent cautery hook, 400 183/420 183; Maryland bipolar forceps, 400 172/420 172; large needle driver, 400 006/420 006). A stable and excellent view was obtained with a 0° camera; the use of a 30° camera did not add any benefit. Initial dissection and resection of pseudolesions within the rectum was performed with parallel ports. The EndoWrist® instruments made tip abduction, adduction and intraluminal triangulation easier than conventional TEM, and resection of lesions was straightforward.

Suturing the defect with intraluminal knotting proved more difficult than expected and was technically challenging. In an effort further to increase intraluminal manoeuvrability the instrument ports were crossed at their fulcrum halfway up the CAD (*Fig. 4*). Control of the robotic arms was switched from left to right, and vice versa, by the surgeon at the console, and in doing so control of the robotic instruments became completely intuitive. This set-up allowed excellent freedom and movement within the rectum, and made it feasible to resect the rectal wall and subsequently close the defect in all four quadrants at various heights (*Fig. 5*). It was also possible to perform mesorectal resections and to dissect into the mesorectal plane up to the level of the promontory, with excellent views of the presacral fascia.

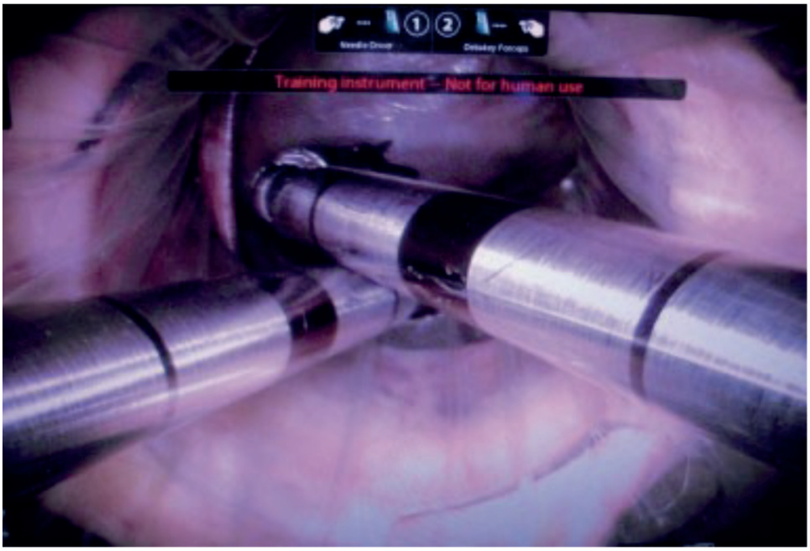

Fig. 4. The glove port in situ; the da Vinci® 8-mm cannulas cross at their remote centre in the middle of the circular anal dilator

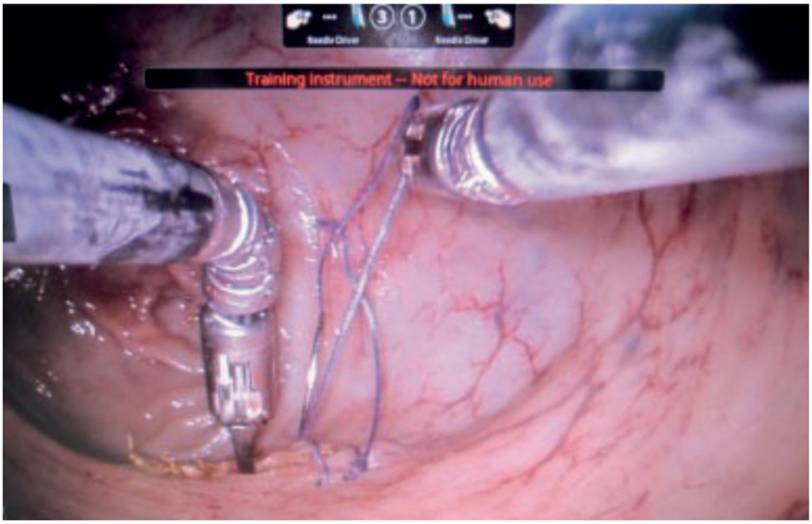

Fig. 5. Intraluminal view after establishing pneumorectum; the robotic technology allows increased manoeuvrability within a confined space, as shown here during suturing

Discussion

The technique of TEM, developed in 1980 by Gerhard Buess, has stood the test of time[1,9]. Although developed initially and used primarily for resection of rectal adenoma, its role in rectal cancer treatment is evolving and various other applications have been reported[3,5,15 – 18]. The increased interest in TEM in recent years came at the same time as that in single-port surgery. The parallel between the two techniques led to the crossover of single-port surgery principles and access platforms for transanal work[10,12,19]. The less rigid and shorter access devices increase the range of motion substantially; the technical skills needed are comparable to those of normal laparoscopy, and thus more intuitive to most colorectal surgeons.

The authors reported recently on a safe and reliable set-up for transanal work with similar drawbacks to commercially available ports[14]. In an effort to overcome these, the role of robotic integration into transanal work has been investigated in an *ex vivo* model. Dry laboratory experiments demonstrated the promise of TEdS and indicated that further cadaveric experiments were justified. The cadaveric experiments revealed that TEdS using the glove TEM port was feasible, and that the set-up developed was ready to be reproduced and tested in patients. TEdS offers the same stable platform as conventional TEM, with an even better magnified three-dimensional view. Further advantages over conventional and glove port-assisted TEM include excellent ergonomics, tremor elimination, motion scaling, and the availability of instruments with multiple degrees of freedom. All these features are ideal for working in a confined space, where conflicts between instruments or between instruments and optics are otherwise common.

Although space was very limited, the flexibility of the glove made it easy to attach the instruments to the robotic arms and insert them into the CAD and rectum. The glove port proved to be robust and allowed a wide range of movement outside, without losing the airtight seal of the glove port and thus maintaining a stable pneumorectum at all times. Another attractive feature of the glove port was that it protected the anal sphincter from damage by any inadvertent movement of the robotic arms. The glove port would also allow one or two extra ports to be used for introduction of needles during suturing, continuous smoke extraction or any other task necessary to complete the procedure. During the experiments it became clear that further intraluminal freedom could be achieved by crossing instruments and by reversing control of the robotic arms, maintaining intuitive control by the surgeon. The crossed set-up allowed all the established principles of laparoscopic colorectal surgery – adequate exposure, traction/countertraction and precise excision of the lesion – to be reproduced, without any intraluminal conflicts.

One of the main limitations of TEdS that needs to be taken into account is the financial implication. A single procedure would cost around £952, whereas costs of consumables for a conventional or glove TEM are clearly lower. However, theatre time for TEdS in complex cases might be shorter and result in overall cost savings. Only a prospective analysis of clinical outcome and accurate cost analysis will determine whether TEdS is economically viable and in which patients it should be used.

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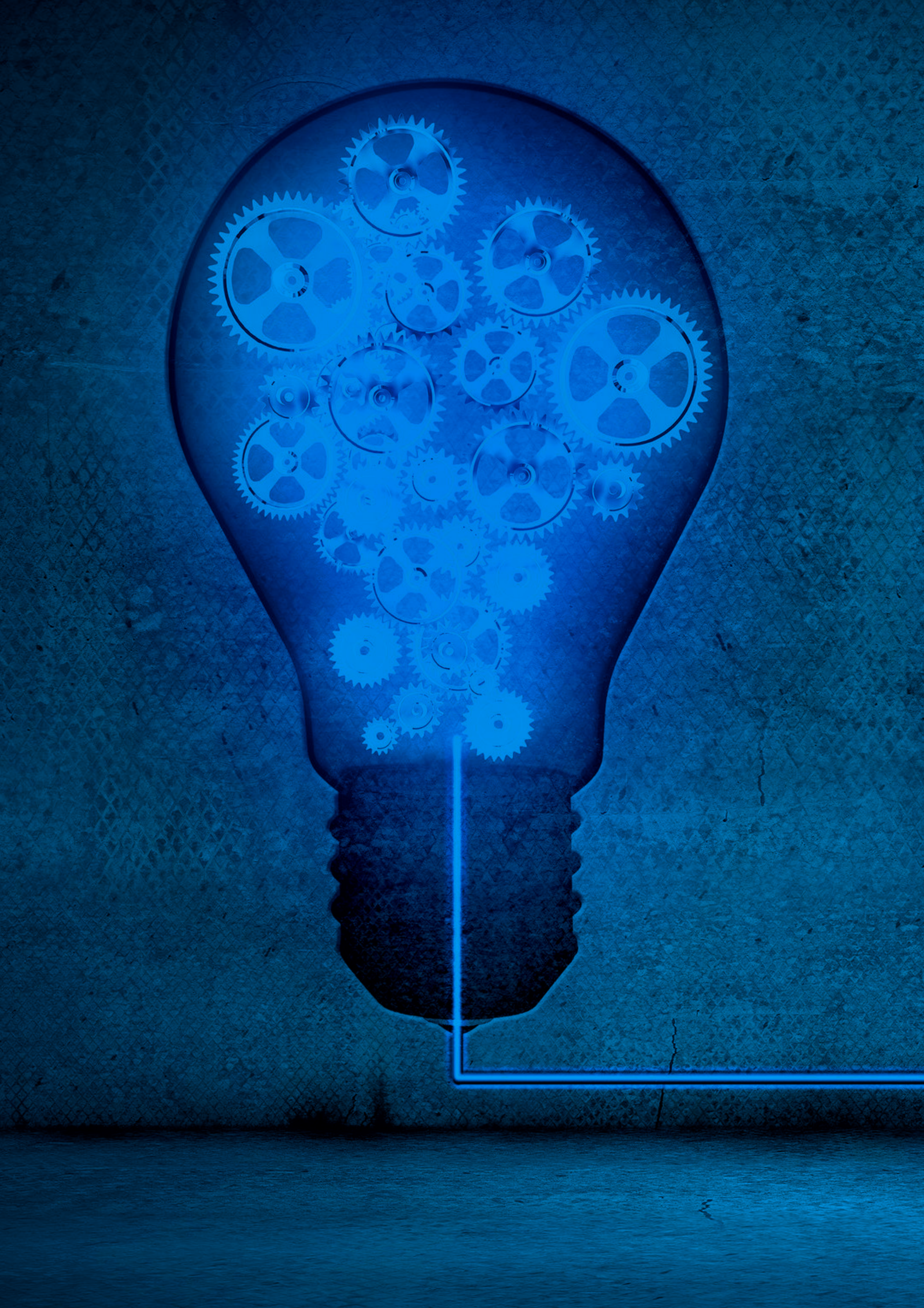

Chapter 4

Transanal glove port is a safe and cost-effective alternative for transanal endoscopic microsurgery

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Br J Surg. 2012 Oct;99(10):1429-35.

Abstract

Introduction
Transanal endoscopic microsurgery (TEM) is a minimally invasive technique for excision of rectal tumours that avoids conventional pelvic resectional surgery along with its risks and side-effects. Although appealing, the associated cost and complex learning curve limit TEM utilization by colorectal surgeons. Single-port laparoscopic principles are being recognized as transferable to transanal work and hybrid techniques are in evolution. Here the clinical application of a new technique for transanal access is reported.

Methods
Consecutive non-selected patients eligible for TEM over a 3-month period (and selected patients thereafter) were offered a procedure performed via a 'glove TEM port'. This access device was constructed on-table using a circular anal dilator (CAD), wound retractor and standard surgical glove, along with standard, straight laparoscopic trocar sleeves and instruments.

Results
Fourteen patients underwent full-thickness resection of benign (8) or malignant (6) rectal pathology. CAD insertion failed in one patient and conventional TEM assistance was needed in another, leaving 12 procedures completed successfully by glove TEM alone as planned (completion rate 86 per cent overall, 92 per cent after initiation). The median (range) duration of operation and resected specimen area were 93 (30– 120) min and 12 (3– 152) cm^2 respectively. There was no intraoperative and minimal postoperative morbidity, with a median follow-up of 5·7 (2·7-9·4) months.

Conclusions
The glove TEM port is a safe, inexpensive and readily available access tool that may obviate the use of specialized equipment for transanal resection of rectal lesions.

Introduction

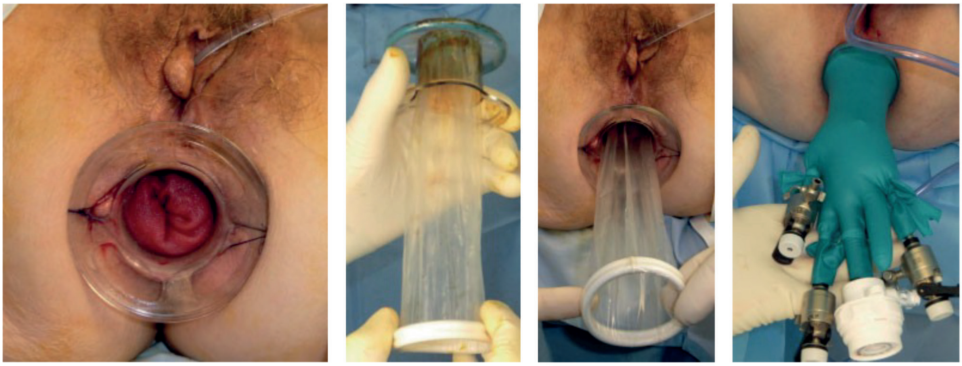
First developed over 25 years ago by Gerhard Buess in Tubingen, Germany, transanal endoscopic microsurgery (TEM) has become the treatment of choice for benign lesions throughout the rectum that are not amenable to flexible endoscopic excision[1–4]. It has also become a valuable option in selected patients with malignant rectal disease, in whom it may provide an acceptable oncological outcome with minimal postoperative morbidity and better functional outcome than standard pelvic resection[5–8]. However, despite clear advantages over both conventional transanal excision and radical surgery in appropriate patients, the universal uptake of this technique has been slow. This has been due to the cost and limited availability of highly specialized equipment, and also because of a steep and complex learning curve[9,10].

Although the instrumentation and procedure for resection of rectal tumours with TEM have been largely unchanged since its introduction, technological innovation and technical expertise in allied colorectal approaches have advanced markedly. Considerable crossover potential now exists, whereby instrumentation designed for one application can be used for a different task[11]. As much as TEM is being proposed as a potential platform for intraperitoneal surgery and natural orifice transluminal surgery, single-port laparoscopic principles are being recognized as being transferable to transanal procedures[12 – 17]. For greatest widespread usefulness, such adapted operating should avoid the technical limitations and even the expense associated with contemporary commercial single ports[11,18].

This report describes the clinical application of a modified technique for transanal endoscopic resection using a single-port access system constructed at the operating table. It is shown to be a cost-effective and safe tool for resection of both benign and malignant lesions within the rectum.

Methods

Departmental approval for this operative approach was obtained before its introduction. All surgeons had previous experience with TEM. The technique was developed and initiated in the Oxford Radcliffe Hospitals and has subsequently been used in another centre (Dublin), since the move there by one of the authors. In a 6-month period (2010– 2011), 14 patients (10 consecutive) eligible for TEM between these two centres were offered the option to undergo this new approach. Fully informed consent was obtained from each individual before surgery, and all were assured a low threshold for conversion to conventional TEM in the event of technical difficulties with either the access or the technique.



a Anal dilator in position **b** Wound protector after insertion **c** Wound protector in position **d** Glove port with trocar sleeves

Fig. 1. Set-up of the glove transanal endoscopic microsurgery port. a The circular anal dilator (CAD) is secured to the anal verge with two retaining sutures at 3 and 9 o'clock positions. b,c The inner ring of a wound protector–retractor (in this case an extra small Alexis®) is b inserted through the CAD and c positioned above the anorectal junction. d The cuff of a sterile surgical glove is then snapped on to the external ring of the wound protector and trocar sleeves are inserted into the tips of any of the five fingers

Fig. 2. Glove transanal endoscopic microsurgery port at the operating table with the anaesthetized patient in position. A 12-mm camera port and two 5-mm trocar sleeves are inserted into the tips of three fingers and secured with latex strips cut from another glove to create an airtight seal. As the pneumorectum is established, the glove and rectum distend in concert allowing standard laparoscopic instruments to be worked via the trocars

All patients had a routine preoperative evaluation as part of the departmental protocol, which included a thorough proctological examination, flexible endoscopy, endorectal ultrasonography, abdominopelvic computed tomography (for malignant lesions only) and pelvic magnetic resonance imaging (MRI). On admission, each patient received a phosphate enema 1 h before the start of the procedure. Routine prophylactic antibiotics (500 mg metronidazole and 2 g ceftriaxone) were administered intravenously before the start of the procedure and standard deep venous thrombosis prophylaxis was instituted.

Surgical Technique

As with a routine TEM procedure, most patients were initially positioned to expose the bulk of the lesion at 6 o'clock in the operative field. To aid in relaxation of the sphincters and improve postoperative analgesia, an anal block (20 ml 0.5 per cent bupivacaine) was administered. Subsequently a circular anal dilator (CAD) (Frankenman International, Sheung Wan, Hong Kong, China) was inserted on its internal obturator, making sure its proximal end reached the top of the anal canal. The CAD was fixed in position with retaining sutures placed at the anocutaneous junction (*Fig. 1a*). The internal ring of a standard wound protector–retractor (Alexis® wound retractor XS; Applied Medical, Rancho Santa Margarita, California, USA) was then inserted through the CAD (*Fig. 1b,c*). Once the ring of the wound protector had opened inside the rectum, it anchored itself on the top of the CAD just above the anorectal ring. The outer ring of the wound retractor was then twisted down to the level of the external aspect of the CAD and the cuff of a size 6, sterile surgical glove (Ansell, Brussels, Belgium) was snapped on to the external ring of the wound protector (*Fig. 1d*). Including the glove in the last two to three twists when tightening down the outer retractor ring prevented slippage of the glove from the outer ring and provided an airtight seal. A latex-free glove was preferred as in general these are thicker and more robust than their latex counterparts.

Standard laparoscopic trocar sleeves – a 12-mm sleeve for the camera and two or three 5-mm sleeves for the instruments – were then inserted through the fingers of the glove and an airtight seal around the ports was achieved with either sutures or (preferably) latex strips cut from another glove (*Fig. 1d*). These ports provided a conduit for ordinary laparoscopic instruments to be used for the procedure (such as camera, graspers, hook dissector and needle holder) as well as facilitating easy exchange during the procedures (*Fig. 2*). Reusable trocars were preferred over disposable ports for reasons of cost, but also because their narrower atrium profile reduced instrument clutter and clash. A 30° laparoscope, if possible one with inline optical cabling, was preferred to ensure optimal viewing with reduced instrument clashing. Standard instrumentation attached to diathermy was preferred, although more advanced energy sealers could also be used if needed.

Excellent views could be obtained with the videolaparoscopic optics after adequate expansion of the rectum by carbon dioxide insufflation to an intrarectal pressure of 10–15 mmHg

(*Fig. 2*). Full-thickness resection of the rectal wall was preferred, as partial-thickness excisions are associated with a sixfold increase in the risk of an involved margin[8]. Mixed partial and full-thickness excisions could be undertaken either to preserve the internal anal sphincter for very distal lesions encroaching on the upper anal canal, or to prevent perforation into the abdominal cavity for more proximal lesions. Intermittent, and occasionally continuous, venting through one of the ports was necessary to remove coagulation fumes. If the peritoneal cavity was not entered, closure of the defect was left to the preference of the operating surgeon.

Surgical Outcomes

Patient, tumour and surgical details were collected prospectively for all patients. Postoperative data recorded included morbidity and mortality classified according to Clavien–Dindo grade[19], hospital stay, histopathological characteristics of the specimen, short and intermediate term outcomes, and need for further therapy.

The follow-up of each patient was completed within the institution of the operating surgeon, and involved a clinical review and flexible endoscopy at 3-month intervals for the first year. Pelvic MRI was performed at 3, 9 and 24 months after surgery in patients with malignant lesions.

Results

During the study period, this access technique was attempted in all 14 patients presenting for TEM; no eligible patient declined the new approach. Patient demographics and tumour characteristics are shown in *Table 1*. Histologically proven adenocarcinoma was confirmed in preoperative biopsies of four patients. Two of these had T1 cancers and the other two had the procedure as a compromise intervention for more advanced rectal cancers. One of these patients was medically unfit for radical surgery, whereas the other refused radical surgery after giving full consent. One patient had the procedure for a carcinoid tumour that had been excised incompletely by flexible endoscopic polypectomy, and another had a transanal full-thickness resection of a residual fold to treat obstructing defaecation secondary to high-grade internal rectal prolapse after a stapled transanal resection procedure. The remainder of patients had a local excision for suspected benign rectal adenomas.

The full procedure was completed successfully using the glove port without any major technical problems in 12 of the 14 patients. Median (range) set-up time of the glove port was 7 (5– 10) min. The technique was unsuccessful in two patients with relatively small tumours. The operation in one man had to be converted immediately to a conventional TEM procedure, as it was not possible to insert the CAD device deep enough owing to his body habitus (body mass index 40 kg/m^2 and very narrow interischial space). A hybrid approach was necessary in the other patient in whom it was not possible to create a stable pneumorectum. Even with the TEM scope inside, the dissection proved very difficult given the movements of the rectal wall. The posterior section of the tumour was resected by conventional TEM; the cranial part of the dissection on the lateral side wall could not be well addressed with the TEM device (the patient was in a supine position) and so was finished with the glove port. In another two patients, lesions of the lateral rectal wall could also be adeptly treated in a modified Lloyd-Davis position without any significant technical problems.

Table 1. Patient demographics and tumour characteristics

	No. of patients*
Sex ratio (M : F)	5 : 9
Age at operation (years)†	72.6 (46–89)
Body mass index (kg/m^2)†	24.3 (20–40)
ASA grade	
I	3
II	8
III	3
Preoperative assessment	
Benign	9
Malignant	4
Residual rectal fold (after STARR)	1
Tumour position	
Anterior	3
Posterior	8
Lateral	2
Distance from anal verge (cm)†	5 (2–10)
Tumour surface (cm^2)†	2.9 (0.3–100)

*Unless indicated otherwise; †values are median (range). ASA, American Society of Anesthesiologists; STARR, stapled transanal resection.

Minor technical problems associated with the glove port included excessive smoke accumulation (3); glove puncture, dealt with by replacing the glove (1); and difficulty in snugly fitting the internal ring of the wound protector on to the internal aspect of the CAD (1). None of these significantly affected operative quality, although fluency and expediency were reduced.

All lesions were excised full thickness, but in four patients with very distal lesions the dissection was started as partial thickness between the dentate line and the top of the puborectal sling. The defect was left open in five patients and closed intraluminally by a running suture in the remainder. No serious intraoperative complications occurred. The median duration of operation, measured from injection of the anal block to removal of the CAD, was 93 (range 30– 120) min. In eight patients the procedure took longer than 1 h for various reasons, including technical problems (glove puncture, internal ring difficult to fit, smoke accumulation and instability of pneumorectum) and anatomical issues, in addition to lesion size. The median (range) specimen size in these latter four patients was 89.8 (29 – 152) cm^2 compared with 9.0 (3–20) cm^2 in the other ten patients.

Table 2. Histopathological characteristics

	No. of patients*
Specimen surface (cm^2)†	12 (3–152)
Resection margin	
R0	12
R1	2
Final histology	
Benign	8
pT1	3
sm1	2
sm2	0
sm3	1
pT2	1
pT3	2

*Unless indicated otherwise; †values are median (range). pT, pathological tumour category; sm, submucosal.

Median follow-up was 5.7 (range 2.7–9.4) months. Final histopathology results are shown in *Table 2*. A negative resection margin was obtained in 12 of 14 patients. In one patient there was a small focus of low-grade dysplasia at the peripheral resection margin of a very large tubulovillous adenoma. This patient was followed closely and a small recurrence found 6 months later was excised. The other patient was diagnosed before surgery with a clinical T2 N0 M0 tumour of the mid-rectum and had refused radical surgery, wishing instead to have a local excision as a compromise. The local excision revealed a pathological T3 cancer (moderately differentiated, focus suspicious of lymphovascular invasion) with focal extension to the inked deep resection margin. After extensive discussion, the patient still refused further surgery, and went on to have adjuvant radiotherapy alone. In two patients the final histology revealed an unexpected cancer. In one 85year-old man this was a very small focus of an invasive cancer in a big villous adenoma and he refused completion surgery (which would have involved abdominoperineal excision). The other patient underwent a laparoscopically assisted ultralow anterior resection 4 weeks after the index operation; final histology revealed no residual tumour and no involved lymph nodes (0 of 23).

Eleven patients were discharged on the day after surgery. Two patients were discharged later (2 and 3 days after operation) for social reasons. One patient had a blood transfusion for rectal bleeding and was discharged on day 5. The postoperative morbidity rate was low, with only two Clavien grade 2 complications: post-TEM fever treated with oral antibiotics, and bleeding requiring transfusion of 2 units of packed cells.

Discussion

Over the past two decades TEM has proven to be a valuable tool for excision of rectal adenomas and its role in early rectal cancers is evolving alongside numerous other indications[1–5,8,20–22]. The easy access and excellent visualization that the TEM scope provides throughout the rectum allows the required surgical task to be performed with great precision. Widespread uptake of TEM, however, has been slow, in part because the surgeon is forced to work through a long rigid (10– 15-cm) rectoscope, which limits triangulation and subsequent instrument manipulation.

To overcome these restrictions several authors have recently reported single cases or small series of patients (usually fewer than 5) in whom they have modified the TEM technique by using equipment for single-incision laparoscopic surgery, generally referred to as transanal minimally invasive surgery (TAMIS)[13,15,17]. To date most authors have employed the SILS™ Port (Covidien, Dublin, Ireland) with the intention of ensuring safe and atraumatic transanal access. Although this is considered to be a reasonable low-cost option compared with TEM, the cost per application is still around £335. Furthermore, the SILS™ Port, like other similar devices, is not ideal in its configuration for transanal work; in particular, it enforces a degree of parallel angulation to the working instruments and proves unstable without supplementary fixation.

Recently, the present authors and others have reported on the usefulness of a glove port in the stepwise integration of single-port laparoscopic surgery into routine colorectal surgical practice[23–25]. The glove port has proved to be a reliable single-port platform, with favourable and effective technical performances. In an effort to expand the applications of the 'glove principle', the glove TEM port was developed as a single-port platform for TAMIS. Its components proved easy to set up as well as being reliable and robust in use. The flexibility of the glove and flush fulcrum, which greatly alleviates pivot point effects, offers a wide axis of movement for instruments inside the rectum, allowing them to be used more widely apart, or easily crossed and/or rotated. This has proved particularly useful for intraluminal suturing, which can be confounded by the long cylindrical axis of the TEM rectoscope. The degree of freedom achieved with this set-up is similar to that of normal laparoscopy and thus should be more familiar to colorectal surgeons than TEM procedures.

This should impact on learning curve issues by increasing the common ground between the techniques and thus broaden the application of this approach. Furthermore, although the bulk of the tumour should always be kept at 6 o'clock for TEM surgery, the freedom of motion regained within the rectum in combination with 360° rotational viewing with a 30° camera may allow liberal positioning of the patient; indeed, this was a noticeable advantage in three of the 14 patients in the present series. The glove TEM is extremely cost-effective not only in comparison with standard TEM equipment but also with the equivalent commercial single ports. The total cost of the glove TEM port per patient is £31 if used in conjunction with reusable trocars (glove £0.70, extra small Alexis® £20.40, CAD device £9.90), and £82.50 if disposable ports are preferred (12-mm port £21, 2x5-mm sleeves without obturator £30.50, glove TEM port £31). The glove TEM port does, however, have some disadvantages, although most of these can be readily surmounted by experience. In patients with very protuberant and fatty buttocks and/or narrow interischial tuberosity distance, it can be difficult to insert the CAD high enough to access the top of the anal canal. This problem can be prevented by judicious patient selection or, better, by use of a modifica tion of the CAD device (the 'winged' CAD[26]), which allows easier introduction in such patients. The authors now use this type of CAD routinely in every patient and have had no further difficulties. A unique feature of the TEM system is the combined suction–insufflation unit, which clears excessive smoke during the procedure without loss of pneumorectum. In three of the present procedures excessive smoke within the rectum was troublesome, although it did not prevent completion of the surgery. Smoke evacuation was largely improved after the introduction of a small filter (Plume-Away 4.0; Stryker, Portage, Michigan, USA), attached to one of the ports to allow continuous evacuation without losing the pneumorectum. As an alternative, a suction device can be introduced through a fourth port. The most major durable drawback of the set-up is the loss of a stable operating platform with its concomitant requirement for a second surgeon to assist as camera operator. This could be resolved by using this technique in combination with a modified laparoscope holder or, ideally, robotic assistance.

This study has shown that the glove TEM port is a safe, inexpensive and readily available tool that can be used in combination with regular laparoscopic tools for transanal resection of rectal lesions. The main benefits are its low cost and ease of use owing to the degree of motion available to the surgeon, making it accessible for every surgeon with an interest in TEM, transanal endoscopic operation or TAMIS. However, access to equipment is only part of the issue, and before offering a service to patients there remains a need to develop expertise in confined-access approaches in addition to specific transanal endoscopic surgical skills. Until these shortcomings have been addressed, use of this approach is probably best where there is TEM back-up in case conversion to the more standard approach becomes necessary. Such a change of strategy, however, carries limited financial penalty when this access device is used at the outset. Although this experience is small and further data are required, as well as refinement of the technique, the authors believe that the glove TEM port has great potential and merits further investigation.

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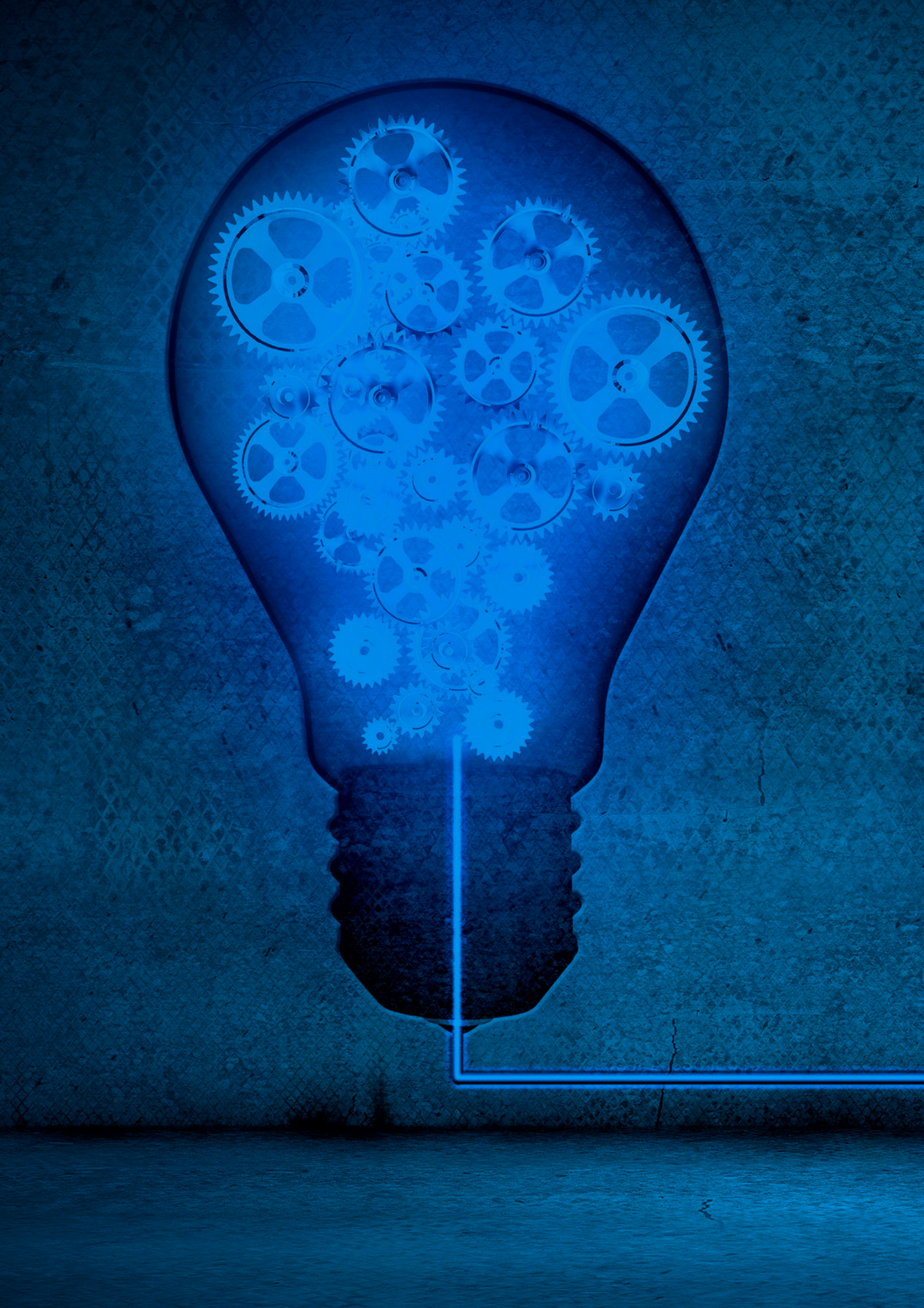

Chapter 5

Robotic transanal minimally invasive surgery for local excision of rectal neoplasms

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Br J Surg. 2014 Apr;101(5):578-81.

Abstract

Introduction
Robotic transanal minimally invasive surgery (TAMIS) may be an option for rectumpreserving excision of neoplasms. Recent cadaveric studies showed improved vision, control and manoeuvrability compared with use of laparoscopic instruments. This study reports the clinical application.

Methods
Consecutive patients eligible for transanal endoscopic microsurgery (TEM) or TAMIS in three participating centres were operated on using a robotic platform and transanal glove port. Patient demographics, lesion characteristics, perioperative data, complications and follow-up of all patients were recorded prospectively.

Results
Sixteen patients underwent robotic TAMIS for rectal lesions with a median (range) distance from the anal verge of 8 (range 3– 10) cm. The median size of the resected specimen was 5·3 (0·5– 21) cm^2. The median docking time and duration of operation were 36 (18– 75) and 108 (40– 180) min respectively. One conversion to regular (non-robotic) TAMIS was needed owing to difficulties accessing the rectum. Glove puncture necessitated replacement in four procedures, an unstable pneumorectum arose during one operation and one patient developed a pneumoperitoneum. One patient required catheterization for urinary retention. The median hospital stay was 1·3 (0–4) days. The additional cost of the robotic approach was approximately €1000 per procedure (excluding the capital expenditure on the robotic system and its maintenance).

Conclusions
Robotic TAMIS is feasible in patients with rectal lesions. Potential advantages over TEM and non-robotic TAMIS will need to be balanced against the cost of the robotic system.

Introduction

Since the introduction of transanal endoscopic microsurgery (TEM) in the early 1980s, preservation of the rectum by local excision of neoplasms has become increasingly popular[1]. An appreciation of cross-over between techniques resulted in the development of transanal minimally invasive surgery (TAMIS) using laparoscopic ports, trocars and instruments. Glove-port TAMIS allows better intraluminal views (360° *versus* 220°) and wider instrument freedom than TEM[2]. Robotic systems offer three-dimensional imaging, motion scaling, tremor elimination, ambidextrous capability, and multidegree movement to enhance dexterity, especially within confined spaces. Experimental work in cadaveric models has confirmed that robotic TAMIS is a potential option[3,4]. This study reports on its initial clinical application.

Methods

Patients eligible for TEM in the three participating centres (Geneva, Switzerland; Oxford, UK; Rochester, New York, USA) were offered a robotic approach. Departmental approval was obtained before recruitment began. All patients were assessed according to local standard protocols. Patients received oral bowel preparation and prophylactic antibiotics. All procedures were performed under general anaesthesia; in Oxford and Geneva, a peripheral nerve block around the anus (20ml 0.5 per cent bupivacaine) was administered to aid relaxation of the sphincters and improve postoperative analgesia.

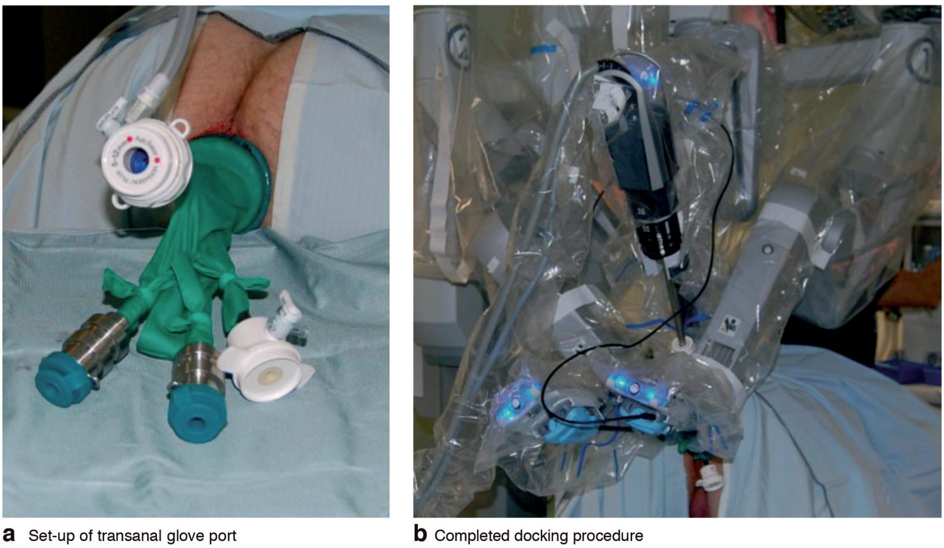

Fig. 1. a Set-up of the transanal glove port; 5-mm (assistant) and 10-mm (camera) laparoscopic ports and two 8-mm robotic cannulas. **b** Completed docking procedure (robot side-docked); the 30° robotic camera is positioned cephalad, and both of the working arms are placed posteriorly (caudal)

All surgeons had previous experience with TEM/TAMIS and robotic TAMIS cadaveric experiments. In Geneva and Oxford, patients were placed in the prone or left lateral decubitus position for anterior or posterolateral lesions respectively, All patients were positioned prone in Rochester. The transanal glove port was constructed on-table and inserted as described previously[2]. A standard 10-mm laparoscopic trocar was inserted through the thumb of the surgical glove ('thumbs-up' position of the camera), with two robotic trocars (8 or 5 mm) and a standard 5-mm laparoscopic port for assistance inserted through the fingers of the glove (*Fig. 1a*). The robot (da Vinci Si Surgical System; Intuitive Surgery, Sunnyvale, California, USA) was side-docked (*Fig. 1b*) with the forks of the robotic cart parallel with the caudal base of the table, as described previously[4]. The set-up and surgical technique are demonstrated in the online video (*Video S1*, supporting information).

Results

A total of 16 patients underwent robotic TAMIS for rectal lesions using the transanal glove port (3 in Geneva, 5 in Oxford, 8 in Rochester). Patient demographics and preoperative tumour characteristics are shown in *Table 1*. Conversion to TAMIS with an anal port was necessary in one patient owing to access problems with the glove port; duration of operation in this patient was 112 min. For the patients who had a successful robotic procedure, the median docking and operating times were 36 (range 18– 75) and 108 (40 –180) min respectively. A crossed or parallel set-up of the cannulas was used in eight and two patients respectively, whereas a combination was used in five patients. Peroperative tearing of the glove occurred in four procedures, followed by uneventful replacement and completion of the operation. Other minor technical problems encountered were intraluminal smoke accumulation during two procedures and an unstable pneumorectum in one patient. None of these affected the quality of resection, but they did interfere with operative fluency and prolonged operating time. Although no peroperative perforation into the peritoneal cavity was reported, one patient developed a clinical pneumoperitoneum that was managed conservatively. No other intraoperative complications occurred.

All but one tumour were excised full thickness as a complete disc. Partial-thickness dissection was started between the dentate line and puborectal sling in one patient. The rectal defect was left open in three patients with small distal lesions, and closed with sutures in all other patients. Final histology revealed six adenomas and four adenocarcinomas (2 T1, 1 T2, 1 T3). No residual tumour was found in the five patients who had excision of scar tissue following polypectomy of malignant lesions. A clear resection margin was obtained in 13 patients. Two patients with involved margins (less than 1 mm) were found to have more advanced lesions than anticipated and subsequently underwent total mesorectal excision; no residual tumour was found in either patient.Table 1. Patient demographics and tumour characteristics

Overall median hospital stay was 1 3 (range 0–4) days for all 15 patients. Two patients developed urinary retention, which required catheterization in one patient who was discharged on postoperative day 2. None of the 15 patients required readmission.

Table 1. Patient demographics and tumour characteristics

No. of patients (*n* = 16)	
Age at operation (years)*	68 (38 –86)
Sex ratio (M : F)	8 : 8
Body mass index (kg/m^2)*	26 (22 –39)
ASA grade	
I	2
II	13
III	1
Lesion position (rectal wall)	
Anterior	5
Posterior	3
Lateral	8
Distance from anal verge (cm)*	8 (3 –10)
Lesion surface area (cm^2)*	5·3 (0·5 –21)

*Values are median (range). ASA, American Society of Anesthesiologists.

Discussion

Although the robotic set-up might seem cumbersome and time-consuming, the transanal glove port facilitated the robotic set-up, enabling flexibility and as such allowed docking of the cannulas away from the limited perianal workspace. Furthermore, the glove port allowed a wide axis of movement for instruments inside the rectum, enabling them to be used more widely apart, or easily rotated and/or crossed. This latter feature is of particular relevance to the robotic approach. The crossed set-up for the cannulas with switched robotic arm control allows additional intraluminal reach while maintaining completely intuitive control.

Inherent to this set-up is the maximal separation of the robotic arms externally, reducing collision between these arms and/or the camera. External conflict was more common when operating on proximal lesions and with the use of the 5-mm robotic instruments (lacking multiplanar manoeuvrability), and the crossed set-up helped avoid this. The benefit of 5-mm instruments is their narrower profile, which allows easy transition from a crossed to a parallel set-up without any help from the bedside assistant. The elbows of the joints can help stent the rectal lumen in the event of an unstable pneumorectum, or gain access to a lesion proximal to a rectal valve of Houston.

It is acknowledged that this feasibility study has some limitations. The sample size is small; larger series will be necessary to confirm the present safety and efficacy data. Randomized clinical trials comparing robotic with conventional TEM or TAMIS may further evaluate excision quality, functional results, complications and costeffectiveness, although such trials may be difficult or impractical to conduct.

Future optimization of this technique, including establishing the ideal set-up (crossed *versus* parallel) and type of instrumentation (8 *versus* 5 mm) for the various lesion locations within the rectum, and new developments in robotic platforms will increase its application to patients with advanced rectal lesions. The stability and intraluminal versatility of this platform will also lend itself to more advanced extraluminal transanal procedures. However, the additional costs associated with the robotic approach in comparison with TEM or TAMIS (approximately €1165 and €837 respectively; capital cost of robotic system not included) should be justified and cost-effectiveness explored.

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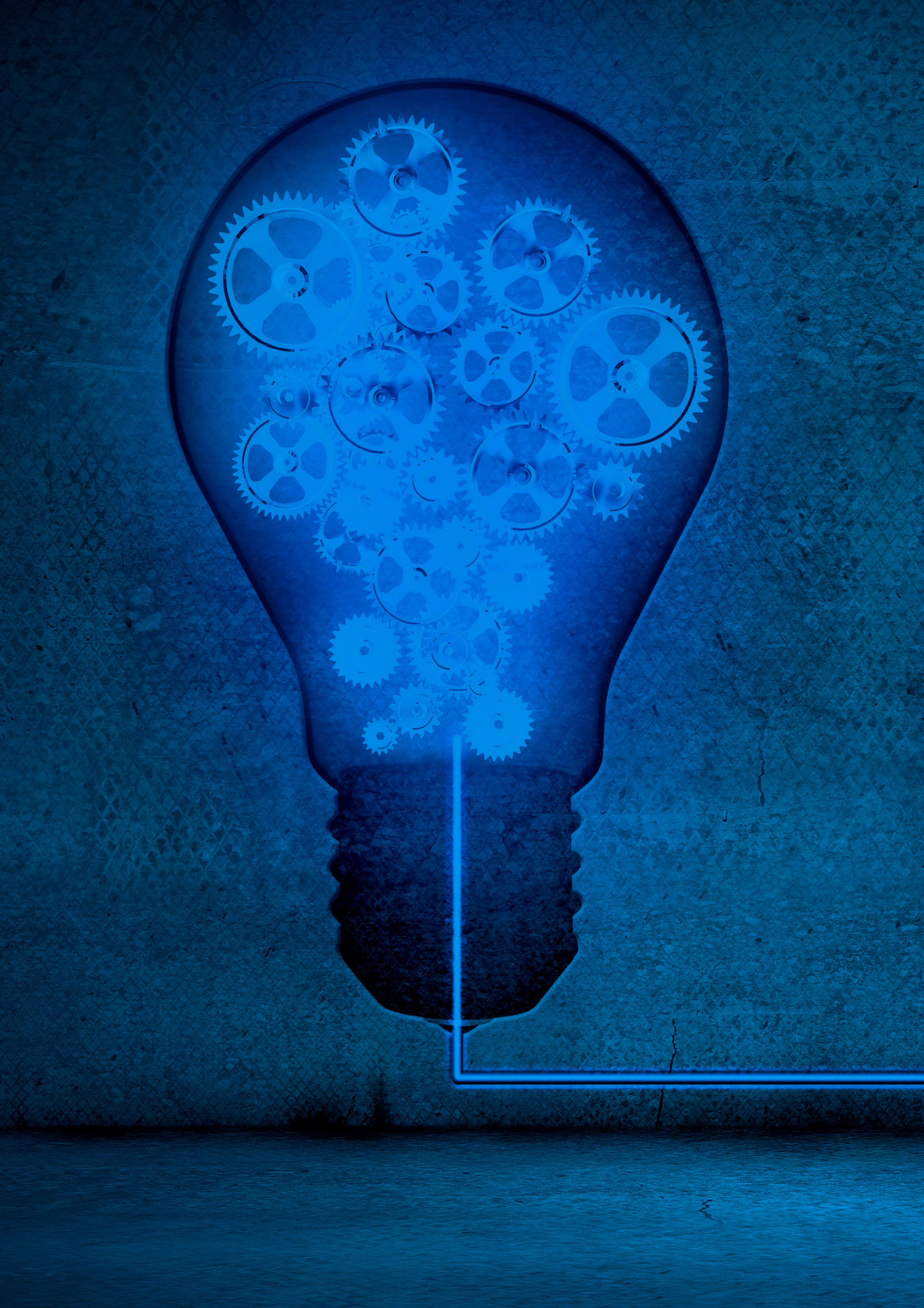
PART II
DEVELOPMENT



Chapter 6

Transanal rectal resection: an initial experience of 20 cases

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Colorectal Dis. 2016 Jan;18(1):45-50.

Abstract

Aim

Low anterior resection (LAR) can present a formidable surgical challenge, particularly for tumours located in the distal third of the rectum. Transanal total mesorectal excision (taTME) aims to overcome some of these difficulties. We report our initial experience with this technique.

Method

From June 2013 to September 2014, 20 selected patients underwent transanal rectal resection for various malignant and benign low rectal pathologies. All patients with rectal cancer were discussed at a multidisciplinary team meeting. Data were entered into a prospective managed international database.

Results

Of the 20 patients (14 male), seventeen (85%) had rectal cancer lying at a median distance of 2 cm (range 0–7) from the anorectal junction. The operations performed included LAR (16). Abdominoperineal excision (2) and completion proctectomy (2), all of which were performed by a minimally invasive approach with three conversions. The mean operation time was 315.3 min. There were six postoperative complications of which two (10%) were Clavien–Dindo Grade IIIb (pelvic haematoma and a late contained anastomotic leakage). The median length of stay was 7 days. The TME specimen was intact in 94.1% of cancer cases. The mean number of harvested lymph nodes was 23.2. There was only one positive circumferential resection margin (tumour deposit; R1 rate 5.9%). One patient developed a distant recurrence (median follow-up 10 months, range 6–21).

Conclusion

TaTME was safe in this small series of patients. It is especially attractive in patients with a narrow and irradiated pelvis and a tumour in the lower third of the rectum. TaTME is technically demanding, but the good outcomes should prompt randomized studies and prospective registration of all taTME cases in an international registry.

Introduction

The introduction of total mesorectal excision (TME) more than 30 years revolutionized the treatment of rectal cancer [1], from both a surgical and an oncological perspective [2]. Development of minimally invasive approaches in subsequent years was another important step toward an improved short-term outcome [3]. Low anterior resection (LAR) can still be technically difficult, particularly for tumours in the lower third of the rectum. The dissection is even more difficult in obese male patients with a narrow pelvis and after radiotherapy [4]. The technical limitations peculiar to laparoscopic LAR, including difficulty in exposure, limitation in instrumentation, ergonomics and stapling, can affect not only the dissection but also the preservation of the autonomic pelvic nerves and the ability to achieve a restorative procedure [5]. Whilst oncological safety does not seem to be compromised [3,6,7], these technical limitations have dampened initial enthusiasm and the uptake of laparoscopy for rectal cancer is relatively low [8].

Through a combination of existing and new surgical approaches, transanal TME (taTME) has emerged as a technique that permits meticulous dissection of the rectum from below while adhering to the concept of TME [9]. TaTME can potentially overcome the inher-ent limitations of laparoscopic approaches to rectal cancer. Several authors have reported encouraging results [4,10,11], and some potential benefits compared with laparoscopic TME [12,13]. Here we report our initial experience with taTME.

Method

From June 2013 to September 2014, 20 selected patients underwent a transanal rectal resection in our institution and were prospectively recorded in an online international registry (http://www.lorec.nhs.uk) [5]. All procedures were performed by colorectal surgeons with experience in minimally invasive TME, intersphincteric dissection and transanal endoscopic microsurgery/ transanal minimally invasive surgery (TEM/TAMIS). This cohort study was approved by our institutional review board and informed consent was obtained from all patients.

Patient selection

Eligibility criteria included patients with a middle and low rectal tumour requiring a full TME and a low colorectal or coloanal anastomosis. Patients with benign rectal pathology that required a proctectomy were also included. Patients not eligible for the standard laparoscopic approach, including those with advanced local disease, emergency presentation and severe medical illness, were excluded.

All patients with rectal cancer had a standard tumour staging according to our local protocol followed by discussion in a multidisciplinary team. Neoadjuvant chemoradiation consisting of 50.4 Gy radiation and capcetabine for 6 weeks was given to selected patients if the preoperative MRI scan had showed a T3c or more locally advanced tumour with a threatened or involved circumferential resection margin (CRM) or extramural vascular invasion. Following neoadjuvant treatment, surgery was undertaken 10–12 weeks after the end of radiotherapy and a restaging MRI scan.

Surgical technique

After mechanical bowel preparation the day before surgery and standard preoperative antibiotic prophylaxis the patient was placed in the Lloyd-Davis position with the legs padded and subjected to intermittent pneumatic compression. The approach was minimally invasive in all cases (18 laparoscopic, one robotic and one total perineal approach). The rectum was irrigated with dilute chlorhexidine solution before and during the transanal procedure up to the point of division of the rectum. The splenic flexure was mobilized via a laparoscopic approach and high ligation of the inferior mesenteric artery performed. Pelvic dissection anteriorly was limited to incision of the peritoneal fold at the level of the rectoprostatic or vaginal reflexion. Posteriorly the rectum was mobilized down to Waldeyer's fascia.

Table 1. Patient characteristics.

Gender	
Male	14 (70%)
Female	6 (30%)
Age years, mean ±SD (range)	59.3 ±13.2 (32-87)
ASA score, mean ±SD (range)	1.8 ±0.5 (1-3)
BMI kg/m^2, mean ±SD (range)	27.1 ±4.8 (17.4-38.4)
Preoperative diagnosis	
Cancer	17 (85%)
Benign	3 (15%)
Preoperative height of the tumour from the anorectal junction (cm) median (range)	2 (0-7)
Preoperative CRM involvement on MRI	3 (17.6%)
Preoperative MRI staging	
≥ T3	10 (58.8%)
N+	9 (52.9%)
≥ T3 or N+	14 (82.4%)
Neoadjuvant treatment	6 (35.3%)
Previous pelvic surgery	7 (35%)

SD: standard deviation. ASA: American Society of Anesthesiologists. CRM: circumferential resection margins. MRI: magnetic resonance imaging.

Table 2. Perioperative data.

Type of procedure	
LAR	16 (80%)
ELAPE	2 (10%)
Proctectomy	2 (10%)
Stoma	20 (100%)
Defunctioning ileostomy	16 (80%)
End ileostomy or colostomy	4 (20%)
Approach	
Laparoscopic / robotic	19 (95%)
Perineal	1 (5%)
Conversion	3 (15%)
Operative time in minutes, mean ±SD (range)	
	315.3 ±77.1 (180-480)
Simultaneous approach	5 (25%)
Specimen extraction site	
Transanal	10 (50%)
Stoma site	3 (15%)
Midline incision	3 (15%)
Pfannenstiel	2 (10%)
Umbilical port	2 (10%)
Intraoperative complications	1 (5%)
Postoperative complications	6 (30%)
Reoperation	2 (10%)
Length of stay in days, median (range)	7 (3-36)
Readmission	4 (20%)

LAR: low anterior resection. ELAPE: extralevator abdominoperineal excision. SD: standard deviation.

For tumours lying within 1 cm of the puborectalis sling, a partial or full intersphinteric dissection with a coloanal anastomosis was performed.

At this point the transanal part of the operation commenced. After insertion of an anal retractor, an endoluminal purse-string suture was inserted to close the lumen of the rectum below the tumour. This was inserted either through a transparent circular anal dilator [14] or the access channel of a transanal platform. The glove port [14] was used for our first five cases and thereafter the Gelpoint Transanal Access Platform (Applied Medical, Rancho Santa Margarita, California, USA) was routinely adopted. Once the transanal platform was in place, a pneumopelvis was created with carbon dioxide at a pressure of 10–12 mmHg. A valveless Airseal insufflator (SurgiQuest, Milford, Connecticut, USA) [15] was used for the last five cases.

A circular incision was made through the anorectal wall below the purse-string suture and the mesorectal plane was identified posterolaterally on each side. Dissection was then continued around the rectum to free it completely anteriorly and posteriorly. The mesorectal dissection

6

continued proximally until connection with the laparoscopic dissection from above was made. In patients who were not having a restorative operation, an extralevator abdominoperineal excision (ELAPE) was performed [16]. The specimen was extracted transanally through a wound protector or via an abdominal incision (stoma site or small Pfannenstiel), depending on its bulk. Depending on the location of the tumour, the anastomosis was fashioned either by hand sewing or a double purse-string stapled technique [17,18]. A diverting stoma was routinely performed. Conversion was defined as the need to change a laparoscopic procedure to open surgery. The complications were graded according to the Clavien–Dindo classification [19].

Table 3. Histopathological data.

Quality of TME	
Intact	16 (94.1%)
Minor defect	1 (5.9%)
T staging	
T0	4 (23.5%)
T1	0
T2	8 (47.1%)
T3	5 (32.2%)
T4	0
N staging	
N0	10 (58.8%)
N1	5 (32.2%)
N2	2 (11.8%)
Number of lymph nodes, mean ±SD (range)	23.2 ±10.2 (11-45)
Tumour size in mm, mean ±SD (range)	24.1 ±13.1 (0-45)
Distal margins in mm, mean ±SD (range)	21.4 ±14.1 (5-55)
Positive	0
CRM in mm, mean ±SD (range)	6.9 ±5.8 (0-20)
Positive	1 (5.9%)

TME: total mesorectal excision. SD: standard deviation. CRM: circumferential resection margins.

Results

Patient characteristics

Twenty patients underwent a transanal rectal resection including taTME (16), endoscopic ELAPE (2) and completion proctectomy (2). Patient characteristics are shown in Table 1. Most (*n* = 17%, 85%) had a resection for cancer. Three had a benign condition including rectovaginal fistula after a total colectomy and ileorectal anastomosis for ulcerative colitis, rectal erosion after ventral mesh rectopexy and rectal stenosis after TEM for a large villous adenoma.

Of note, seven patients had already undergone previous colorectal or pelvic surgery including full thickness TEM (three), total colectomy (one), transurethral resection of the prostate (one), laparoscopic ventral mesh rectopexy (one) and loop colostomy (one).

Perioperative outcome

Most patients underwent LAR (*n* = 16%, 80%) (Table 2). Eleven had a circular stapled anastomosis, two had an endoscopic ELAPE and two had a completion proctectomy. A total perineal approach was used for a completion proctectomy for a rectal erosion following a mesh rectopexy. There were three conversions, including one due to bleeding from the pelvic side wall and two due to dense abdominal adhesions in one case and a narrow pelvis in the other.

The mean operation time was 315.3 ± 77.1 min. Complications occurred in six (30%) patients. Most (66.7%) were minor (≤ Grade II) and included postoperative ileus that resolved with conservative management (*n* = 3) and one anastomotic sinus treated conservatively. Only two patients developed Grade IIIb complications, including a pelvic haematoma after a completion proctectomy for rectovaginal fistula requiring drainage and delayed pelvic sepsis (> 30 days) secondary to contained anastomotic leakage. The overall median length of hospital stay was 7 (3–36) days. Four patients were readmitted (20%) for anastomotic leakage (one), anastomotic sinus (one), pelvic haematoma (one) and a high ileostomy output (one). Of the 16 patients with a colorectal or coloanal anastomosis, 12 (75%) underwent closure of the defunctioning stoma and three are waiting for this to be done (01 September 2015). One patient refused stoma closure because she was undergoing palliative chemotherapy for liver and lung metastases.

Histopathological examination of the resected specimen

The histopathological data are summarized in Table 3. A complete TME specimen was observed in 16 (94.1%) cancer patients and only one had a near complete TME specimen. Overall, the R0 rate was 94.1%. The final histopathological examination showed four patients with a pT0 lesion, two of whom were ypT0N1 after TEM and neoadjuvant treatment. One was ypT0N0, after neoadjuvant treatment for an initial mT3N1 lesion. Finally, an initial mT2N0 tumour was confirmed as a large tubulovillous adenoma with high-grade dysplasia.

The mean number of harvested lymph nodes was 23.2 (range 11–45). The average length of the distal margin was 21.4 ± 14.1 mm. There was no positive distal margin. The mean distance of CRM was 6.9 ± 5.8 mm with one (5.9%) positive margin. This was due to a 3-mm tumour nodule within 1 mm of the mesorectal fascia posteriorly. The patient developed lung and liver metastases at 3 and 7 months after the surgery without any evidence of local recurrence. None of the other patients developed recurrence after a median follow-up of 10 (6–21) months.

Discussion

Despite three decades of standardization and innovations in TME surgery, the management of low rectal tumours is still difficult, especially in the narrow and irradiated pelvis. The risk of a poor outcome has reduced the initial enthusiasm for laparoscopy in these difficult patients, and might explain, at least in part, the limited adoption of minimally invasive rectal cancer surgery [8]. TaTME is the latest development in an effort to improve TME surgery and to reduce conversion rates, and early results have been encouraging [4,12,13,20–25].

Our experience since 2013 has demonstrated a satisfactory short-term outcome. It compares favourably with other published work [10,20,21,24,25], with no mortality and acceptable morbidity. We acknowledge that the operation time is still long, reflecting a steep learning curve. This might be shortened by working synchronously. While the conversion rate might seem high, it should be mentioned that only one conversion was related to the transanal approach – this was early in our experience and we would now be able to control any bleeding with Airseal technology (SurgiQuest) allowing a more stable pneumopelvis even when suction is required.

Overall the technique appears safe, meets the oncological requirements for rectal cancer surgery and seems to offer obvious advantages during dissection of the distal mesorectum [20]. In particular, an excellent quality of specimen and a low R1 rate can be achieved in tumours within 2 cm of the anorectal junction. It is noteworthy that there was only one positive CRM, which was not related to a poor specimen. For tumours with a high risk of a positive CRM, a primary transanal endoscopic approach facilitates the dissection [21] and thus minimizes the risk of locoregional failure. The main challenge in low rectal tumours is the need to achieve a clear CRM and distal margins, which is a major prognostic factor for local recurrence [26]. In a narrow and irradiated pelvis, the risk of a positive CRM is high, and taTME might be an option to obtain a higher rate of R0 resection and a better quality of TME specimen [10,13]. Recently, Denost *et al.* [22] published a randomized study of peranal (n = 50) *vs* abdominal LAR (n = 50) for low rectal cancer within 6 cm of the anal verge. Laparoscopic instruments and a laparoscopic platform were not used for the peranal phase, but despite this they clearly found a reduced rate of CRM positivity using this approach (4% for peranal *vs* 18% for abdominal LAR; P = 0.025). There was also a trend in favour of the peranal approach regarding anastomotic leakage and the operation time. Another recent comparative study between standard laparoscopic LAR and taTME showed no difference in CRM positivity and a longer distal resection margin [12]. In addition, the perioperative outcome favoured taTME, with a significantly shorter operation time of less than 37 min, a shorter (not statistically significant) hospital stay of less than 2.2 days and fewer readmissions (22% for laparoscopy *vs* 6% for taTME, P = 0.03).

The risk of poor function is of some concern, owing to an increased use of coloanal anastomosis, removal of part or all of the internal sphincter and stretching of the anal sphincter during taTME. This potential risk has not yet been investigated, but the experience of TEM has shown that at least a third of TEM patients have some degree of temporary incontinence [27]. The extrapolation from TEM to taTME is hypothetical, but in the present series there were no cases of clinically significant faecal incontinence after reversal of the defunctioning stoma. The function after taTME is still being monitored and definitive data are not yet available. Atallah *et al.* [10] reported that most of the patients in their series had developed mild faecal incontinence 8 weeks after ileostomy closure, but only one found this to limit his lifestyle. These data were confirmed by others [4,11], but the use of flexible instruments rather than the rigid TEM kit might also reduce any negative impact that taTME may have on anorectal function [21]. Further studies are required to investigate this potential problem.

While taTME is a good option for low rectal tumours or difficult cases requiring completion proctectomy, several technical considerations might limit its wide acceptance. Some degree of technical difficulty was encountered in more than half of the patients in our series, including the stability and integrity of the pneumopelvis and the accumulation of smoke. It is obvious that continuing technical developments are required, notably regarding the platform itself and the instrumentation. It may be that the use of Airseal (SurgiQuest) will be beneficial, as seemed to be the case in our last two patients. The key issue is the identification of the correct tissue planes transanally; starting the dissection in the posterior quadrant of the anorectal lumen might make it easier to find the TME plane from below. Increasing experience will help answer some of the questions regarding details of surgical dissection.

The study has several limitations. First the patients were treated in an experienced laparoscopic centre and inevitably there was patient selection bias. Many of the patients were indeed selected based on young age, low American Society of Anesthesiologists score and a low T-stage, but others were overweight and many were male. Despite the encouraging reports in the literature of taTME compared with standard laparoscopic anterior resection [12,13], it is difficult to apply these findings to all centres. Our approach was to explore the use of taTME in difficult cases rather than those that could be readily managed by a standard laparoscopic approach. There is a need to develop formal training courses and an international registry to allow the results to be optimized [5,23], as has been suggested in the UK National Institute of Health and Care Excellence guidelines [28].

In conclusion, TaTME is feasible and is particularly attractive for male patients with a narrow and irradiated pelvis. Firm conclusions on safety, efficacy and cancerspecific results will require analysis of larger series of patients, hopefully leading to a randomized controlled trial.

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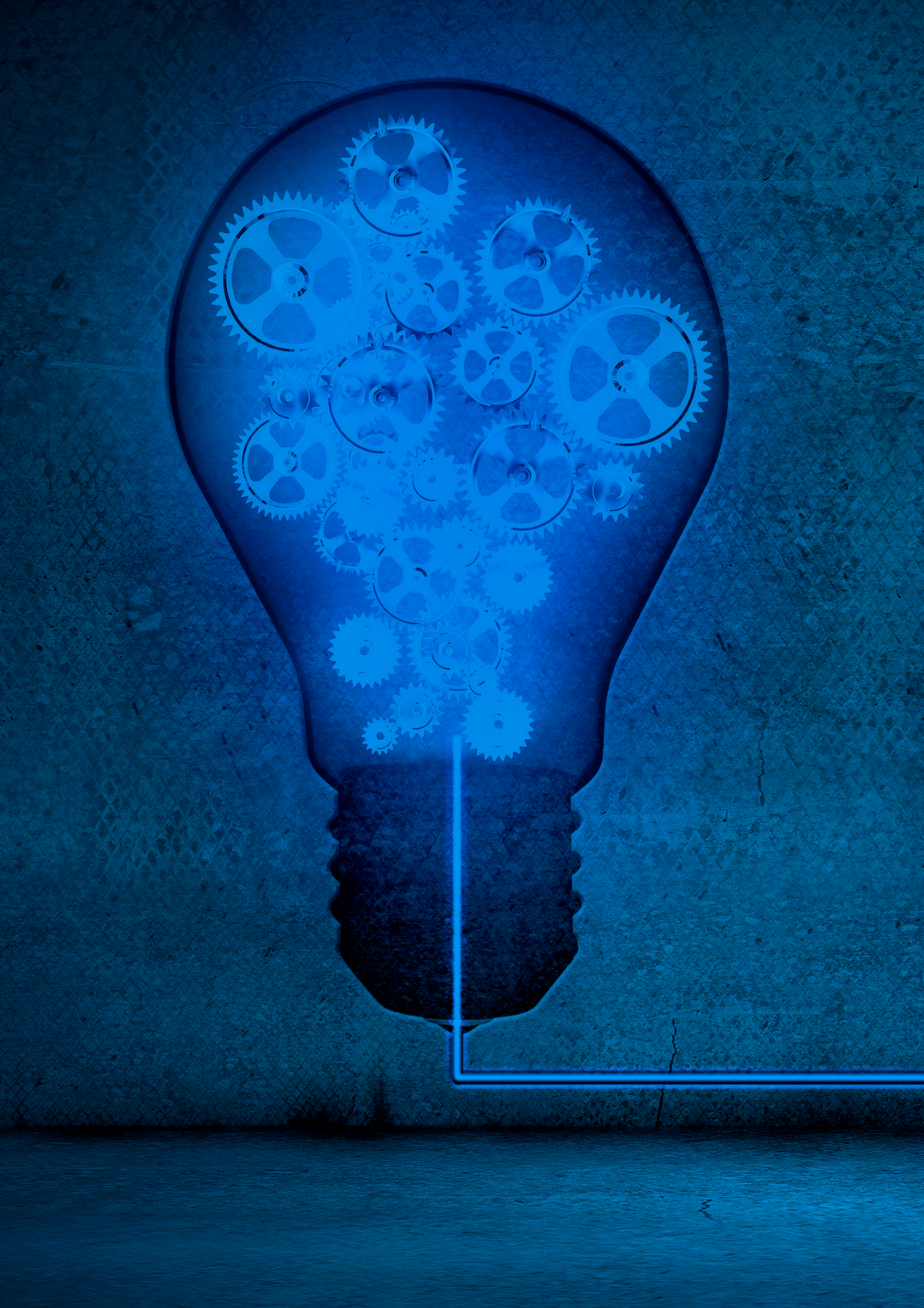

Chapter 7

Optimal dissection for transanal total mesorectal excision using modified CO2 insufflation and smoke extraction

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Colorectal Dis. 2015 Nov;17(11):O265-7.

Abstract

Aim
The new approach of transanal total mesorectal excision is technically challenging and demands a stable field of dissection with optimal view of anatomical landmarks. We aimed to describe and demonstrate a modification of both the insufflation of carbon dioxide and smoke evacuation, in order to optimize dissection.

Methods
The comparison of standard insufflation to an AirSeal platform demonstrates a clear difference. This is shown in the accompanying video-recordings.

Results
A more stable pneumorectum and better smoke evacuation as well as more convenient and precise dissection were achieved with the AirSeal platform.

Conclusions
Using the technique outlined, the operating surgeon is able to perform the surgical dissection in a stable operating environment with increased visibility compared to the standard approach.

Indications

As surgeons continue to embrace the evolution of new techniques for better and safer resection of both tumours and benign disease processes of the rectum, it is important to share insights into further technical advances and improvements [1,2]. Recently, transanal total mesorectal excision (taTME) has been advocated as an alternative approach for safe surgical removal of mid and low rectal tumours [3,4]. Reported benefits are a clearer definition of a safe, tumour-free distal margin and the ability to perform deep pelvic dissection of the 'no man's land' with greater accuracy, even in the narrow male pelvis or in obese patients. While initial single institution reports have reported encouraging short-term results, taTME remains in the early phase of wider acceptance as a more efficient approach to operating in an anatomically challenging location [5]. Standardization of the technique through sharing of experience and knowledge will further improve outcomes and allow for safe diffusion into daily surgical practice. We have encountered two notable obstacles in attaining a perfect transanal endoscopic surgical field.

These have also been noted as limitations by other early adaptors of taTME (S. Atallah & M. Albert, Florida Hospital, Winter Park, Florida, USA, C. Sietses, Gelderse Vallei Hospital, Netherlands, J. Tuynman, VUMC Amsterdam, Netherlands, personal communication). First, the current set-up as described previously results in excessive diathermy-induced smoke in an already restricted operative field [2]. Second, bellowing or oscillation of the rectum ('unstable pneumorectum') can be counterproductive. Here we aim to describe and demonstrate a modification in the current set-up for the perineal portion of this procedure in order to circumvent these two issues by use of the AirSeal® System. It consists of an Intelligent Flow System (iFS) control unit, one valveless access port and one contiguous trilumen filter tube set. This has recently been applied and described in relation to transanal minimally invasive surgery for early rectal cancer [6].

Method

Once the abdominal portion of the taTME procedure has been completed, the transanal part is performed, or vice versa, while a synchronous procedure is also feasible. With the patient in a dorsal lithotomy position, a GelPOINT® path transanal access platform (Applied Medical Inc., Rancho Santa Margarita, California, USA) is inserted into the anal canal. In a standard set-up three self-retaining ports are inserted through the removable gel cap. To use the AirSeal System (SurgiQuest Inc., Milford, Connecticut, USA) to achieve a 'pneumorectum' in taTME procedures, one of the Applied GelPOINT ports is replaced by a 5, 8 or 12 mm AirSeal valveless access port which is then connected to the trilumen filtered tube set. The three lumens of the filter tube set work in concert to recirculate CO_2 gas into the target cavity with

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the provision of CO_2 inflow though one lumen, outflow through a second lumen and realtime monitoring and maintenance of set pressure through the third lumen. After the filter canister of the tube set is inserted into the iFS control unit, intraluminal pressure is set to an initial pressure of 8 mmHg, and the low smoke evacuation option is selected. Throughout the case the pressure can be elevated to 12–15 mmHg and/or the high smoke evacuation option can be selected if required. The set-up and differences in pelvic views achieved with and without the AirSeal System are demonstrated in the online video (Video S1).

Comparison with other methods, advantages and disadvantages, difficulties and complications

Traditional laparoscopic insufflators normally toggle between CO_2 gas insufflation for approximately 3 s, rest for 1 s to measure pressure, and then cyclically re-insufflate to maintain the 'set' pressure. In laparoscopic procedures, standard mechanical insufflators cause constant and cyclical pressure fluctuation within the target cavity. This contributes to the 'rectal bellowing' typically seen at operation. The small operating field and volume for circulating CO_2, particularly at the start of the taTME procedure, make even small changes in pressure far more noticeable and difficult for the surgeon and assistant to manage effectively. Both the surgical smoke and bellowing interfere with operative efficiency due to constant readjustments and camera cleaning ultimately significantly extending total procedure time. Furthermore, it can hamper correct identification of tissue planes, which can put pelvic side wall structures, nervi erigentes and the mesorectal package at risk of damage. Control of any bleeding is also more difficult, in particular when aspiration is required to obtain an adequate view of the bleeding point.

The SurgiQuest AirSeal System abdominal management platform responds immediately to the slightest changes in the set pressure by automatically adjusting flow rate in real time. This serves to eliminate loss of pneumorectum and loss of pneumoperitoneum as the case may be. The AirSeal System is not new to surgery, having been successfully studied and used to good effect in intra-abdominal applications due to its ability to provide a stable pneumoperitoneum even under constant suction/aspiration, leakage or trocar dislodgement [7]. It therefore affords the surgeon excellent vision compared to previous insufflator devices. Due to reduced oscillation of pressure, the system results in less CO_2 gas absorption by the patient with resultant benefits. Another major benefit is less fogging of the camera view. Because the AirSeal System recirculates the insufflated CO_2 rather than continually adding fresh, cooler CO_2 there is a tendency to assimilate patients' abdominal (or pelvic in this case) ambient temperature and moisture. These aspects of design differentiate it from conventional insufflators. In particular, the recirculation of insufflated CO_2 sets the AirSeal platform apart from other offerings on the market.

Although a number of other high performance insufflators are now available on the market we have not trialed equipment from other major medical device manufacturers. Stryker, Olympus and Storz all have updated systems. Stryker's PneumoSure 45L insufflator gives 'real time pressure sensing for increased accuracy during a procedure'. It also has an updated tube set to allow higher flow [8]. The current Olympus equipment, the UHI-4 insufflation unit, offers the ability to select modes for different cavity capacities. It has an automatic smoke evacuation feature that can be enabled when coupled with a new or existing energy Olympus platform [9]. In addition, the Storz endoflator 40 provides an integrated gas heater to minimize fogging as well as electronic control providing quick provision and stability of pneumoperitoneum or pneumorectum. The filament in their insufflation tube ensures that there is no heat loss in the tube during the insufflation process and that CO_2 flows into the operative field at a steady 37°C [10].

These systems help to overcome well documented limitations of previous equipment such as occasional loss of working space during suction aspiration and inability to rapidly compensate for intra-abdominal pressure in an effective manner. We are not aware, however, of any published technical notes or data in the field of colorectal surgery to allow comparison to the AirSeal system.

Conventional insufflators connect with conventional trocars (Ethicon, New Brunswick, New Jersey, USA; Covidien, Dublin, Ireland or Applied, Rancho Santa Margarita, California, USA) via a single lumen tube. There are several major limitations as a result of this relationship. CO_2 can only travel in one direction into the patient causing camera fogging, build-up of intraabdominal smoke and plume, and fragmentation of tissue during specimen removal.

The AirSeal iFS platform addresses these with its iFS control unit: a three lumen filter tube set which connects to one valveless AirSeal trocar. One lumen of the filter tube set provides carbon dioxide inflow, one lumen provides carbon dioxide outflow and the third lumen provides real-time constant monitoring of abdominal pressure to compensate for any dynamic intra-abdominal pressure change. This has been demonstrated to reduce CO_2 absorption by the patient during laparoscopic surgery [11]. Along with removing smoke, the powerful filter component of the tube set removes carcinogens and pathogens from smoke down to 0.01 lm to eliminate the hazards of surgical smoke. The valveless AirSeal port provides the benefits of smudge-free scope entry, unfragmented specimen removal along with easier insertion of clips, needles, sutures and mesh. The three alternative systems mentioned above do not have tri-lumen tubing as part of their platform.

The adoption of this technique therefore allows the operator to focus more on the important aspects of surgical dissection rather than being distracted by the need for continually venting smoke, loss of insufflation, pausing to clean the endoscope, and having the assistant battling to maintain an optimum view in a pneumorectum with fluctuating levels of pressure. The experience with both a standard set-up for TaTME and the modified set-up using the SurgiQuest AirSeal System are shown in the video. Further details are also available online [12].

In relation to costing, the additional price of AirSeal System consumables has to be taken into account. Further technical aspects of the set-up include the rigidity of the insufflation tubing hampering optimum port position in a confined space. In addition, it is important to keep the AirSeal trocar cannula in the upper part of the GelPOINT gel cap as aspiration of a large amount of fluid (particularly from irrigation) into the trocar can lead to the filter canister collecting the fluid and subsequently shutting off the control unit momentarily until the contiguous filter canister and tube set is replaced. Lastly, a 5 or 8 mm port is sufficient to achieve the desired stability and view in the pneumorectum. The use of a 12 mm port has the additional flexibility of being used as a camera port if a 5 mm camera is not available without interfering with overall operative performance.

A further application of the AirSeal platform is that it can be used to establish intra-abdominal pneumoperitoneum for a traditional laparoscopic set-up for a second surgical team operating synchronously from above. The advantages are similar to those mentioned previously.

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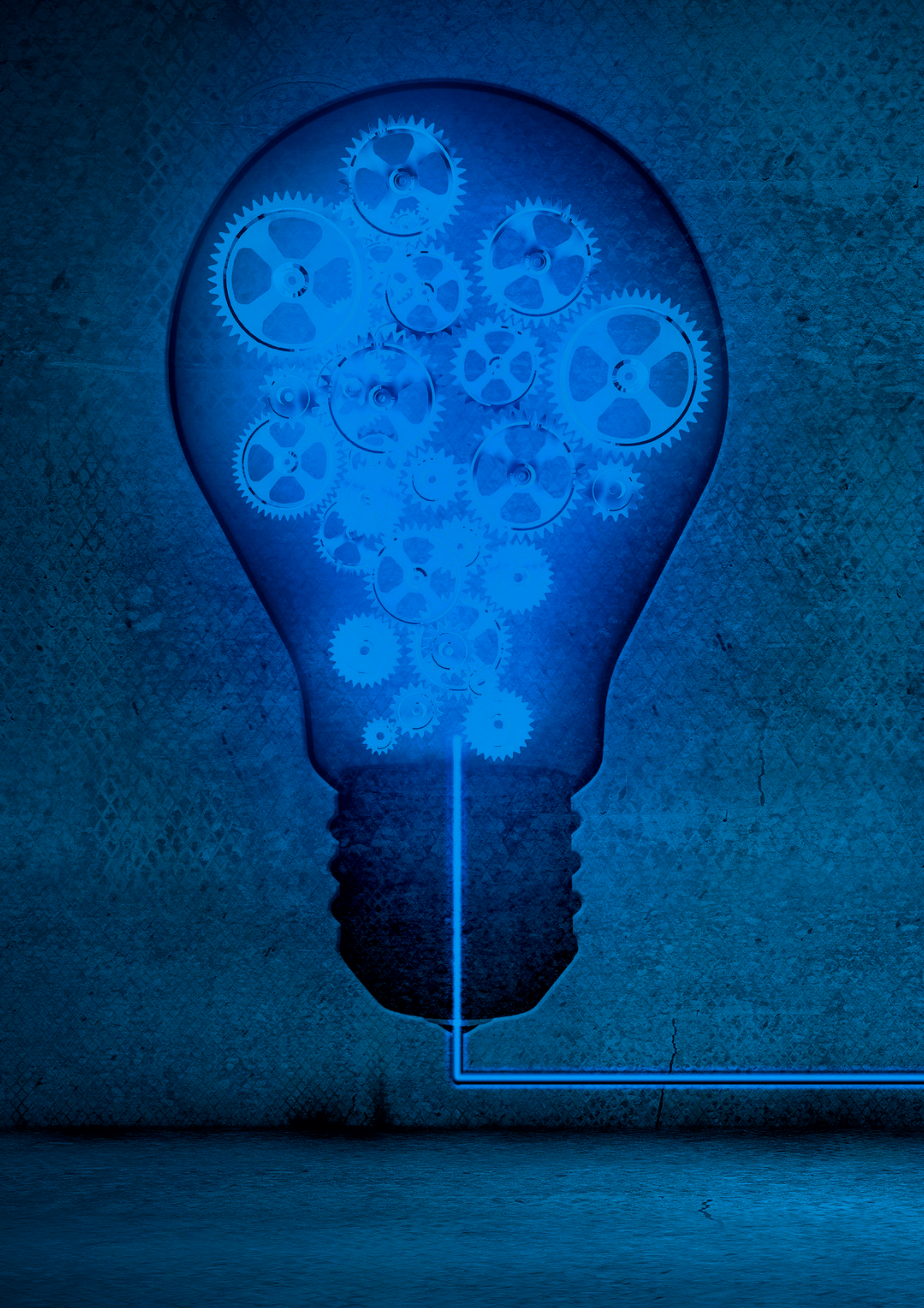

Chapter 8

Transanal total mesorectal excision: dissection tips using ‘O’s and ‘triangles’

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Tech Coloproctol. 2016 Nov;20(11):775-778.

Abstract

Purpose

Transanal total mesorectal excision (taTME) requires specific technical expertise, as it is often difficult to ascertain the correct dissection plane. Consequently, one can easily enter an incorrect plane, potentially resulting in bleeding (sidewall or presacral vessels), autonomic nerve injury and urethral injury. We aim to demonstrate specific visual features, which may be encountered during surgery and can guide the surgeon to perform the dissection in the correct plane.

Methods

Specific features of dissection in the correct and incorrect planes are demonstrated in the accompanying video.

Results

The 'triangles' created using appropriate traction can aid in performing a precise dissection in the correct plane. Recognition of features described as 'O's can alert surgeons that they are entering a new fascial plane and can avoid incursion into an incorrect plane.

Conclusions

Understanding and recognizing the described features which can be encountered in taTME surgery, a safe and accurate TME dissection can be facilitated.

Introduction

Since the first clinical case of a transanal total mesorectal excision (taTME) with laparoscopic assistance was published in 2010 [1], multiple case series have been reported which indicate the feasibility and safety of this technique [2]. However, the reported experience is influenced by case selection and has mostly been acquired by highly trained specialized surgeons and therefore may not represent an accurate indication of the technical expertise required to perform such a dissection in a safe manner.

Notoriously, any rectal dissection is potentially difficult via the open or laparoscopic approach, especially for bulky rectal tumours and/or in the obese male with a narrow pelvis. While taTME provides a clear view of the coveted TME plane without the 'access' issues encountered in a standard abdominal approach, incorrect planes can be highlighted with the insufflation of CO_2, leading to inadvertent injury to surrounding structures or incursions into the mesorectal fat if not recognized and corrected. Two areas in which this is particularly problematic are: laterally (level of mid rectum), and posteriorly (level of mid rectum and upper rectum). Deviations from the TME plane in these areas can lead to autonomic nerve injury and troublesome haemorrhage [3]. To our knowledge, none of the published literature specifically reports these intraoperative issues. However, specialist advisers involved in production of a procedure guidance document on taTME for the National Institute for Health and Care Excellence (NICE) provided anecdotal reports of "bleeding from the pelvic side wall, pelvic haematoma and dissection into the incorrect plane into the pelvic sidewall" [4].

Another significant complication specific to the taTME technique is that of urethral injury as the membranous urethra exits the apex of the prostate. One of the earlier case series published reported urethral injury in two of 30 patients. The urethral injuries were identified and repaired intraoperatively [5]. Burke et al. have also reported a single urethral injury out of 50 patients [6] and commented that this is avoidable with "appropriate patient selection and proper training" [3].

Here, we describe two visual features, which have been recognized by early adaptors of the taTME technique and can aid dissection in the TME plane: triangles and 'O's.

Method

A standard laparoscopic approach for the abdominal component of the procedure is performed, either prior to the transanal part or as synchronous procedures. Set-up and use of the GelPOINT path® transanal access platform (Applied Medical, Inc., Rancho Santa Margarita, California, USA) have been previously described [7]. A stable pneumorectum and optimal smoke evacuation can be achieved using the AirSeal Access Port (SurgiQuest Inc., Milford, Connecticut, USA) for CO_2 insufflation [8].

Once a full-thickness rectotomy is performed, the dissection in the TME plane is commenced, usually posterolaterally (5 or 7 o'clock position), as the plane between the presacral fascia (parietal endopelvic fascia) and the TME envelope is relatively easy to identify. This is achieved by a combination of sharp dissection and careful 'blunt' pushing motion. Early on in the dissection, the grasper can be placed on the knotted purse string suture and traction achieved by pushing the rectum away (i.e. cephalad). Note this is in contrast to the laparoscopic technique of usually pulling the rectum out of the pelvis towards the operator to achieve traction. Using this technique, several 'triangles' are created in the tissue. The apex of any such triangle is positioned on the 'specimen', and the base of the triangle is at the point of maximum traction (Fig. 1a). Put simply, a 'triangle' represents a tethering point of a deeper plane which has not been released. The apex indicates the correct dissection plane between that deeper plane and the current plane of dissection (Fig. 1b). If the 'current' plane is correct, then the dissection should be along the top of the triangles, releasing the tethered tissue. It is important to note that this feature is not unique to taTME dissection and can be seen at laparoscopic abdominal surgery when applying traction. Possibly due to familiarity in operating in this area as well as operating on a broader front, the formed 'triangles' are not readily acknowledged as a feature to aid dissection.

The mesorectal dissection is continued circumferentially in this manner, progressively moving around in serial circles so as not to mobilize one side or area excessively. This aids in avoidance of asymmetrical rectal retraction, which can potentially make identification of the correct plane more difficult. As the dissection progresses cephalad and the specimen becomes more mobile, an open grasper is used to retract the specimen to continue to expose the apex of the 'triangles' for dissection, like going from one 'mountain top' to the next.

Any violation or incursion into a new fascial plane will lead to the formation of an 'O' or 'halo' sign. This occurs as the insufflation of CO_2 leads to pneumatic dissection which evenly distributes pressure forces and blows the fascial defect into the shape of a circle (Fig. 1b, c). This should alert the surgeon to slow down and carefully ascertain the correct plane of dissection. Usually, a deeper plane is opened, and the 'O' sign will appear at the base of a 'triangle', but occasionally, it can also direct the surgeon into the correct plane (see video).

Importantly, the 'O' sign can appear in a correct or incorrect plane as it simply represents a hole in any fascial envelope. This highlights the point that the 'O' sign and 'triangles', both common, albeit less-utilized findings at laparoscopic surgery, are not magic tricks enabling mastery of a taTME dissection. Rather, they are helpful clues which, when understood, can improve surgeon perception in the less familiar endoscopic transanal view.

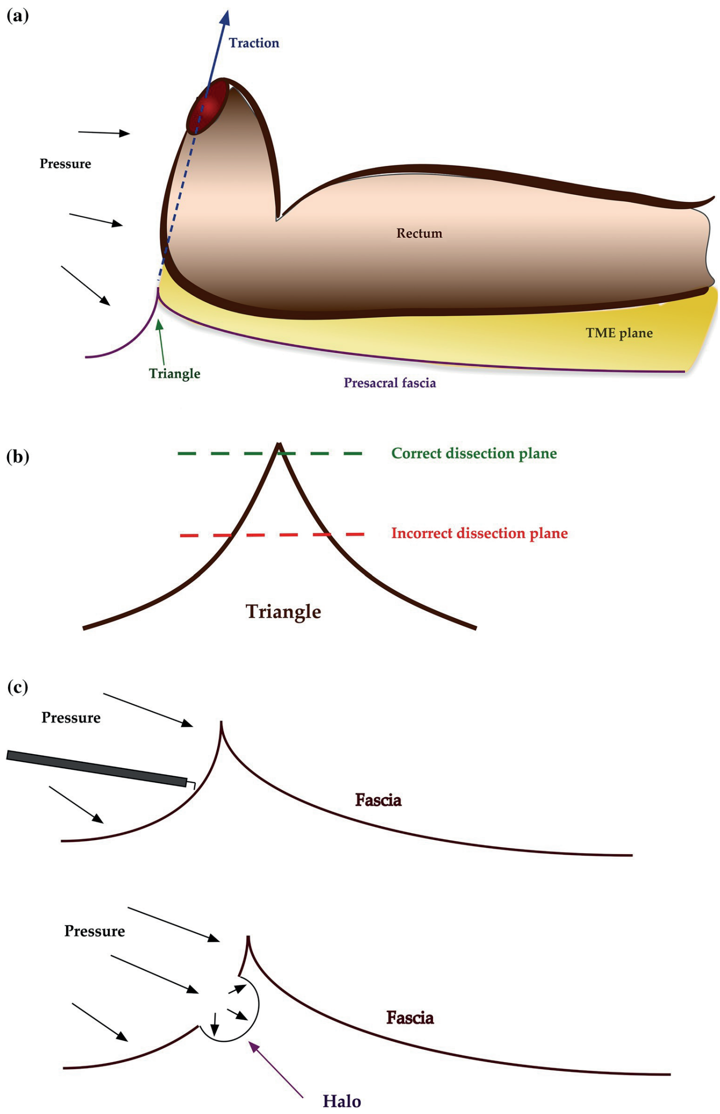

Fig. 1. Development of triangles and haloes. a Traction on the rectum and the fascia is unidirectional and creates a triangle, b Dissection should be performed at the apex of this triangle to prevent entering a new plane, c Once entering the triangle too peripherally, a new plane will be opened and the insufflation pressure will open the new plane to form a halo

Posteriorly, bleeding from the sacral venous plexus is well recognized as a potentially major intraoperative complication occasionally encountered with the abdominal approach to mesorectal dissection. This also holds true using the taTME technique if the dissection is carried too far posteriorly. However, in taTME, bleeding is more readily recognized and dealt with quickly using unipolar or bipolar diathermy so that it does not usually escalate into a major issue as for the abdominal approach. It is important to recognize the change in curvature of the sacrum to avoid inadvertent injury to the presacral vessels. The shape of the sacrum can be best appreciated preoperatively from examination of the MRI images for that patient. These principles have been illustrated in the accompanying video and figures.

Urethral injury can occur with perineal dissection for abdominoperineal resection or intersphincteric dissection for coloanal anastomosis. However, urethral transection appears to be a complication unique to thetaTME approach to rectal dissection as part of an ultra-low anterior resection. Posteriorly directed traction on the rectum again demonstrates the correct plane by following the apex of the ‘triangles’ now located anteriorly. In males, the plane is posterior to Denonvillier’s fascia. This dissection may be tailored depending on the position of the invasive portion of the tumour, intentionally proceeding anterior to Denonvillier’s fascia if necessary to secure a clear margin. The view obtained of this plane using the taTME approach is superior to the view from the abdominal approach and is one of the potentially important advantages of this technique. Unfortunately, it is also relatively easy to veer ‘offplane’ and once entered, the plane along the apex of the prostate can appear enticing and lead to the urethra as it emerges from the prostate to become the membranous urethra. Injury to the urethra is more likely to occur when the dissection is begun very low (e.g.: intersphincteric), whereby the incorrect plane deep to the parietal fascia is continued proximally and anteriorly, thus mobilizing the prostate. This complication has been reported to occur early on in the learning curve for taTME and is avoided as more experience is obtained [5].

Conclusion

Experience in taTME is growing as the advantages of this approach when operating in what is an anatomically demanding area are appreciated. Performing a taTME dissection is clearly not as simple as following the visual features of ‘triangles’ and ‘O’s, and knowledge of their existence does not in anyway equate to proficiency of the taTME technique. They are described here as adjuncts or clues which, when understood, may facilitate adherence to the correct mesorectal plane. It is anticipated that complications such as nerve, vessel and urethral injury can be avoided as the technique becomes standardized, and experiences including adverse events are shared.

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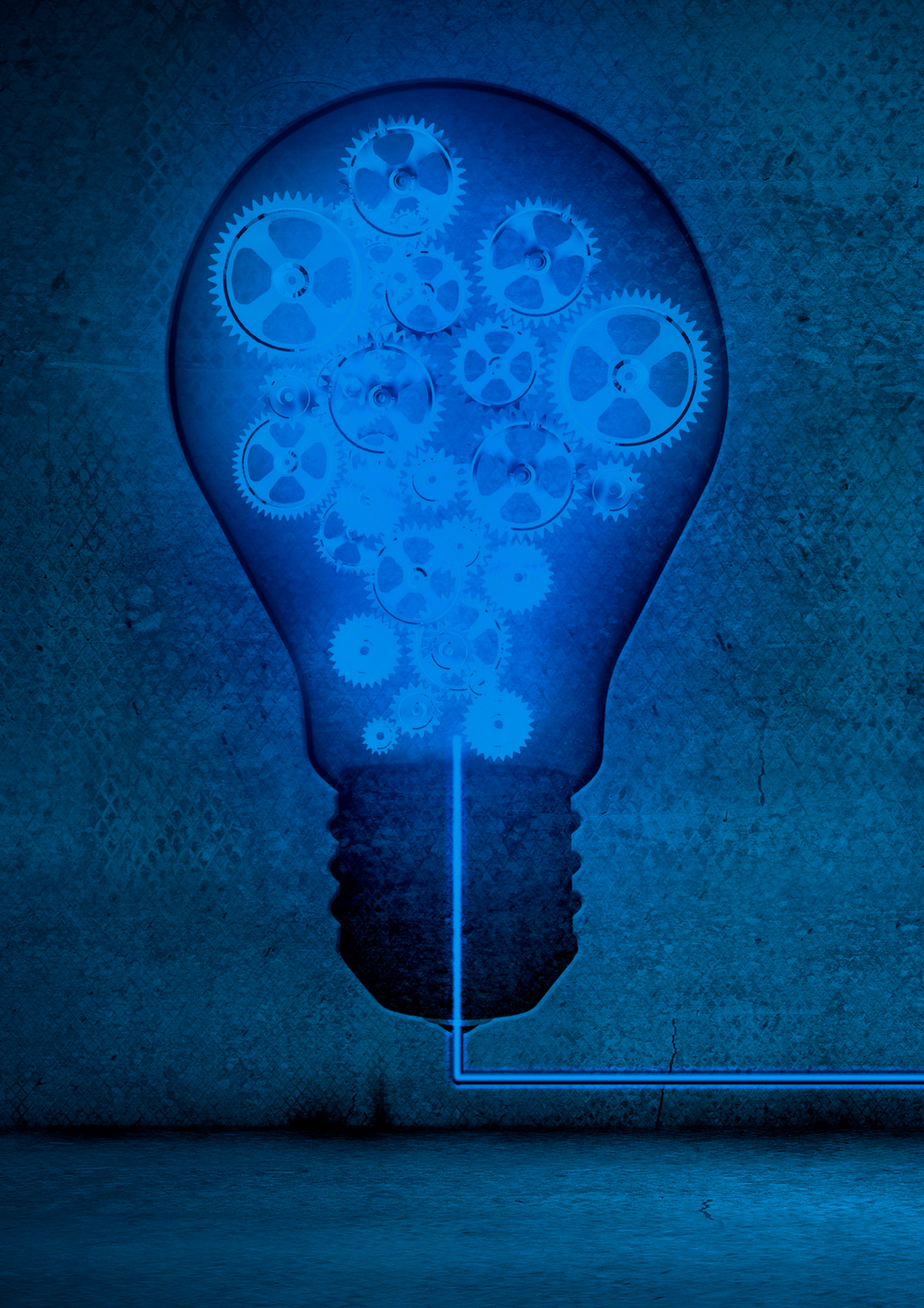

Chapter 9

Four anastomotic techniques following transanal total mesorectal excision (TaTME)

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Tech Coloproctol. 2016 Mar;20(3):185-91.

Abstract

Transanal total mesorectal excision (TaTME) is a novel approach pioneered to tackle the challenges posed by difficult pelvic dissections in rectal cancer and the restrictions in angulation of currently available laparoscopic staplers. To date, four techniques can be employed in order to create the colorectal/coloanal anastomosis following TaTME. We present a technical note describing these techniques and discuss the risks and benefits of each.

Introduction

Transanal total mesorectal excision (TaTME) is a novel approach that has emerged following technical advances in minimally invasive surgery [1], transanal endoscopic microsurgery (TEM) [2], and natural orifice transluminal approaches [3].

After the combined laparoscopic and transanal TME dissection, specimen removal and formation of an anastomosis are critical steps of the TaTME procedure. In addition to hand-sewn coloanal anastomosis, three stapling techniques for the colorectal anastomosis have been employed: a stapled anastomosis using the EEA™ Haemorrhoid Stapler (AutoSuture; Covidien, Dublin, Ireland) [4], a standard diameter circular stapler either in combination with a guiding 10Fr redivac drain [5] or a pullthrough method. In this technical note, we describe the different anastomotic techniques in detail and discuss their main differences.

Technical Note

Traditional hand-sewn coloanal anastomosis

The descending colon is delivered into the pelvis and brought into position for a coloanal hand-sewn anastomosis. A 14Fr Foley catheter inserted into the lumen can be useful to help deliver the colonic conduit into the anal canal avoiding any twist (Fig. 1). Alternatively, tagging sutures can be placed into the proximal colon to guide the colonic conduit down. A self-retaining retractor is positioned to improve exposure and obtain adequate views of the anorectal stump wall. Commonly used retractors are the Lone Star (Lone Star Medical Products Inc., Houston, TX, USA) or the Scott Ring retractors (Lone Star Medical Products, Stafford, TX, USA). A one-layer (or two-layer) anastomosis is then fashioned using interrupted polyglycolic acid 2/0 or 3/0 sutures, as originally described by Sir Alan Parks [6]. Each suture incorporates the mucosa of the anorectal cuff, a portion of the upper internal sphincter and full-thickness muscular layer of the colon. The anastomosis can be constructed as a side-to-end anastomosis, colonic J-pouch, or straight (end-to-end) anastomosis.

Double pursestring circular stapled anastomosis three techniques

If oncologically safe, it is advised to perform a stapled colorectal anastomosis, which tends to result in better functional outcome due to higher length of the rectal cuff. Compared to standard laparoscopic or open stapling of the distal rectum, the TaTME allows stapling techniques with excellent visualisation and avoidance of cross stapling, especially in a male patient with narrow pelvis and obese patients. As a result, the TaTME procedure may lead to lower leakage rates and better functional and oncological outcomes. However, more data from large international cohorts and randomised trials are awaited.

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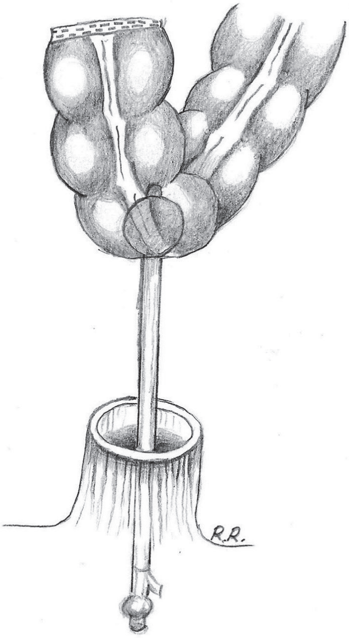

Fig. 1. In preparation for a hand-sewn anastomosis, a 14Fr Foley catheter inserted into the lumen of the bowel can help deliver the colonic conduit into the anal canal avoiding any twist

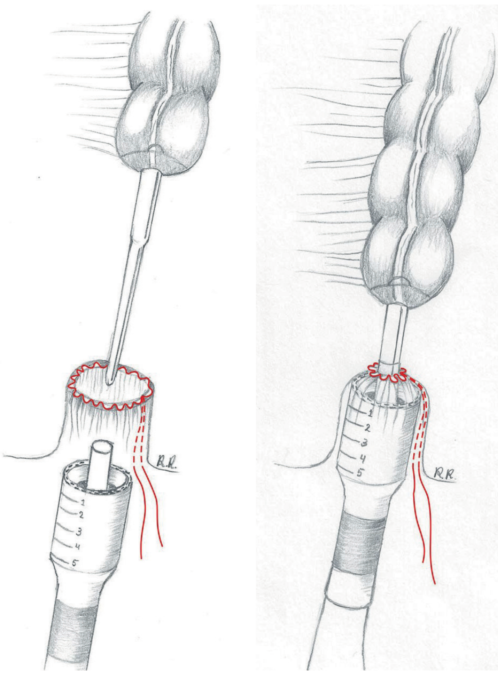

Fig. 2. Pursestring is placed on the open anorectal stump, and the long spindle of the circular EEATM stapler is brought transanally through the centre of the pursestring suture (left image). The anvil is connected to the centre shaft of the stapler, and the pursestring is then tightened around the centre rod (right image)

The main difference for a stapled intestinal reconstruction compared to a standard laparoscopic anterior resection is the open rectal stump after a TaTME procedure. A key aspect to ensure a reliable anastomosis is a full-thickness pursestring suture (monofilament polypropylene suture 2/0) of the open rectal stump. Gaps in the pursestring need to be avoided as this can lead to defects in the anastomosis. Furthermore, it is important to ensure that only the anorectal wall is incorporated into the pursestring. Particularly in female patients, the surgeon has to carefully inspect the vaginal wall. The pursestring can be placed either through the access channel of the GelPoint Path (Applied Medical) for a colorectal anastomosis or within the anal canal for a coloanal anastomosis. A circular anal dilator can enhance exposure when dealing with a very low rectal cuff, which tends to retract into the anal canal [7]. After completing the pursestring, three different stapling techniques can be applied, each with its own advantage points, described below. As the anastomosis is close to the anal margin, it can be inspected after construction and reinforced if required under direct vision with hand placed interrupted sutures. The abdominal CO2 allows easy visualisation transanally of any air leak through the anastomosis. Similar to hand-sewn anastomoses, a side-to-end, colonic J-pouch or straight (end-to-end) anastomosis can be constructed.

EEA™ haemorrhoid stapled anastomosis

The proximal colon is prepared by inserting the detachable 33-mm circular stapling anvil (AutoSuture EEA™ haemorrhoid and prolapse DST series; Covidien) and securing a pursestring around the centre rod. Placement of a pursestring on the open anorectal stump then occurs. The extended reach of the centre rod on the anvil (13.5 cm) allows for sufficient access to pass it through the anal canal to connect with the stapler device before tying the rectal pursestring in a safe and efficient manner under direct vision (Fig. 2 and Video). The stapler is then closed, holding it perpendicular to the opening of the anus. remove the drain, uncovering the spindle intra-abdominally. With the assistance of the laparoscopic graspers, the anvil and spindle are connected, and the anastomosis is performed under direct laparoscopic vision (Fig. 3b).

Modified pull-through circular stapled anastomosis 28–31 mm with transanal view

A novel technique involves the use of a standard circular stapler. The colon with the anvil is brought down to the pelvic floor using a 2.0-multifilament suture. First, the proximal colon is prepared with the anvil of the 28–31 mm circular stapling device in a conventional way. The supplied white plastic cap with attached a long multifilament suture is connected to the anvil. The proximal colon with the anvil is gently pulled down to the pelvic floor by grasping the multifilament suture attached to the anvil with a laparoscopic grasper inserted transanally. The anvil is brought through the anorectal stump opening so that the pursestring of the rectal stump can be tightened around the anvil enabling a tight and secure pursestring. Optimal exposure with the Lone Star retractor is essential. Whilst the anvil is held in place with a

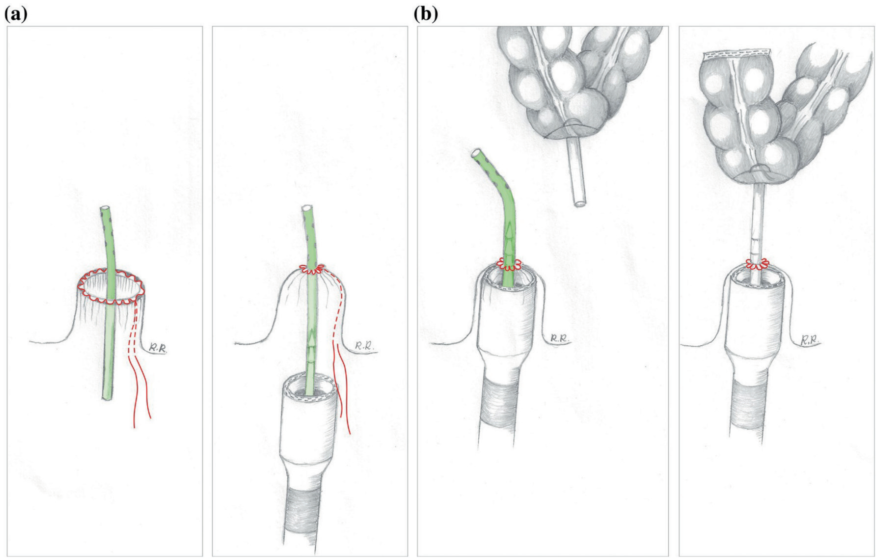

Fig. 3. A 10Fr redivac drain is inserted through the central opening of the pursestring and secured by tying the pursestring (a). The spindle of a standard 28or 31-mm AutoSuture CEEATM circular stapler is attached to the distal end of the drain (a) and advanced into the pelvis (b). With the assistance of the laparoscopic graspers, the drain is removed, and the anvil is connected to the spindle ready to form the anastomosis (b)

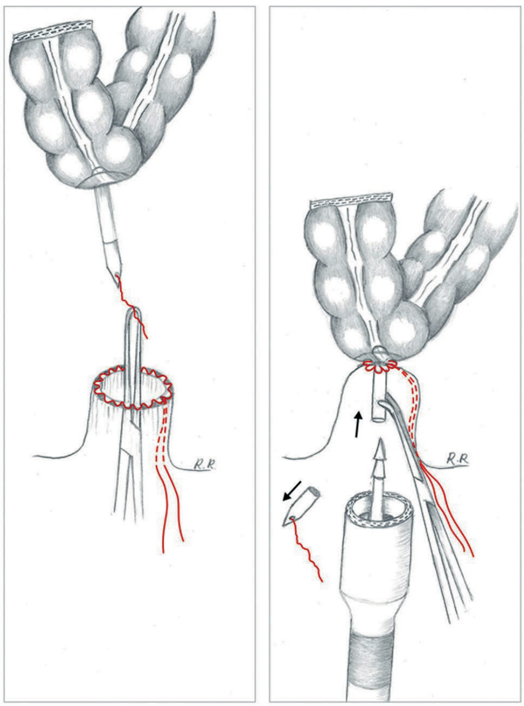

Fig. 4. A multifilament suture is attached to the white plastic cap that is connected to the anvil which has been secured with a pursestring in the bowel. A laparoscopic grasper passed transanally grasps the multifilament suture and guides the anvil down to the rectal opening in order to tighten the second pursestring around the anvil. Whilst the anvil is held in place with a curved Roberts artery forceps, the white cap is removed, and the stapling gun attached allowing the anastomosis to be performed under direct vision

curved Roberts artery forceps, the white cap is removed and the stapling gun attached allows the anastomosis to be performed under direct vision (Fig. 4 and Video).

Discussion

The formation of a colorectal or coloanal anastomosis is one of the critical steps post-TaTME that has been performed using both hand-sewn and stapling techniques. During a TaTME procedure, the distal rectal wall is divided at the start of the transanal dissection. This leaves an open distal rectal stump, which can easily be retracted and held in position for a hand-sewn anastomosis. The handsewn approach appears to be more suitable for very low coloanal anastomoses, as a pursestring closure is unlikely to be possible due to insufficient stump length. The level of the pursestring is dependent on the height of the tumour. If oncologically safe with an adequate margin, a rectal cuff just above the internal sphincter is preferred in order to have better functional outcome compared to the coloanal anastomosis. Conversely, a longer rectal stump may owe itself more readily to a stapling technique, as the visual exposure may be inadequate, and the distance from the anus too far for a hand-sewn anastomosis.

The EEA™ Haemorrhoid Stapler (Covidien) has been frequently used post-TaTME. The advantage of this stapler is the longer central rod on the anvil (13.5 cm) that allows connection to the stapler device before closure of the pursestring. However, there are two potential disadvantages associated with its use. The first is that the stapler's large diameter of 33 mm could risk incorporating sphincter muscle or even the vagina into the stapler when forming a low coloanal anastomosis. This may lead to a worse functional outcome. Secondly, it is not always possible to fit the large-sized anvil into the new colonic conduit, even in a side-to-end orientation.

More recently, a stapling technique using the CEEA™ stapler has been described previously including a video and outlined above [5]. The addition of the 10Fr redivac drain acts as a guide and safety mechanism for the insertion of the spindle of the AutoSuture CEEA™ circular stapler through the pursestring. The diameter of the CEEA™ stapler is also smaller, 28 or 31 mm, compared to the 33-mm EEA™ stapler, posing less of a risk of incorporating sphincter muscle into the stapler. We have reported on a series of 12 cases using the AutoSuture CEEA stapler in which there were no anastomotic leaks, and to date, all patients have had a good functional outcome [5]. A potential drawback of this technique is that it demands good visualisation of the pelvic floor and the rectal stump from the abdominal side before completing the anastomosis since the anvil is placed onto the stapling gun using conventional laparoscopic methods. In the difficult narrow pelvis with a short rectal stump, this exposure is sometimes limited. To overcome problems with abdominal exposure, whilst still avoiding the disadvantages of the wide 33-mm stapling device, a standard 28-mm stapler can be utilised using the pull-through method which relies on a good transanal view rather than abdominal. Further, it creates the possibility of a transanal anastomosis with excellent control of the distal pursestring. A potential disadvantage of this technique is the relative short anvil, which has to be clamped inside the anal canal in order to attach the stapler. Therefore, its use is not recommended in higher anastomoses above 4–5 cm. The author, Tuynman, who pioneered this technique has performed 36 cases so far and experienced two clinical leaks, both managed by transgluteal drain positioning.

The potential advantages and disadvantages of each anastomotic technique are outlined in Table 1. However, the true benefits and optimal approach are yet to be tested and confirm in comparative studies (Table 1).

Since each patient and each tumour has their own characteristics, it may be reasonable for a surgeon to be able to perform a number of anastomotic techniques in order to tailor the approach to the patient's anatomy. This has been suggested in Knol et al.'s recent publication on technical aspects of TaTME, a more individualised approach may be better depending on the distance of the tumour from the anorectal junction (ARJ) [4]. This will determine whether a platform is used at the start of the transanal TME dissection and what the most favourable anastomotic technique will be. For example, see Table 2.

Regardless of the technique used, care should always be taken to ensure well-vascularised anastomotic ends, optimal visualisation, and awareness of the potential risk to nearby structures such as the anorectal sphincters and vagina, especially when adherent to the rectal wall.

Recently, Tuech et al. [8] published the first functional outcome results in 56 consecutive patients who underwent endoscopic transanal proctectomy (ETAP) and hand-sewn coloanal anastomosis for low rectal cancer. The overall morbidity after surgery was 26 % with three patients developing a clinical anastomotic leakage (none required reoperation) and a local recurrence rate of only 1.7 % (median follow-up: 29 months, range 18–52). It is reassuring to find that the median Wexner score after stoma reversal was 5 (range 3–18), and only three patients (5.7 %) required a colostomy due to severe faecal incontinence. Given the more distal tumours included in this study, all of which had hand-sewn coloanal anastomoses, functional results are likely to be even better following more proximal stapled anastomoses.

Two further groups have published their initial experience with TaTME including the Dutch group, Veltcamp Helbach et al. [9], and Dr Lacy [10] from Barcelona. Eighty patients underwent TaTME in the Dutch group [9]; stapled anastomosis using the EEA™ haemorrhoidal stapler was used in cases in which gastrointestinal continuity was restored. Post-operative complications were seen in 39 % of patients, nine of whom required reoperation. One patient returned to theatre due to anastomotic leak.

Table 1. Comparison of hand-sewn and stapling techniques for coloanal and colorectal anastomoses post-transanal total mesorectal excision

Anastomotic technique	Advantages	Disadvantages
Hand-sewn coloanal	Suitable for coloanal and low colorectal anastomoses Suture placement and depth of suture controlled by surgeon under direct vision Avoids the difficult step of placing a rectal pursestring	Difficult anastomosis if a long rectal stump due to: Inadequate visual exposure Too far to reach with 'open' instruments Potentially worse functional outcomes compared to colorectal anastomoses
Stapled EEA™ Haemorrhoid Stapler 33 mm	Long central rod allows passage through the anal canal and attachment to the spindle prior to pursestring closure Good for long rectal stumps	Large 33-mm stapler diameter posing a risk to adjacent structures, such as anal sphincters and vagina Needs sufficient rectal stump length to form the rectal pursestring
Abdominal double pursestring stapled 28- or 31-mm CEEA™ stapler	Smaller stapler diameter posing less risk to adjacent structures Precise placement of the anvil through the centre of the pursestring under direct vision Abdominal conventional anvil-stapling device attachment	Needs sufficient rectal stump length to form the rectal pursestring May be difficult to connect the anvil to the spindle laparoscopically in an obese narrow pelvis with poor visualisation
Transanal double pursestring stapled 28- or 31-mm CEEA™ stapler	Smaller stapler diameter posing less risk to adjacent structures Precise placement of the anvil through the centre of the pursestring under direct vision Transanal stapling technique for low anastomoses	Can be used only for low anastomoses. Good transanal exposure is essential and therefore not suitable for heights above 4 cm. For higher anastomoses, the two other techniques are preferred

Table 2. Suggested cutoff distances of tumour from anorectal junc tion to determine the use of a platform to start the transanal dissection and subsequent anastomotic technique

Tumour distance from anorectal junction (cm)	Start of transanal TME dissection	Anastomotic technique
Coloanal	Without platform	Hand-sewn
2–3	With platform	28- or 31-mm CEEA™ stapler; transanal technique
3–4	With platform	28- or 31-mm CEEA™ stapler; abdominal technique
> 4 or wide colon/pelvis	With platform	EEA™ Haemorrhoid Stapler

Lacy et al. [10] have published the largest case series of 140 patients to date. Hand-sewn coloanal anastomosis was performed for patients with the most distal rectal tumours, whilst for midand proximal tumours, an EEA 33-mm circular stapler was used. Major complications were seen in 10 % of cases, with anastomotic leaks detected in 12 patients (8.6 %), three treated successfully conservatively, whilst one required percutaneous drainage and two had rectal tube transanal and intravenous antibiotics. The remaining nine patients returned to theatre with one of these patients requiring a stoma. Anastomotic bleeding occurred in three patients of whom one underwent a reoperation for transanal reinforcing stitches to control the bleeding.

Studies specifically comparing hand-sewn versus stapled coloanal/colorectal anastomosis following TaTME have yet to be published. Similis et al. [11] conducted a systematic review including 37 studies with a total of 628 participants who underwent TaTME resection. The review found that 66 % of anastomoses were hand-sewn coloanal and only 34 % were stapled. Anastomotic leak occurred in 25 cases, anastomotic stenosis in 11, and fistula formation in one case. Due to the heterogeneity of the studies included, with a low number of stapled anastomoses and cases likely to have been performed at an early stage in the surgeon's learning curve for TaTME, firm conclusions as to the optimal anastomotic method cannot be made. Anastomotic techniques have been compared following traditional laparoscopic and open rectal resections, with conflicting results. Cong et al. [12] found significantly lower rates of anastomotic leakage and stricture formation following stapled coloanal anastomosis compared to manual anastomosis following laparoscopic intersphincteric resections. The complication rates were similar for fistula formation, bleeding, and neorectal mucosal prolapse between the two groups. An earlier randomised study comparing hand-sewn versus stapled techniques in colonic J-Pouch-Anal anastomosis for rectal cancer found that anastomotic stricture rates were lower in the stapled group but did not reach statistical significance [13]. Post-operative morbidity and functional problems were similar between the two groups, but intra-operatively, the time taken to perform a stapled anastomosis was significantly faster. In 2012, a Cochrane review found insufficient evidence to demonstrate superiority of stapled over hand-sewn techniques in colorectal anastomosis surgery, regardless of the level of anastomosis [14]. The only statistically different results were that stricture formation was more frequent with stapling ($P<0.05$), and the time taken to perform the anastomosis was longer with hand-sewn techniques.

As with all emerging techniques, small modifications and technical optimisation are often required to further enhance the feasibility and safety profile. Three anastomotic colorectal techniques post-TaTME are in practice, and this description allows tailoring of the technique to length of the anal canal and height of anastomosis. However, studies comparing these techniques with functional outcome have yet to be published. Ideally, large randomised studies are required to compare post-operative outcomes between hand-sewn and stapling groups. However, as stated by Professor Wexner, 'the rapid adoption by inadequately trained low-volume surgeons may sadly jeopardize the ultimate achievement' of TaTME. Therefore, structured training, skills acquisition, mentorship, and credentialing with a standardised surgical approach are essential requisites in order to elicit and achieve the true potential benefits of TaTME.

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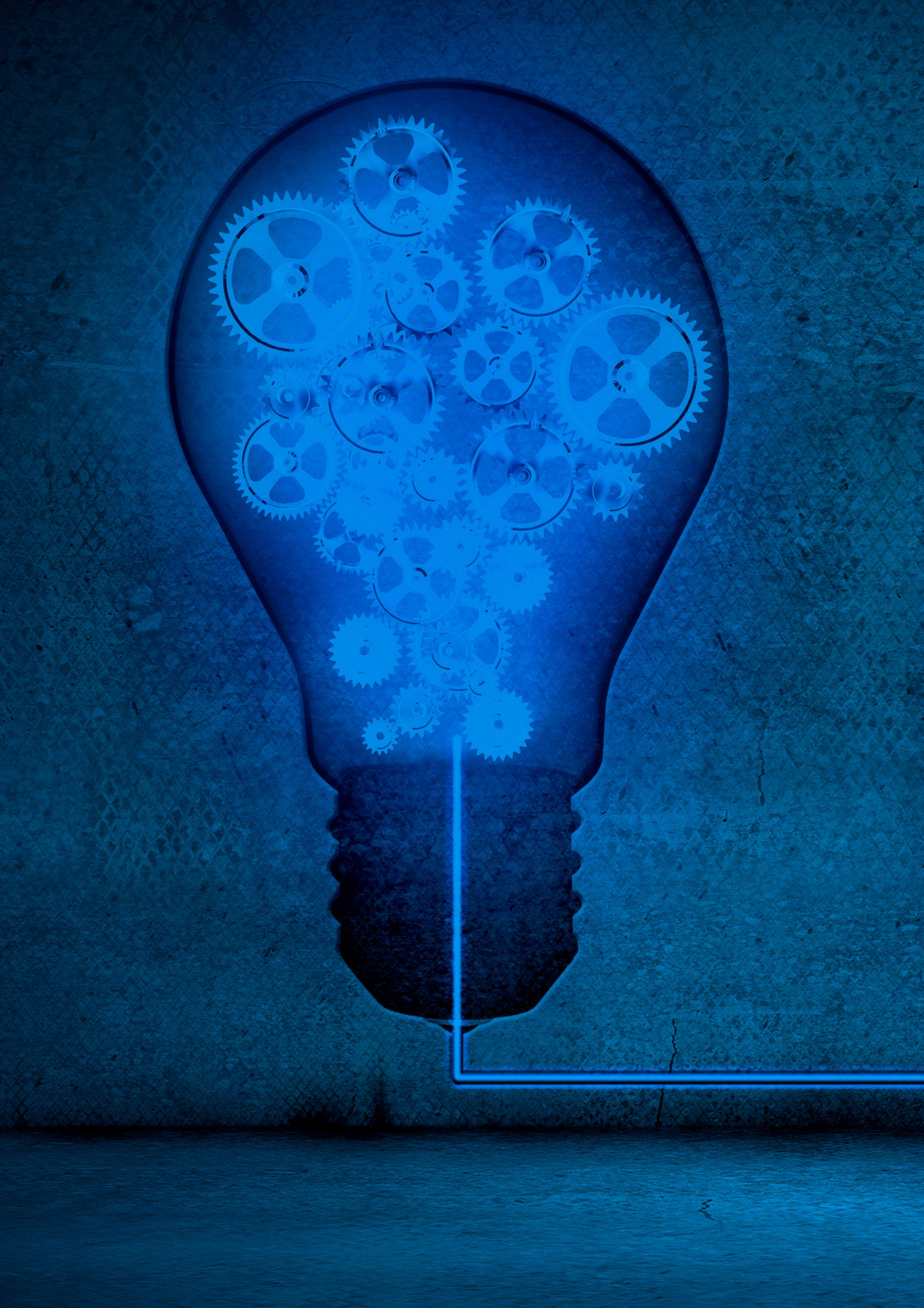

Chapter 10

A systematic review of transanal total mesorectal excision: is this the future of rectal cancer surgery?

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P.P. Tekkis

Colorectal Dis. 2016 Jan;18(1):19-36.

Abstract

Aim

The surgical technique used for transanal total mesorectal excision (TaTME) was reviewed including the oncological quality of resection and the peri-operative outcome.

Method

A literature search of MEDLINE, Embase, Science Citation Index Expanded and Cochrane was performed in order to identify studies reporting on TaTME.

Results

Thirty-six studies (eight case reports, 24 case series and four comparative studies) were identified, reporting 510 patients who underwent TaTME. The mean age ranged from 43 to 80 years and the mean body mass index from 21.7 to 31.8 kg/m^2. The mean distance of the tumour from the anal verge ranged from 4 to 9.7 cm. The mean operation time ranged from 143 to 450 min and mean operative blood loss from 22 to 225 ml. The ratio of hand-sewn coloanal to stapled anastomoses performed was 2:1. One death was reported and the peri-operative morbidity rate was 35%. The anastomotic leakage rate was 6.1% and the reoperation rate was 3.7%. The mean hospital stay ranged from 4.3 to 16.6 days. The mesorectal excision was described as complete in 88% cases, nearly complete in 6% and incomplete in 6%. The circumferential resection margin was negative in 95% of cases and the distal resection margin was negative in 99.7%.

Conclusion

TaTME is a feasible and reproducible technique, with good quality of oncological resection. Standardization of the technique is required with formal training. Clear indications for this procedure need to be defined and its safety further assessed in future trials.

Introduction

Total mesorectal excision (TME) was first described in 1982 by Heald *et al.* [1] and since then it has been established as the gold standard treatment of middle and lower third rectal cancers. TME is based on the principle of excising the rectal tumour and the mesorectum *en bloc,* including its blood supply and lymphatic drainage, to optimize locoregional clearance. TME has classically been performed by an open anterior abdominal approach, but advances in technology and surgical technique have enabled TME to be performed using minimally invasive techniques.

Laparoscopic TME (LapTME) has been shown to give similar results to the classical open approach with regard to peri-operative morbidity, surgical margins, quality of the surgical specimen, number of resected lymph nodes, local recurrence and overall survival [2–7]. In addition, LapTME was found to be associated with fewer wound infections, reduced blood loss, shorter hospital length of stay, earlier return to normal diet and earlier return of bowel function [3,5–11]. Nevertheless, a high conversion rate from laparoscopic to open surgery is still being reported (0–34%) [2–4,6,8,10–13] with an associated increased morbidity and worse oncological results [10,13,14]. Roboticassisted laparoscopic anterior resection has also been performed which has been shown to have a similar outcome to LapTME with regard to operation time, operative blood loss, peri-operative morbidity, length ofhospital stay, number of lymph nodes harvested, resection margins and local recurrence [15–17].

More recently, a transanal technique for TME has been developed with promising results. In transanal total mesorectal excision (TaTME) the rectum is mobilized transanally in a retrograde fashion. The technique has become possible due to advances in transanal endoscopic microsurgery (TEM) [18], transanal abdominal transanal proctosigmoidectomy with coloanal anastomosis (TATA) [19–21], transanal minimally invasive surgery (TAMIS) [22] and natural orifice transluminal endoscopic surgery (NOTES). TEM was introduced in 1983 by Buess *et al.* for resection of rectal adenomas and early carcinomas through a wide bore rigid proctoscope [18]. The TATA approach was described by Marks *et al.* in 1984 as an effective sphincter-preservation operation to avoid a permanent colostomy for low-lying rectal cancers [19–21]. Atallah *et al.* [22] introduced TAMIS, which uses a single-incision laparoscopic port to gain endoscopic access to the rectal vault using laparoscopic instruments. NOTES allows surgical procedures via natural orifices, e.g. transoral (gastrotomy), transvaginal or transanal (transrectal or colotomy). Transanal NOTES applied to colorectal disease is intuitive and makes more sense than other access routes because the target organ for transluminal access houses the pathology. NOTES transanal endoscopic rectosigmoid resection was first performed by Whiteford *et al.* [23] in 2007 on a human cadaver.

Extensive experimental research demonstrated the feasibility and safety of the transanal access for colon and rectal resections initially on animal [24–29] and human cadaver models [30–37]. The knowledge and experience gained from animal and cadaver studies led to human clinical trials. From 2010, TaTME, with or without laparoscopic assistance, has been performed on patients with rectal cancer and has shown promising results [38–42]. Studies have demonstrated the feasibility of this technique also with transanal robotic assistance [43–45].

The aim of this systematic review is to provide an up-to-date literature review based on all the studies reporting on the use of TaTME and to assess the perioperative outcome and the oncological quality of resection. In particular, the review will critically evaluate the feasibility and safety of this new and promising surgical treatment for rectal cancer.

Method

Search strategy

A comprehensive literature search using a combination of free-text terms and controlled vocabulary when applicable was performed of the following databases: MEDLINE, Embase, Science Citation Index Expanded, and Cochrane Central Register of Controlled Trials (CENTRAL) in the Cochrane Library. The search period was from 1 January 2007 to the latest date for this search, which was 8 December 2014. The following search headings were used: 'transanal', 'transanal minimally invasive surgery' or 'TAMIS', 'transanal endoscopic microsurgery' or 'TEM', 'natural orifice transluminal endoscopic surgery' or 'NOTES', combined with each of the terms 'total mesorectal excision', 'TME' and 'proctectomy'. The detailed search strategy is provided in Table S1. The 'related articles' function from PubMed was used to broaden the search, and all abstracts, studies and citations scanned were reviewed. The references of the identified studies were also searched to identify additional studies for inclusion. No restrictions were made based on language or publication status.

Inclusion criteria and data collection

Case reports, case series or comparative studies, performed prospectively or retrospectively, were considered for this systematic review. Only studies reporting on TaTME performed on live human subjects were considered for inclusion. Full text was sought for any references which were identified for potential inclusion and further selection for inclusion was made based on the full text. The following data were extracted from each study: first author, year of publication, hospital, country, inclusion and exclusion criteria, sample size, study design, participant characteristics [such as age, gender, body mass index (BMI), neoadjuvant therapy received], tumour characteristics (clinical stage, distance from the anal verge or dentate line, tumour size), surgical technique (transanal platform used, transabdominal approach, anastomosis performed, use of diverting stoma), operative outcome (operation time, operative blood loss, extraction site, intra-operative complications, conversion to open surgery), postoperative outcome (length of hospital stay, postoperative complications, reoperations), histopathology results (length of specimen extracted, TME description, circumferential and distal resection margins, lymph nodes harvested and pathological stage) and long-term outcome (survival and cancer recurrence).

Statistical analysis

Continuous variables were analysed and reported as

1. overall range from all the included studies, e.g. age range of all participants;
2. range of means or medians for an outcome of interest reported by the included studies, e.g. range of reported means for age;
3. the most frequent mean or median reported by the included studies, e.g. the most frequent mean age reported by the studies.

Binary or dichotomous variables were analysed and reported as

1. ratio of an outcome of interest, e.g. male to female ratio of the participants;
2. percentage of patients with event from total number of participants based on the studies reporting on the outcome of interest, e.g. percentage of T1 tumour stage among studies reporting on preoperative tumour stage.

Results

Eligible studies

Figure 1 shows the study flow diagram. Of 874 references identified through electronic searches of Science Citation Index Expanded (n = 377), Embase (n = 325), MEDLINE (n = 164) and CENTRAL (n = 8), 215 duplicates between databases were excluded. A further 579 clearly irrelevant references were excluded through screening titles and reading abstracts. Eighty references were retrieved for further assessment. Three more studies were identified for further assessment through scanning reference lists of the identified studies. This left 83 studies that were investigated in detail in full text [27–29,32– 111]. Of these 83 references, after reviewing the studies in detail the following studies were excluded for the following reasons: 16 studies were review articles [47–50,55,62,66,69,71,73,75,85,88,93,94,107], 12 were abstracts of published case series already included in the analysis [56,59,60,65,86,87,91,97,98,100,102,110], six were articles describing the surgical technique or videos [51,68,72,83,99,103], six were reporting on TaTME performed on cadavers [32–37], three were describing TaTME performed on animals [27–29], two were describing the anatomy for TaTME [46,57] and one was reporting on a study protocol design for comparing TaTME with LapTME [77]. One case report [54] was excluded because the same patient was reported in a case series [43] published by the same group.

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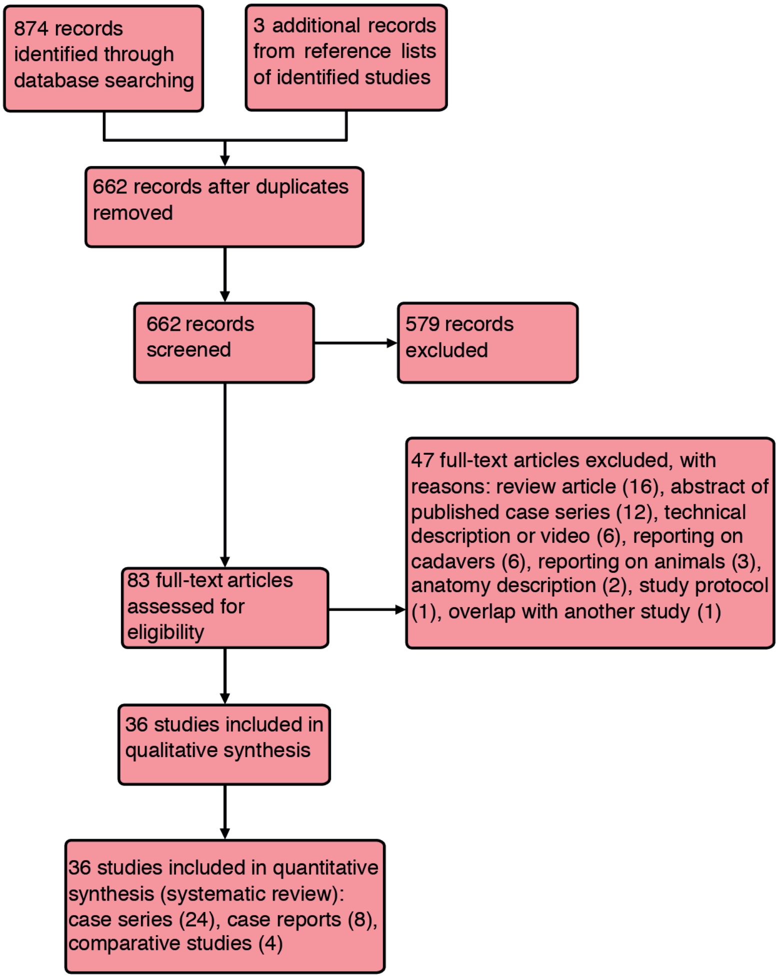

Figure 1. Study flow diagram.

After all exclusions 36 studies [38–45,52,53,58,61,63,64,67,70,74,76,78–82,84,89,90,92,95,96,101,104–106,108,109,111] reporting on 627 participants (510 participants who underwent TaTME and 117 participants who underwent LapTME) fulfilled the selection criteria and were included in the systematic review. They comprised eight case reports reporting on eight patients [38–40,53,67,79,106,109], 24 case series reporting on studies comparing 113 patients who underwent TaTME with 117 who underwent LapTME [64,78,82,104]. Included in the case series, there were eight published abstracts [44,63,74,80,81,89,92,96] and one unpublished abstract [70]. There were two published abstracts [78,82] included in the comparative studies. Table 1 is a summary of the patient characteristics, surgical technique and operative and postoperative outcome in all the included studies. A more detailed description of each study is given in Tables S2–S5. Table S2 shows the patient characteristics, surgical technique and operative and postoperative outcome of the case reports, Table S3 shows the outcome from the case series published as articles, Table S4 from the case series reported as abstracts and Table S5 from the comparative studies. 389 patients [41–45,52,58,61,63,70,74,76,80,81,84,89,90,92,95,96,101,105,108,111] and four comparative studies.

Patient characteristics

In all, 510 patients underwent TaTME. Rectal adenocarcinoma was the indication for surgery in all except for 16 patients with benign disease. The age of patients in the studies ranged from 23 to 87 years and the mean age ranged from 43 to 80 years with the most frequent mean age being 65 years. The overall male to female ratio, calculated from the studies reporting gender, was 2:1. The BMI ranged from 16 to 42 kg/m^2 and the mean BMI ranged from 21.7 to 31.8 kg/m^2, with the most frequent mean BMI being 26 kg/m^2. Based on the studies reporting on neoadjuvant therapy, 71% of participants received chemoradiotherapy, 7% received radiotherapy, 1% received chemotherapy and 21% received no neoadjuvant treatment.

The tumour characteristics, including preoperative tumour staging, tumour size and distance of the tumour from the anal verge or from the dentate line, are summarized in Tables S2–S5. The distance of the tumour from the anal verge ranged from 1 to 15 cm, and the means of the studies ranged from 4 to 9.7 cm with the most frequent mean distance being 5 cm from the anal verge. Tumour size ranged from 0.6 to 9.3 cm and the mean size ranged from 2.5 to 3.7 cm. Among studies reporting on preoperative (clinical) tumour stage, 6% of the participants were staged as T1, 21% as T2, 65% as T3 and 8% as T4. For preoperative lymph node staging, 2% of patients were staged as Nx, 52% as N0, 29% as N1 and 17% as N2.

Surgical technique

TaTME was performed purely transanally (pure transanal TaTME) [58,79,95,108,109] or with laparoscopic assistance (hybrid TaTME) [39–42,52,61,76,90,101, 105,108]. Pure transanal TaTME was performed in 18 reported cases [58,79,95,108,109]. Where hybrid TaTME was performed, laparoscopic assistance was provided through multiport laparoscopy (four or five ports) [42,43,84,90,95,101,106,108], mini-laparoscopy (three-port laparoscopy) [39,61,76,111] or single-port access [40,41,101,105]. For single-port laparoscopy the port was positioned in the planned ileostomy site. The ports reported to have been used for single-port laparoscopic assistance were Endorec Trocar (Aspide Medical, La Talaudiere, France) [40], GelPOINT (Applied Medical Inc., Rancho Santa Margarita, California, USA) [41] and SILS Port (Covidien, Mansfield, Massachusetts, USA) [105]. Multiport laparoscopy was performed using three ports [39,76,111] or more ports [39,42,61,76, 95]. Multiport laparoscopy with the da Vinci Robotic Surgical System–Si (Intuitive Surgical Inc., Sunnyvale, California, USA) was performed by some studies for the abdominal phase [43,45,67].

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Table 1 Summary of patient characteristics, surgical technique, operative and postoperative outcome of the included studies.

	N	Age*	Gender, M:F	Abdominal assistance†	Transanal platform†	OT* (min)	Intra-operative complications†	Postoperative complications†	LOS* (days)
Case reports published as articles									
Sylla *et al.* (2010) [39], Chen *et al.* (2010) [38], Tuech *et al.* (2011) [40], Leroy *et al.* (2013) [79], Zhang *et al.* (2013) [109], Gomez Ruiz *et al.* (2014) [67], Atallah *et al.* (2015) [53], Verheijen *et al.* (2014) [106]	8	57	3:5	ML {4}, none {2}, SL {1}, RL {1}	GelPOINT Path {3}, TEO proctoscope {2}, PPH {2}, Endorec {1}, *Robotic TaTME {2}	289	Rectal perforation {1}	Infected pelvic haematoma {1}	4.7
Case series published as articles									
Dumont *et al.* (2012) [41]	4	67	4:0	SL	GelPOINT Path	360	Intraperitoneal gas leak {1}	Anastomotic fistula {1}	13
Zorron *et al.* (2012) [42]	2	64	1:1	ML	Colonoscope {1}, single-port triport {1}	355	None	Transient feet paraesthesia {1}	7
Lacy *et al.* (2013) [76]	3	73	1:2	ML	GelPOINT Path	143	None	Dehydration – renal failure {1}	4.7
Lacy *et al.* (2013) [61]	20	65	11:9	ML	GelPOINT Path	235	None	Urinary retention {2}, ileus {1}, dehydration {1}	6.5
Rouanet *et al.* (2013) [90]	30	65	30:0	ML	TEO proctoscope	304	Conversion to open {2}, urethral injury {2}, air embolism {1}	Bowel obstruction {2}, peritonitis {1}, sepsis {1}, transient urinary disorder {2}, *reoperation {2}	14
Sylla *et al.* (2013) [95]	5	49	3:2	None {3}, ML {2}	TEO proctoscope	275	None	Ileus {1}, urinary retention {2}	5.2
Velthuis *et al.* (2013) [105]	5	69	3:2	SL	SILS Port	178	Pneumatosis of mesentery and retroperitoneum {1}	Ileus {1}, pneumonia {1}, presacral abscess {1}, *reoperation {1}	NR

Table 1 (Continued).

	N	Age*	Gender, M:F	Abdominal assistance†	Transanal platform†	OT* (min)	Intra-operative complications†	Postoperative complications†	LOS* (days)
Atallah *et al.* (2014) [52]	20	57	14:6	ML {11}, RL {6}, open {3}	GelPOINT Path, SILS Port	243	None	Wound infection {2}, anastomotic leak {1}, pelvic abscess {4}, ileus{4}, pneumonia{1}, renal failure {1}, perianastomotic fluid collection {2}, anastomotic stricture {4}, death due to pulmonary embolism 8 weeks post-op {1}, *reoperation {1}	4.5
Atallah *et al.* (2014) [43]	3	45	2:1	ML	GelPOINT Path, *Robotic TaTME	376	None	Peristomal dermatitis {1}, dehydration {1}, pulmonary embolism {1}	4.3
Chouillard *et al.* (2014) [58]	16	58	6:10	None {10}, SL {5}, ML {1}	GelPOINT Path, SILS Port	265	None	Small bowel obstruction in pelvis {1} and at diverting stoma {1}, pelvic abscess {1}, *reoperation {3}	10.4
Meng *et al.* (2014) [84]	3	80	2:1	ML	TEM rectoscope	365	None	None	6.5
Tuech *et al.* (2015) [101]	56	65	41:15	ML {43}, SL {8}, open {4}, RL {1}	Endorec Trocar {42}, SILS Port {11}, GelPOINT Path {3}	270	Conversion to open due to technical difficulties in obese patients {2} and due to adhesions {1}	Anastomotic leak {3}, pelvic sepsis without anastomotic leak {3} (2 needed CT-guided drainage), urinary retention {5}, blood transfusion {2}, cerebral infarction{1}	10

Table 1 (Continued).

	N	Age*	Gender, M:F	Abdominal assistance†	Transanal platform†	OT* (min)	Intra-operative complications†	Postoperative complications†	LOS* (days)
Wolthuis *et al.* (2014) [108]	14	65	5:9	ML {11}, none {3}	GelPOINT Path	148	Conversion to open {2}, inadequate exposure due to bleeding {1} or difficulty of maintaining insufflation {2}, rectal perforation {1}, difficult dissection due to fibrosis post-radiotherapy {1}	Transient fever {2}, urinary tract infection{3}, small pelvic haematoma {1}	8.7
Zorron *et al.* (2014) [111]	9	63	5:4	ML	Single-port triport {7}, colonoscope {2}	311	Conversion to open {1}, conversion to laparoscopic{1}	Transient feet paraesthesia {1}, anastomotic leak {1}, *reoperation {1}	7.6
Ruiz *et al.* (2015) [45]	5	53	4:1	RL	GelPOINT Path, *Robotic TaTME	375	None	Anastomotic leak {1}	6
Case series reported as abstracts									
Espin-Basany *et al.* (2014) [63]	20	71	17:3	NR	NR	NR	NR	Anastomotic leak {1}, presacral abscess{4}, *reoperation {3}	7
Kazieva *et al.* (2014) [74]	6	54	3:3	ML	Endoscopic TEM	243	NR	Anastomotic leak {4}, ileus {2}	12
Lezoche *et al.* (2014) [80]	8	66	5:3	ML	TEM rectoscope	450	None	Anastomotic leak {3}, urinary incontinence {1}, anastomotic stricture {2}, rectovaginal fistula {1} treated with stent	16.6
Malik *et al.* (2014) [81]	8	43	4:4	NR	NR	298	Pelvic bleeding treated by pelvic packs for 24 h {1}	Ileus {2}, high output stoma {1}, anastomotic stricture {1}	9
Rasulov *et al.* (2014) [89]	15	52	NR	ML	NR	302	NR	Urinary retention {3}	NR
Ruiz *et al.* (2014) [44]	8	62	5:3	RL	*Robotic TaTME	368	NR	Anastomotic leak {1}	5.5
Schirnhofer *et al.* (2014) [92]	9	69	6:3	SL	SILS Port, GelPOINT Path	243	Resection could not be completed {1}, conversion to open due to urethral injury{1}	NR	NR

Table 1 (Continued).

	N	Age*	Gender, M:F	Abdominal assistance†	Transanal platform†	OT* (min)	Intra-operative complications†	Postoperative complications†	LOS* (days)
Tasende *et al.* (2014) [96]	100	NR	NR	ML	NR	178	Pfannenstiel incision for specimen extraction {10}	Anastomotic leak {8}, other complications not reported	6
Hompes *et al.* (unpublished) [70]	20	NR	14:6	NR	NR	315	Conversions to open {3}	Complications {6} including pelvic haematoma {1}, anastomotic leak {1}	7
Comparative studies published as articles									
Velthuis *et al.* (2014) [104]	25	64	18:7	SL	SILS Port, GelPOINT Path	NR	NR	NR	NR
Fernandez-Hevia *et al.* (2015) [64]	37	65	24:13	ML	GelPOINT Path	215	NR	Anastomotic leak {2}, collection {1}, haemorrhage {1}, urinary retention {1}, ileus {4}, ascites {1}, fever {1}, high ileostomy output {1}, *reoperation {3}	6.8
Comparative studies published as abstracts									
Lelong *et al.* (2014) [78]	34	NR	NR	NR	NR	NR	Conversion to open {1}	Complications {9}	8
Marks *et al.* (2014) [82]	17	NR	NR	NR	NR	NR	NR	Complications {4}	NR 4.3–
Overall	510	43–80	2:1	None {18}	Robotic TaTME {18}	143–450	9.6% (27/282),‡ urethral injury {3}	33.5% (126/376),‡ reoperation 3.7% (14/376)	16.6

For a more detailed description of each study please see Tables S2–S5.

LOS, length of stay; M:F, male:female; ML, multiport laparoscopy; *N*, number of participants; NR, not reported; OT, operation time; PPH, procedure for prolapsing haemorrhoids; RL, robotic laparoscopy; SL, single-port laparoscopy; TaTME, transanal total mesorectal excision; TEM, transanal endoscopic microsurgery; TEO, transanal endoscopic operation.

*Reported as a mean or median.

†{Number of participants}.

‡Based on the studies reporting on this outcome.

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For hybrid TaTME, the abdominal portion of the operation can be completed laparoscopically, robotically, hand-assisted or with an open approach. During laparoscopy the abdomen and pelvis were inspected for tumour invasion of the peritoneum and to confirm the absence of dense pelvic adhesions and other factors that would preclude a proper dissection [61,95]. The splenic flexure was taken down laparoscopically, and the descending and sigmoid colon were mobilized. The sigmoid mesentery was divided with high ligation of the inferior mesenteric vessels [52,71,95]. Part of the superior rectal dissection could be initiated laparoscopically according to TME principles [71]. If the operating team consisted of an abdominal team and a perineal team, the abdominal and transanal phases during TaTME with laparoscopic assistance could be performed synchronously [64,95]. Synchronous two-team surgery has the potential to reduce the operation time [61,64,76,84] and allows the two teams to act synergistically by providing traction and countertraction [64] and by guiding each other to the correct dissection plane in a 'rendezvous' manner, i.e. meet each other from above and below [84]. Nevertheless, not every surgical department has the capability to perform TaTME synchronously as synchronous two-team surgery requires two separate nursing teams, two senior surgeons experienced in TaTME and two assistants.

Once the abdominal portion is completed, transanal TME is performed in most cases, but the operation could also begin with the transanal TME prior to entering the abdomen. Before the transanal phase begins, digital rectal examination, anoscopy or rigid proctoscopy is performed to confirm the location of the tumour and identify a safe distal margin [71,95]. For the transanal approach, a retractor was positioned for exposure and to circumferentially transect the distal rectum. To expose the lower rectum, a Lone Star retractor (Lone Star Medical Products Inc., Houston, Texas, USA) [41,43,58,61,95,108] may have been used, or a Scott ring retractor (Lone Star Medical Products, Stafford, Texas, USA) [104]. For low-lying tumours encroaching on the anorectal junction or located < 1.5 cm from the anorectal junction, a partial intersphincteric open dissection is performed under direct vision [52,71,95]. The mucosa and internal sphincter muscle are dissected circumferentially starting at least 1 cm below the distal margin of the tumour [95]. A purse-string suture is used for luminal occlusion of the rectum below the tumour and intersphincteric dissection is extended cephalad up to the level of the pelvic floor [52,61,71,95]. For tumours with a distal margin of more than 1.5 cm from the anorectal junction, the rectum is occluded with a circumferential rectal purse-string suture securing a safe distal margin (at least 1 cm below the lower tumour margin). This is done with the help of an anorectal retractor, or an anoscope, or proctoscope for exposure [52,95], or through the transanal platform [71]. Following rectal occlusion with the purse-string, the rectum is washed out with tumouricidal wash to prevent implantation of exfoliated tumour cells [71].

The transanal platform is then introduced transanally and the rectum is insufflated with CO_2 to a pressure of 9–15 mmHg [43,52,95]. Different transanal platforms have been used by the included studies such as a transanal endoscopic operation (TEO) proctoscope (Karl Storz, Tuttlingen, Germany) [39,79,90,95], Endorec Trocar (Aspide Medical) [39,79,90,95,101], GelPOINT Path Transanal Access Platform (Applied Medical) [41,43,53,58,61,76,106,108], transanal access port (PAT, Developia Inc., Spain) closed on the back with GelPOINT (Applied Medical) [45,67], SILS Port (Covidien) [52,105] and single-channel colonoscope (Olympus, Tokyo, Japan) [42,111]. The included studies demonstrated that TaTME can be performed using disposable flexible or reusable rigid platforms. There are currently no comparative data available between rigid and flexible transanal platforms. The rigid platforms are more costly as an initial investment, but may be costeffective in the long term because they are reusable. Also, they provide a rigid stable platform for instrument manipulation and effective tissue retraction. With rigid platforms there is no need for a cameraman and the TEM scope has an integrated ventilator [95,112]. On the other hand disposable flexible platforms are pliable and allow for an adjusted fit within the anal canal and greater manoeuvrability [61,76]. In addition, disposable flexible platforms provide a less traumatic retraction possibly resulting in a less negative impact on anorectal function compared to rigid platforms [61,76]. The da Vinci Robotic Surgical System–Si (Intuitive Surgical) was used by some studies for the transanal resection and the robotic cart was side-docked parallel and as close as possible to the base of the operating table [43,45,67,106].

Standard laparoscopic instrumentation was used for rectal dissection and energy source devices reported to have been used were diathermy, the Harmonic Scalpel (Ethicon Endo-Surgery, Cincinnati, Ohio, USA) [95] or LigaSure (Covidien) [58]. The avascular presacral plane is identified when insufflated gas enters the tissue planes between the parietal endopelvic fascia and mesorectal envelope [71]. Posteriorly, the presacral plane is entered and the posterior dissection continued cephalad in the avascular presacral plane in accordance with TME principles [61,71]. The mesorectum is mobilized, and the plane of dissection extended medially and laterally [61,71]. Anteriorly, a plane on either side of Denonvilliers' fascia is chosen according to the location of the tumour, and the rectum is dissected from the posterior vagina or prostate until the peritoneal reflection is reached and opened [71,95]. The dissection then proceeds cephalad to communicate with the dissection performed laparoscopically from above. For pure TaTME, with no abdominal assistance, the left colon and the splenic flexure are mobilized transanally and the inferior mesenteric artery pedicle is divided transanally [58,95].

With completion of the mesorectal excision and with the colon adequately mobilized, the rectum is grasped and the colon exteriorized transanally [58,95,104]. The specimen can be extracted through the transanal platform if it is not bulky [71] or through an Alexis wound protector (Applied Medical) positioned transanally. Alternatively, if the specimen is too bulky a conventional abdominal extraction site and wound protector are used [71]. Proximal colonic resection is performed extracorporeally [61,95] and an anastomosis is performed transanally or with laparoscopic assistance [61,95].

The anastomoses performed have been end-to-end hand-sewn coloanal [39,41,43,45,52,58,61,95,108], side-to-end hand-sewn coloanal [40,79,101], end-toend stapled [61,67,76,84,109], side-to-end stapled [61,76] and J-pouch anastomosis [52]. The double purse-string technique is used for stapled anastomosis [71]. From the studies reporting on the anastomotic technique 66% of the anastomoses have been hand-sewn coloanal and 34% were stapled, giving a ratio of handsewn coloanal to stapled anastomoses of 2:1. A diverting loop ileostomy is created in most cases unless a permanent stoma is to be fashioned [39,40,43,45,52,67, 104,106,111].

Operative details

The operation time ranged from 76 to 495 min, and the mean operative time reported by the included studies ranged from 143 to 450 min. The operative blood loss ranged from 0 to 600 ml, and the mean reported by the included studies ranged from 22 to 225 ml. Twelve conversions to open surgery were reported. The reasons given for nine of the conversions were posterior fixity of the tumour (two) [90], intra-abdominal adhesions after previous laparotomy (three) [101,108], a bulky and high tumour (one) [111], urethral injury (one) [92] and technical difficulties in an obese male patient (BMI 32) [101] and an obese female patient (BMI 37) [101].

Intra-operative complications included one small tear of the rectal wall which was sutured using the Endostich device inserted through the transanal platform [39], and a rectal perforation which occurred in a patient with known metastatic rectal cancer to liver and lung [108]. One study reported a case of intra-operative pelvic bleeding treated by pelvic packs for 24 h [81]. Other reported intra-operative complications were urethral injury (three) [90,92], two of which were sutured transanally [90] and oxygen desaturation with suspicion of air embolism in one case [90].

Wolthuis *et al.* [108] reported inadequate surgical field exposure due to the difficulty of maintaining insufflation (two cases) or due to bleeding (one case), which complicated the critical view to dissect safely in a cephalad direction. The same study reported difficult dissection on the Denonvilliers' fascia owing to fibrosis after radiotherapy for concurrent prostate cancer (one case) [108]. Dumont *et al.* [41] reported accidentally opening the peritoneum of the pouch of Douglas before completion of the middle lateral rectal dissection, and the transanal procedure had to be stopped because ofleakage of intraperitoneal gas leading to low pelvic pressure with poor vision. Another study reported pneumatosis of the retroperitoneum and mesentery of the small bowel, making laparoscopic mobilization of the sigmoid difficult [104]. Finally, Tasende *et al.* [96] reported that a Pfannenstiel incision was required for specimen extraction in 10% of their cases due to bulky tumours.

Postoperative course

The length of postoperative hospital stay ranged from 2 to 29 days, and the mean length of hospital stay reported by the included studies ranged from 4.3 to 16.6 days. There was no 30-day mortality. A single death due to pulmonary embolism was reported 8 weeks postoperatively [52]. The anastomotic leakage rate was 6.1%. The peri-operative morbidity rate, including operative and postoperative morbidity, based on the studies that reported this outcome, was calculated to be 35%.

The following postoperative complications were reported by the included studies: anastomotic leakage (26 cases) [44,45,52,63,64,70,74,80,96,101,111], pelvic abscess formation (16 cases) [43,52,58,63,64,101,104], urinary retention and transient urinary dysfunction (15 cases) [61,64,89,90,95,101], small bowel paralytic ileus (15 cases) [52,61,64,74,81,95,104], anastomotic stenosis (seven cases) [52,80,81], water and sodium depletion due to increased ileostomy output causing renal failure (five cases) [43,61,64,76,81], bowel obstruction (four cases) [58,90], pelvic haematoma formation (three cases) [70,79,108], urinary tract infection (three cases) [108], fever (three cases) [64,108], wound infection (two cases) [52], pneumonia (two cases) [52,104], transient paraesthesia of both feet due to intraoperative positioning (two cases) [42,111], red blood cell transfusion postoperatively (two cases) [101], pulmonary embolism 2 weeks postoperatively treated with systemic anticoagulation (one case) [43], pulmonary embolism 8 weeks postoperatively which led to the death of the patient (one case) [52], anastomotic fistula (one case) [41], sepsis requiring critical care (one case) [90], urinary incontinence (one case) [80], ascites (one case) [64], acute renal failure (one case) [52], rectovaginal fistula (one case) [80], haemorrhage (one case) [64], stoma dermatitis related to high output from diverting ileostomy (one case) [43], cerebral infarction with a favourable outcome (one case) [101] and peritonitis secondary to ileal injury without a direct link with the TaTME procedure (one case) [90]. Seventeen more cases were included in postoperative complications from studies which did not report the cause of morbidity in detail [70,78,82].

Some studies described the interventions required for management of the complications. One patient who developed an anastomotic stricture was successfully trea ted with dilatation [81], and one who developed a rectovaginal fistula was treated by stenting [80]. Two patients diagnosed with pelvic sepsis without evidence of anastomotic leakage required CT-guided drainage [101]. Fourteen reoperations were reported in total [52,58,63,64,90,105,111], giving a reoperation rate of 3.7%. From the studies that reported on the causes for reoperation, one presacral abscess was treated by repeated laparoscopic drainage [104] and another pelvic abscess without anastomotic leakage required reoperation [58]. Small bowel obstruction was the cause of reoperation in two cases, one occurring at the level of the diverting stoma and the other due to incarceration of a small bowel loop in the pelvis [58]. Two anastomotic leaks related to necrotic proximal colon due to ischaemia necessitated reoperation with dismantling of the coloanal anastomosis and construction of a permanent end colostomy [52,111].

Histopathologic results

The number of lymph nodes harvested ranged from 5 to 81, with a mean ranging from 11.5 to 33. Among studies reporting on postoperative histopathological tumour stage, 11% of participants were staged as T0, 1% as Tis, 10% as T1, 26% as T2, 48% as T3 and 4% as T4. With regard to postoperative N stage, 72% of participants were staged as N0, 19% as N1 and 9% as N2.

From the 462 reports on the histopathological examination of the TME specimens, the mesorectal excision was described as complete (287 reports) or intact (26) or Grade 3 (42) or satisfactory (42) or adequate (eight) in 88% of cases, as nearly complete (22) or Grade 2 (seven) in 6% of cases, and as incomplete (23) or inadequate (three) or Grade 1 (two) in 6% of cases. From the 455 reports on the circumferential resection margin (CRM), this was negative with a distance between resection margin and tumour of more than 1 mm in 433 (95%) cases and was positive (i.e. tumour infiltration within 1 mm or less from the resection margin) in 22 (5%) cases. Regarding tumour at the distal resection margin (DRM), there were 326 reports in total, 325 of which were negative (99.7%) and one was positive (0.3%).

Follow-up

Six studies reported the follow-up after TaTME [52,58,78,90,95,101]. Rouanet *et al.* [90], with a median follow-up of 21 (10–41) months, reported four cancer-related deaths, including one due to an isolated locoregional recurrence and one caused by hepatic cirrhosis. The same authors also reported that 12 patients were treated for locoregional or distant recurrence, and four experienced locoregional recurrence alone. The reported overall survival rates at 12 and 24 months were 96.6% [95% confidence interval (CI) 78.0–99.5]and 80.5% (95% CI 53.0–92.9), and the recurrence-free survival rates at 12 and 24 months were 93.3% (95% CI 75.9–98.3) and 88.9% (95% CI 69.0–96.3) [90]. Furthermore, Atallah *et al.* [52] at a 6-month median follow-up reported no locoregional recurrence but one case with distant metastases. Sylla *et al.* [95] reported that at a mean follow-up of 5.4 ± 2.3 months all patients were disease-free. Chouillard *et al.* [58] followed their patients for 9 months and reported no recurrence, whether local or distant.

Tuech *et al.* [101] followed their patients for a median time of 29 (18–52) months and reported an overall survival rate of 96.4%. There were four patients in the study with synchronous liver metastases who underwent hepatic resection. Of these two died at 24 and 37 months of metastases, one was alive without recurrence and one with liver and lung metastases continued to be followed up [101]. Tuech *et al.* [101] also reported a 1.7% rate of local recurrence and a 5-year disease-free survival rate of 94.2%. Among the 52 patients with non-metastatic rectal cancer at diagnosis, this study reported two cases of metastatic and one oflocal recurrence [101]. The single case of local recurrence developed at 24 months postoperatively and affected one of three patients with a CRM of < 1 mm (R1 resection) [101]. In a comparative study published as an abstract, Lelong *et al.* [78] followed up their patients for a median time of 24 months. The study reported comparable survival rates between TaTME and LapTME, and local recurrence rates of 3% (one case) for TaTME and a 6% (two cases) for LapTME.

Discussion

The limitations of current surgical TME techniques

LapTME can be technically demanding in patients with a bulky or an advanced distal rectal tumour showing a poor response to neoadjuvant treatment. Pelvic exposure during LapTME is particularly restricted in male patients with a narrow pelvis and in obese patients [52,90,95]. Previous pelvic radiation can make laparoscopic pelvic dissection more difficult, and tumours located on the anterior rectal wall have an increased risk of inadequate oncological clearance [52,95]. The use of laparoscopic staplers in a narrow pelvis is difficult and the multiple firings of staples across the low rectum is of concern [58,69,71]. Difficulties in pelvic exposure and limitations of instrumentation can affect not only the dissection during LapTME but also the preservation of autonomic pelvic nerves and the possibility of achieving a restorative procedure [71]. Moreover, conversion from LapTME to open surgery is reported to be required in 0–34% of cases due to local tumour invasion or tumour fixation, difficult dissection in a narrow male pelvis, poor vision, obesity, bulky tumour, low rectal tumour, previous irradiation, bleeding, rectal perforation, dilated small bowel, extensive or dense adhesions, and anastomotic failure [2–4,6,8,10–13]. Patients converted from LapTME to open resection are known to have a higher operative mortality and morbidity and worse oncological results, compared with patients having laparoscopic or open TME [10,13,14].

The advantages of TaTME

TaTME was developed to overcome technical difficulties associated with LapTME and open TME. It may address some of the difficult aspects of laparoscopic or open TME, such as exposure, rectal dissection, distal cross-stapling of the rectum and sphincter preservation [71,95]. During TaTME, visualization of the deep pelvis is improved, with unobstructed views of the presacral and perirectal planes [69,71,95]. Transanal dissection is facilitated by tissue distention by CO_2 and pneumodissection and tissue retraction can be performed effectively through the transanal platform [52,69,71,95]. TaTME facilitates dissection of the difficult distal part of the TME dissection in the narrow pelvis but also allows clear definition of safe, tumour-free, radial and longitudinal margins, and may be ideal in patients for whom a laparoscopic pelvic dissection may be difficult with the risk of inadequate oncological clearance [69,71,95]. In addition, the specimen can be exteriorized transanally with TaTME, whereas an abdominal incision is routinely required for specimen extraction with the LapTME technique [71,95].

Oncological quality of TaTME

The oncological quality of resection for TaTME is comparable to that of open and laparoscopic TME. In this systematic review, following TaTME the CRM was positive in 5% of cases and the DRM was positive in 0.3% of cases. The reported incidence of a positive CRM for open TME ranges from 1.3% to 18.1% [2–4,9–11,13,113,114] and for LapTME from 1.2% to 18.1% [2–4,9–11,13,113,114]. The reported positive DRM in the literature for open TME is 0% to 1.2% [2,3,114]

and for LapTME is 0% to 1.3% [2,3,114]. Furthermore, the studies included in this systematic review described the mesorectal excision as complete in 88% of cases, as nearly complete in 6% of cases and as incomplete in 6% of cases. In a study by Penninckx *et al.* [114] mesorectal excision was reported as incomplete in 11.4% of open TME cases and in 13.2% of LapTME cases, as nearly complete in 28% and 24.8% respectively, and as complete in 60.6% and 62%. Moreover, the mean number of harvested lymph nodes with TaTME ranged from to 33, which is comparable to the reported mean number of harvested lymph nodes during open TME (11–18 lymph nodes) and LapTME (5.5–17 lymph nodes) [2–4,9–12,114]. The possibility of publication bias in the results reported by the included studies, however, should be taken into consideration.

Peri-operative morbidity

The peri-operative morbidity rate of 35% for TaTME is comparable to that of 8.5–37% for open TME [13,113] and 6.0–40% for LapTME [13,113]. Included in the intra-operative morbidity were three cases of urethral injury [90,92], two of which were sutured transanally [90]. Urethral injury is a serious complication related specifically to TaTME and is uncommon during open TME, LapTME or robotic TME. During TaTME the prostate may be inadvertently pulled down into the plane of dissection resulting in a urethral injury. Reassuringly there were two cases (< 1%) of rectal perforation [39,108]. The rate of intra-operative rectal perforation reported by Penninckx *et al.* [114] was 9.4% for open TME and 6.2% for LapTME. Furthermore, with TaTME, there is an increase in the need for coloanal anastomosis with its associated morbidity. The ratio of hand-sewn coloanal to stapled anastomosis was 2:1. The most frequently reported postoperative complication of anastomotic leakage at 6.1% is comparable to the rates of 1.4–12% reported for open TME [2– 4,13,113,115] and of 1.2–10% reported for LapTME [2–4,9,13,113,115].

Urinary and sexual dysfunction

The other most common complication reported was urinary retention and transient urinary dysfunction of about 5%. Sylla *et al.* [95] performed urodynamic testing on their two cases of urinary dysfunction, which demonstrated evidence of minimal detrusor activity consistent with parasympathetic nerve injury. Postoperative urinary and sexual dysfunctions resulting from direct or indirect injury to the pelvic hypogastric or the sacral splanchnic nerves are recognized complications of rectal resection [116,117]. After laparoscopic or open TME, the reported incidence of urinary dysfunction is 0–26% and that of sexual dysfunction is 11–38% [116,118– 120]. TaTME provides improved pelvic visualization with enhanced anatomical definition, allowing more accurate dissection through the presacral plane between the mesorectal and pelvic fascia, which may result in sparing of the autonomic nerves during mesorectal dissection and therefore a lower incidence of urinary and sexual dysfunction [59,69]. With the mean operation time ranging from 143 to 450 min the effects of constant anal dilatation for a prolonged period are not known and, given the risks of urgency and incontinence associated with rectal resection, it is important to ensure that TaTME does not have an additive effect on damaging the sphincter muscles [71].

Comparative studies

There have been four studies [64,78,82,104] which have compared TaTME with LapTME. Two were published only as abstracts and none was a randomized controlled trial (RCT). Velthuis *et al.* [104] compared the pathological quality of specimens from patients who underwent TaTME with those obtained after traditional LapTME and found a statistically significant difference in the number of specimens with a complete mesorectum in 96% of the TaTME group and 72% of the LapTME group. No differences between the groups were seen in the length of specimen or the state of the CRM or DRM [104]. Fernandez-Hevia *et al.* [64] observed no significant difference in the 30-day postoperative complication rate between TaTME (32%) and LapTME (51%) (P = 0.16). In the same study, the TaTME group was found to have a significantly lower early hospital readmission rate and a significantly shorter operating time compared with the LapTME group [64]. In the TaTME group coloanal anastomosis was performed significantly more frequently and the DRM was significantly longer [64]. The comparative study by Marks *et al.* [82], published as an abstract, demonstrated no significant difference in the peri-operative or histopathological outcome compared with standard LapTME. The other comparative study published as an abstract by Lelong *et al.* [78] demonstrated a more favourable short-term outcome for TaTME than LapTME, including a lower conversion rate and a shorter hospital stay, with a comparable oncological quality of resection. The same study also reported the intermediate-term outcome at a median follow-up of 24 months, and showed comparable rates of local recurrence and overall survival between TaTME and LapTME [78].

Prerequisite skills and training

The oncological quality of resection and the peri-operative outcome of TaTME are related to the learning curve of the surgeon. TaTME can be technically difficult particularly for surgeons not used to performing transanal procedures. For these reasons, it should only be performed by a colorectal surgeon with expertise in advanced colorectal surgery, intersphincteric resections, laparoscopic and minimally invasive approaches, and advanced transanal platforms, such as TEM, TEO or TAMIS [52,69,71,95]. To date, formal training for transanal TME has not been established, and many surgeons strongly advocate procedural training on animals and/or human cadavers before attempting the procedure on patients [52,95]. Large case series on human cadavers have demonstrated a significant improvement in specimen length and operation time with increasing experience [32] and this may be the actual learning curve. Expertise in robotic surgery is also valuable, because robotic TaTME has the added advantages of a magnified view in three dimensions and high definition, as well as the seven degrees of freedom provided by the robotic wristed instruments [43].

Indications and standardization of technique

At present, there is no consensus between colorectal surgeons on the patient selection criteria for TaTME, including indications and contraindications for this procedure. Based on the findings of this review, TaTME would be suitable for patients requiring low anterior resection for low and mid rectal tumours. TaTME would also be more suitable in male patients with a narrow pelvis and in patients with a high BMI. Patients with a T4 tumour or one with a threatened CRM and with possible sphincter involvement should not be candidates for TaTME. Furthermore, the technique for TaTME has to be standardized to allow a safe and responsible introduction and general dissemination of the technique. Our group is planning to use a Delphi methodology to achieve a consensus of surgeons experienced in TaTME to make recommendations on the patient selection criteria and surgical technique for TaTME.

Limitations of the current review and future studies

Based on the information reported by the studies included in this systematic review, TaTME, with or without laparoscopic assistance, is a feasible and reproducible technique. Nevertheless, the results of the current review are limited by the nature of the included studies which are mostly case reports and case series. Only four comparative studies [64,78,82,104] were included in the analysis, and two of these were published as abstracts. No RCTs have been published to date. The oncological safety associated with TaTME needs to be validated, and future multicentre large sample RCTs are required to investigate further the perioperative, oncological and long-term outcome with respect to local recurrence and overall survival. Precise primary and secondary end-points to be investigated by an RCT have yet to be agreed. To ensure adequate numbers for evaluation of this new procedure, a UK registry has been set up to collect relevant and high quality data on TaTME [71], and these data should help further to determine the best primary and secondary end-points for an RCT. A study design by Lacy *et al.* [77] for a two-arm multicentre RCT comparing TaTME with LapTME suggested that oncological histopathological results (circumferential margin and mesorectal quality) and postoperative morbidity should be the primary outcome of the RCT, and time to first oral intake, length of hospital stay, postoperative pain and functional outcomes as the secondary outcomes.

TaTME is a new surgical technique with potential in the treatment of rectal cancer. This systematic review of the literature has shown that with or without laparoscopic assistance TaTME is feasible and reproducible. Negative circumferential and distal margins and quality of mesorectal excision are comparable to those achieved by current surgical techniques. Standardization of the technique is required with formal training. Multicentre RCTs with defined selection criteria and defined perioperative, pathological and long-term outcomes are required to evaluate the efficacy and safety of TaTME as a valid treatment for rectal cancer.

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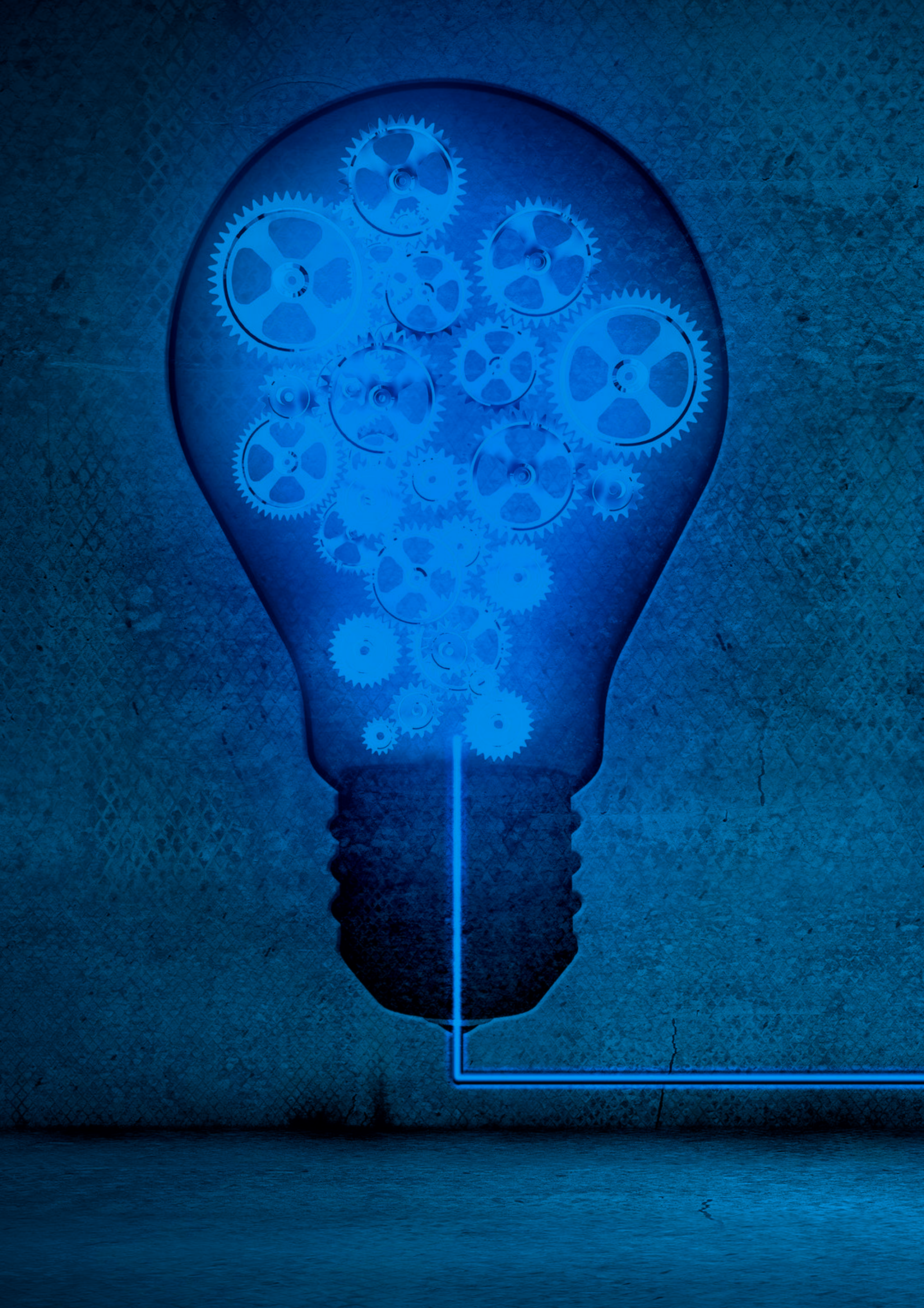
PART III
EXPLORATION



Chapter 11

Towards the safe introduction of transanal total mesorectal excision: the role of a clinical registry

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Colorectal Dis. 2014 Jul;16(7):498-501.

Background

In the past two decades there has been a clear trend in surgery towards minimal access and surgeons have embraced this evolution. Necessities of advanced, differing skill sets in combination with added procedural complexity can impede widespread adoption of specific minimally invasive approaches. In the UK, for instance, the current uptake of laparoscopic surgery for colon cancer is approximately 40% (Hospital Episode Statistics April–September 2012), while the uptake for rectal cancer is lagging behind owing to debate around technical limitations and oncological safety of laparoscopic low anterior resection. Indeed the challenges of treating rectal cancer are quite different from those for colon cancer particularly in the obese male patient. Here, difficulties in pelvic exposure and limitations of instrumentation can affect not only dissection but also the preservation of autonomic pelvic nerves and the difficulty in achieving a restorative procedure. Furthermore, challenges surrounding the use of laparoscopic staplers across the low rectum and the concept of avoiding multiple firings have resulted in some surgeons advocating the use of a Pfannenstiel incision with an open approach to crossstapling. This hybrid approach may remove some of the benefits of the laparoscopic approach, especially for ileoanal pouch surgery where the laparoscopic approach has been shown to improve fecundity in women [1].

Laparoscopic rectal resection

Various reports have shown that laparoscopic rectal resection is safe and decreases length of hospital stay and time of postoperative convalescence [2–4]. These shortterm benefits must not interfere with the main principle of achieving good cancer outcomes and reducing the risk of local recurrence. The long-term data from randomized controlled trials on laparoscopic rectal resection have not yet been reported and are eagerly awaited.

The CLASICC trial reported a conversion rate of 34% with 40% morbidity after laparoscopic rectal excision, and also demonstrated that circumferential resection margin (CRM) positivity was different between open and laparoscopic surgery [5]. Even in expert hands, conversion rates can still be around 16% and are significantly higher in male patients where a low anastomosis is attempted [6]. Recent data from the COLOR II trial (where surgical competence was assessed at entry into the trial) have revealed a similar conversion rate (16%), with the most common cause for conversion being a narrow pelvis seen in a quarter of patients [7]. This trial also demonstrated that adequate resection margins and good quality specimens can be achieved by skilled surgeons in selected patients. In the subgroup of patients with a low rectal cancer, the rate of positive CRM was lower in the laparoscopic group compared with the open surgery group (in contrast to the CLASICC trial), which may be attributed to increased surgeons' skills and improved visualization of the lower pelvis with the magnified image of the laparoscope. There is clearly still more room for improvement allowing for ease of dissection and reduced conversion rates while achieving good oncological outcomes.

The endoscopic transanal approach

In a recent editorial, Heald predicted that endoscopic transanal approaches to radical low rectal dissection would revolutionize our approach to the most difficult area of the 'holy plane' dissection, low down in the pelvis [8]. A variety of acronyms have been proposed for this type of surgery: transanal total mesorectal excision (TaTME), 'bottom-up' TME, 'down-to-up' TME, transanal minimal invasive surgery (TAMIS) TME. TaTME is a technique that allows the rectum to be mobilized transanally from distal to proximal using a variety of flexible or rigid transanal platforms. It not only facilitates radical dissection of the difficult distal part of the TME dissection in the narrow rigid pelvis but also allows clear definition of safe, tumour-free distal margin. TaTME is not a completely new concept and should be seen as a combination of ground-breaking surgical concepts: transanal endoscopic microsurgery (TEM) introduced by Buess, the concept of TME and the transabdominal transanal (TATA) approach described by Marks. More recently the introduction of TAMIS has fueled interest in the concept of TaTME.

Technique

Unlike pure natural orifice transluminal endoscopic surgery (NOTES), TaTME at the moment still requires abdominal assistance for splenic flexure and left colon mobilization and high ligation of the inferior mesenteric vessels. We prefer to complete the abdominal part of the procedure in a standard medial to lateral fashion and start the superior part of the rectal dissection according to TME principles. This allows for clear identification of both ureters and hypogastric nerve bundles before starting the perineal dissection. The most appropriate limit/extent of pelvic dissection is unknown, but in our opinion can be extended as far as exposure will allow without compromising mesorectal integrity. The abdominal phase can be completed in isolation but can also be performed synchronously, with the potential to reduce operative time. The transanal phase is started with confirmation of tumour location and identifying a safe distal margin. For tumours encroaching on the anorectal junction (< 1.5 cm), a partial intersphincteric open dissection is performed up to the level of the pelvic floor followed by luminal occlusion with a pursestring and subsequent placement of a transanal platform. In tumours with a distal margin of more than 1.5 cm from the anorectal junction, a circumferential rectal purse-string is placed, securing a safe distal margin. In most cases this can be done through the transanal platform, followed by washout and full-thickness rectotomy.

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In both approaches it is vital to secure a tight seal with the purse-string and ensure a generous tumouricidal wash to prevent implantation of exfoliated tumour cells. The end result after this initial step is a sealed specimen released from a defined distal segment. Next, with the transanal platform in place, a 'pneumopelvis' is created at an initial pressure of approximately 10 mmHg and standard laparoscopic instrumentation is used for dissection. We prefer to define the avascular presacral plane first, which is identified when insufflated gas enters the tissue planes between the parietal endopelvic fascia and mesorectal envelope. The mesorectum is mobilized, and dissection proceeds cephalad in accordance with TME principles and extended medially and laterally. Anteriorly a plane on either side of Denonvilliers' fascia can be chosen according to location of the tumour. The dissection is progressed cephalad until communication with the one from above. Specimen extraction can be through the transanal platform; however, this should be avoided in the case of a bulky mesorectum or tumour, when the preference should be to use a conventional abdominal extraction site and wound protector. Anastomosis to the lower end can be hand sewn or achieved by a double purse-string stapled approach. A video illustration (dissection and anastomosis) is provided in an online video vignette [9].

Results

Several authors have described the technique and small series have been published highlighting its safety and technical feasibility [10–13]. The three largest published series to date report a total of 70 patients [10,14,15]. de Lacy *et al.* and Atallah each reported 20 carefully selected patients and demonstrated that the technique is safe and seems to meet oncological requirements for high quality rectal cancer surgery [10,14]. Rouanet *et al.* [15] reported 30 male patients with advanced or recurrent rectal cancer with unfavourable anatomical and/or tumour characteristics. While acomplete mesorectal excision was achieved in all patients and an R0 resection in the majority (87%) of these challenging cases, four experienced loco-regional recurrence after a median follow-up of 21 months. The reported morbidity was 30% and two patients had a urethral injury at the start of their experience, suggesting that there is a clear learning curve and that patient selection is important early on. So far, given it is a concept in evolution and larger series are awaited, no objective benefits beyond technical ease of the procedure can currently be supported.

Evaluation

The principal issue that arises in evaluating a new procedure or technique is the long-term consequences of such procedures. While it is assumed that the procedure is only a technical variation of an established procedure the oncological and functional effects of this variation are not known. Prospective evaluation ofTEM has demonstrated some short-term functional deterioration which appears to resolve with time. The addition of rectal resection and anastomosis to this procedure is unknown. In the series published by de Lacy *et al.* [10] the average operating time was 235 min. The effects of constant anal dilatation for such a duration are not known and, in addition, the effect of the transanal device on the anal sphincters has not been evaluated. For example it is not clear if a flexible device such as the Gelpoint Path (Applied Medical, Inc., Rancho Santa Margarita, California, USA) would confer less trauma than a rigid metal device such as that used for TEM. Given the risk of urgency and incontinence associated with rectal resection it is important to ensure that this procedure does not have an additive effect.

Perhaps the technically most challenging part of the procedure is to perform a safe stapled anastomosis. de Lacy *et al.* [10] has described both a coloanal handsewn anastomosis and a stapled anastomosis using the circular stapler used to perform transanal stapled haemorrhoidopexy. The double purse-string technique for colorectal anastomosis allows an anastomosis to be performed without cross-stapling and proponents would argue that such an approach could potentially reduce the risk of anastomotic leak. In addition this approach has the added advantage of reducing the cost of the procedure if cross-stapling is not required. It is important that the safety and functionality of the anastomosis is evaluated in a prospective manner and it could be argued that as the operator is at the initial phases of the learning curve careful selection of cases will be required. Patients requiring proctectomy may be a good starting point as this would alleviate the need to perform an anastomosis.

A further benefit of the procedure is that in many situations the rectum can be extracted transanally. This has a significant advantage in potentially avoiding abdominal extraction incisions and should result in a reduced risk of incisional herniation. The technique can be considered to represent the natural evolution of minimal access colorectal surgery.

The learning curve associated with this procedure is also very important to determine. At this stage, the procedure is being carried out by a few experienced enthusiasts. As the potential benefits become more apparent TaTME may gain popularity with a resultant increase in the number of procedures performed. It is important that this should be carried out with the appropriate evaluation and clinical governance. The development of laparoscopic colorectal surgery throughout the UK has gone even further; the success of the National Training Programme in Laparoscopic Surgery (LAPCO) to train colorectal surgeons demonstrated an excellent model to develop the educational framework to ensure safe nationwide practice.

The TaTME registry

Prospective evaluation of this procedure requires national data collection to ensure adequate numbers for evaluation. Similar databases such as the National Ileoanal Pouch Registry have been successful in analysing volume and outcomes nationally, and have the advantage of ensuring that there is adequate governance surrounding the procedure. Through support of the Pelican Cancer Foundation, we have set up a registry to collect relevant and high quality data on transanal rectal resection surgery for benign and malignant pathology. The TaTME registry is a voluntary database with online access through the LOREC (Low Rectal Cancer Development Program) portal (http://www.lorec.nhs.uk). All members of the Association of Coloproctology of Great Britain and Ireland will be invited by email to subscribe to the registry, but its use is not limited to any society membership and free application is encouraged for any individual colorectal surgeon or surgical department that performs these procedures. Each participant will have access to his or her own departmental data set. Each data set consists of several sections including patient demographics, procedural/technical data and postoperative outcomes (early/late morbidity, readmissions, pathology and oncological follow-up). Data sets can be extracted easily for statistical analysis and an overview page is available for individual patients. We are currently working on a further module that will incorporate functional and quality of life data. We aim to provide continuous information through newsletters and announcements on the registry website. The registry will allow monitoring of the uptake of this technique within the surgical community and compile data on technique, oncological safety and functional outcomes. Essentially this should provide a safe and responsible introduction and drive/enable further research.

Conclusion

The TaTME procedure is an exciting innovation in colorectal surgery which has the potential to increase the number of patients who may benefit from laparoscopic/endoscopic rectal surgery. The technical feasibility of the procedure has been well described. Several issues such as anastomotic technique and adherence to oncological principles need further evaluation. A national registry will allow the collection of detailed data and will have the ability to report such outcomes as operation time, blood loss, conversion rates, local recurrence, pelvic nerve injury and function. This technique, if combined with other more minimally access techniques such as single port surgery or mini laparoscopy may have further benefits such as reduced pain and faster recovery. The long-term results will need ongoing evaluation and the registry should facilitate reporting on such data in the future. Until long-term oncological outcome data are available, we would advocate that these procedures should be performed under institutional protocol, with multidisciplinary team discussion by surgeons experienced in all aspects of minimal access surgery (advanced laparoscopy, transanal techniques) and comfortable with all types of ultra-low anastomoses. Contributing to the registry data set will allow audit and governance of outcomes in any institution wishing to expand into this exciting development of colorectal surgery.

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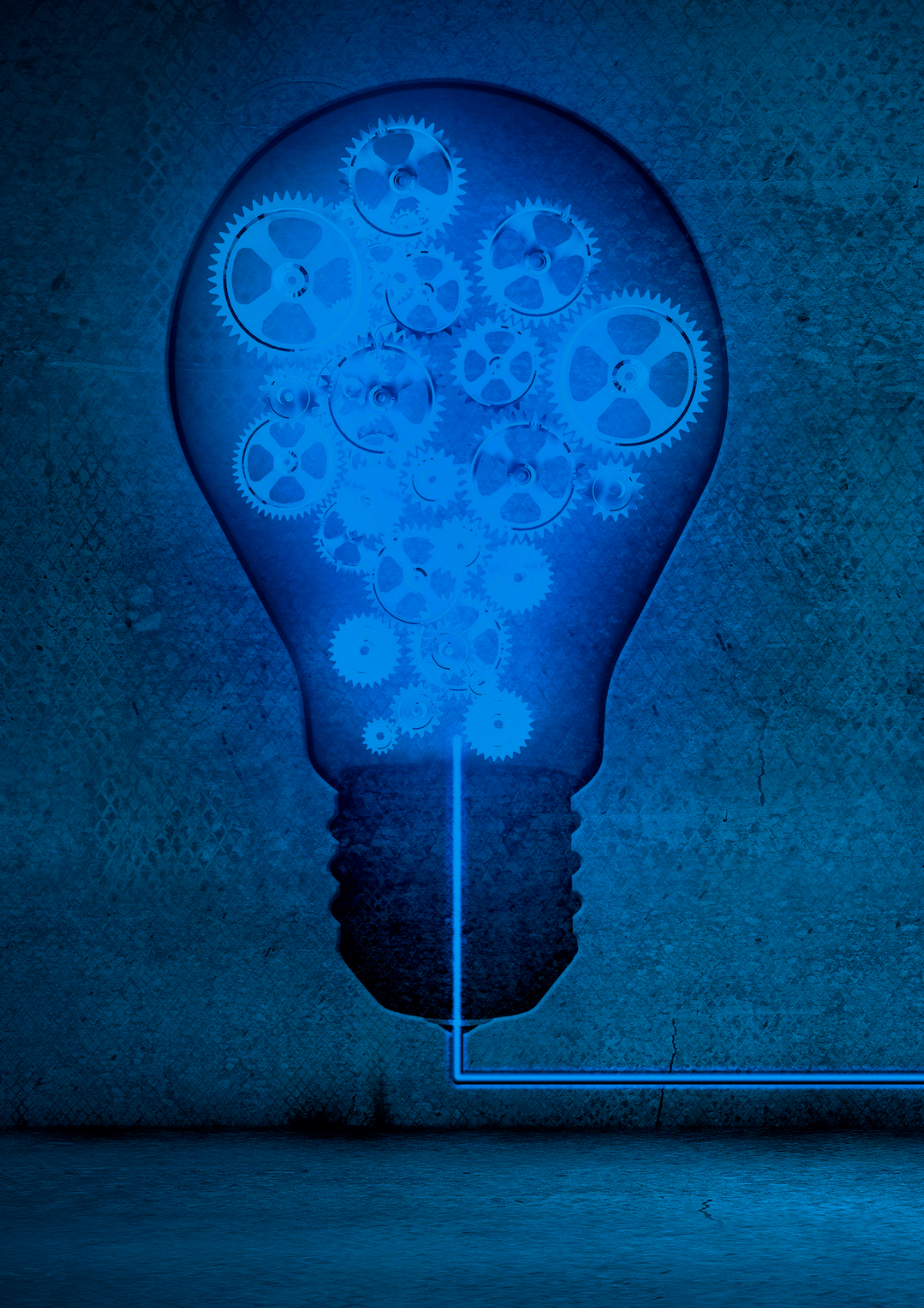

Chapter 12

Consensus on structured training curriculum for transanal total mesorectal excision (TaTME)

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F. Carter
R. Hompes

On behalf of the International TaTME Educational Collaborative Group.
Surg Endosc. 2017 Jul;31(7):2711-2719.

Abstract

Background

The interest and adoption of transanal total mesorectal excision (TaTME) is growing amongst the colorectal surgical community, but there is no clear guidance on the optimal training framework to ensure safe practice for this novel operation. The aim of this study was to establish a consensus on a detailed structured training curriculum for TaTME.

Methods

A consensus process to agree on the framework of the TaTME training curriculum was conducted, seeking views of 207 surgeons across 18 different countries, including 52 international experts in the field of TaTME. The process consisted of surveying potential learners of this technique, an international experts workshop and a final expert's consensus to draw an agreement on essential elements of the curriculum.

Results

Appropriate case selection was strongly recommended, and TaTME should be offered to patients with mid and low rectal cancers, but not proximal rectal cancers. Pre-requisites to learn TaTME should include completion of training and accreditation in laparoscopic colorectal surgery, with prior experience in transanal surgery. Ideally, two surgeons should undergo training together in centres with high volume for rectal cancer surgery. Mentorship and multidisciplinary training were the two most important aspects of the curriculum, which should also include online modules and simulated training for purse-string suturing. Mentors should have performed at least 20 TaTME cases and be experienced in laparoscopic training. Reviewing the specimens' quality, clinical outcome data and entering data into a registry were recommended. Assessment should be an integral part of the curriculum using Global Assessment Scales, as formative assessment to promote learning and competency assessment tool as summative assessment.

Conclusions

A detailed framework for a structured TaTME training curriculum has been proposed. It encompasses various training modalities and assessment, as well as having the potential to provide quality control and future research initiatives for this novel technique.

Introduction

Transanal total mesorectal excision (TaTME) is the latest advanced surgical technique for rectal mobilization that has captured the focus and attention of the colorectal surgical community. The adoption of TaTME has been growing rapidly worldwide and, although initially pioneered for rectal cancer [1], the procedure has also been adapted for benign disease [2, 3]. The first data analysis from the international TaTME registry and largest cohort to date was recently published, suggesting an oncologically safe and effective technique with acceptable short-term patient outcomes [3]. Surgeons, however, did experience intra-operative equipment and technical difficulties in approximately 40% of cases, including incorrect plane dissection, pelvic bleeding, unstable pneumopelvis with excessive smoke and visceral injuries. Technical challenges of the transanal approach have been acknowledged by expert surgeons and early adopters of this technique as partly due to the unfamiliar view and interpretation of the anatomy from below, with possible difficulty in identifying correct tissue planes. This is likely to have contributed to the early reports of visceral injuries which occurred during the perineal phase, of which five were urethral injuries reported in the registry data [3]; a complication rarely seen with traditional abdominal TME surgery.

These early reports have highlighted the importance of provision of optimal training prior to embarking on this technique, taking advantage of all the lessons learnt so far from the early adopters. Early adopters of the technique advocate proctorship early in the learning curve. Evidence from previous surgical training studies suggest that proctoring can shorten the learning curve, help to avoid long operative times, reduce conversions and most importantly, reduce major complications (i.e. urethral injury, rectal tube perforations, pelvic sidewall bleeding) [4–7]. Despite the perceived advantages of the mentorship, the registry data suggest that less than one-third of initial cases are actually mentored, suggesting a lack of a formal training pathway. In a recent survey of the Association of Coloproctology of Great Britain and Ireland (ACPGBI) consultant members, structured TaTME training was the top educational-need priority. However, there is no evidence of an established training pathway that can assist surgeons who wish to commence TaTME [8]. Training guidance is required to ensure safe adoption of this technique in patients who truly benefit from this approach. This should encompass not only the technical steps of the operation but case selection as there is a lack of clarity about the indications for this approach.

The aim of this study, therefore, was to establish a consensus on a detailed structure of the whole training curriculum for TaTME to support the safe introduction of a new surgical access technique to benefit selected patients with mid or distal rectal cancer.

Materials and Methods

A consensus process to agree on the framework of a TaTME training curriculum was conducted, seeking the views of 207 surgeons across 18 different countries worldwide including 52 international experts in the field of TaTME. The consensus process was conducted in three phases: (i) learners survey; (ii) expert workshop and (iii) final expert consensus.

TaTME potential learners

This phase aimed to seek the thoughts of colorectal surgeons as potential learners of this technique in order to identify the learning needs and potential gaps in training for this novel technique. It was also targeted to capture their views on the essential elements of the training curriculum. An initial survey was distributed by electronic mail [9] with a subsequent reminder to all colorectal consultant members (829) of the ACPGBI. The survey consisted of 21 questions which were formulated by the study steering group and reviewed by both medical and non-medical professionals to ensure clarity and avoid any biased or ambiguous phrases. The questionnaires included open-ended questions and a 3or 5-point Likert scale was preferentially used when appropriate in order to allow the individual to express how much they agree or disagree with a particular statement. Respondents also had the opportunity to share further thoughts and comments by free text.

TaTME training and assessment expert workshop

This first international consensus workshop on TaTME was conducted in Bristol (United Kingdom) on 12th October 2015 [10] and aimed to discuss the results of the learners' survey and draft the consensus statements for the final process. The workshop involved twelve expert surgeons from seven different countries with extensive experience in rectal and transanal surgery as well as education leads who attended the workshop and discussed the need for and structure of a TaTME training curriculum. The workshop proposed the consensus statements of the training framework for final voting by a wider group of international experts as the final stage of the process. During the Workshop, the Global Assessment Scale forms were developed and tested as a formative assessment tool [10]. In addition, it proposed the formation of the international TaTME educational collaborative group to help develop the TaTME training curriculum.

TaTME final expert consensus process

This final stage aimed to obtain consensus from a wider group of international experts on six main themes of the TaTME educational curriculum: (i) indications and case selection, (ii) development of TaTME service focusing on selection of units, the number of surgeons per unit and how many cases each unit should perform in order to maintain competency, (iii) learning and mentoring requirements, (iv) training centres requirements (v) key elements of training curriculum, (vi) assessment and data collection (registry). An online survey was designed using 'Survey monkey' [11] and sent to 78 international experts in the field of TaTME who were selected by peer recommendations as the innovators and early adopters of the TaTME technique. The international experts were presented with statements that were proposed at the consensus workshop and asked to indicate their level of agreement to a set of statements/questions based on a scale from 1 to 5 (1 = strongly disagree, 5 = strongly agree). The experts were also invited to make any additional suggestions on the proposed aims and objectives of the international TaTME educational collaborative drafted during the consensus workshop.

Data analysis and study steering group

The final results were tabulated and expressed as a percentage of the respondents, mean ± standard deviation or median with range. The final consensus results were presented with the level of experts' agreement required to obtain consensus. The project steering group consists of the national tutor for coloproctology in the UK (NF), the co-founder of the international TaTME registry (RH), educational experts (HM and FC) and a PhD research fellow (MP) on the subject of TaTME. NF and MP were in charge of designing the questionnaires; collating the results and drafting the manuscript with the help of HM, FC and RH. NF and RH oversaw the whole project.

Results

Learners' survey

148 colorectal surgeons (18% of the total consultant members) responded to the initial survey and were distributed across 16 different regions in Great Britain and Ireland. The median number of years' experience as independent practitioners in rectal surgery was 7 years (0.5–25) with 89% being independent in laparoscopic TME. Only 33% were independent in transanal surgery (TEMS or TAMIS) and 17 (11%) surgeons had some degree of TaTME experience.

Ninety-two surgeons (62%) felt that a TaTME service should not be offered in every unit and a minimum of 10–15 cases should be performed per year per unit in order to maintain competence. The majority of respondents (86%) believed that at least 20 cases of laparoscopic rectal resections should be performed independently prior to learning TaTME. Key components of a training curriculum were also explored. The learners group assigned clinical proctorship (90%) and MDT training (88%) as the two most important aspects that must be incorporated into a TaTME curriculum. Surprisingly, technical skills training on cadavers received the lowest level of importance proposed by the learners group. Comments were made regarding the limited availability of cadaver courses for TaTME at present, including the difficulties in organizing such a course and their associated high attendance fees.

TaTME training and assessment expert workshop

All statements from the learners survey were presented at the TaTME expert workshop [10]. Key components of a training curriculum were also explored and the final questionnaires proposed by the experts for the final consensus phase. In addition, the GAS forms to assess the performance of the operative technique in a proctored case were adapted for TaTME, agreed on by the experts and piloted at the workshop [10]. Finally, an international TaTME educational collaborative group was developed and the experts proposed the aims, objectives and remits for final voting.

Final consensus

Fifty-nine experts (76%) responded to the final consensus survey, representing 48 colorectal units in 18 different countries (Argentina, Australia, Austria, Belgium, Brazil, England, France, Germany, Italy, Korea, Netherlands, New Zealand, Norway, Russia, Scotland, Spain, Switzerland, USA), including 24 professors of surgery/heads of department and 35 consultant surgeons. Fifty-two of these respondents are amongst the group of international surgeons with the most experience in TaTME, whilst the remaining seven are colorectal surgeons with expertise in education and advanced rectal surgery. The median years of experience was 10 (1–30) as independent practitioners in rectal surgery. 90% of them were independent in laparoscopic TME and 93% in transanal surgery. The median number of TaTME performed by the experts was 25 cases (10–250).

Indication for TaTME

There was a clear positive majority verdict that TaTME should be offered to both male and female patients (86% agreement) with mid and low rectal cancers (78% agreement). There was no agreement that TaTME should be restricted to only cancer patients, or patients with a raised body mass index, (BMI); only low rectal cancers; or only offered to male patients.

Experts commented that TaTME should be viewed as a “tool” that can be used to assist the surgeon in obtaining better quality of surgery represented by the best specimen under the circumstances available. The experts proposed that attempting more difficult cases (bulky low tumours) should only be considered once a surgeon has become more experienced with the technique.

TaTME service development

The majority of the experts (69%) agreed that TaTME should not be offered by every colorectal unit, but rather, the operation should be centralized to specialist centres with a high volume of rectal cancer cases of a minimum of 20 cases per year. Furthermore, 21 respondents (36%) stated that only well-trained, experienced surgeons with a dedicated team and infrastructure in place should take on this advanced surgical approach.

There was no real agreement on the number of cases per year which is required to maintain competency, but 52% of the experts quoted at least 20 cases per year (median 20 cases, range 5–60). The majority of surgeons (88%) agreed that ideally two surgeons per unit should be trained to perform TaTME.

TaTME learning and mentoring

A positive majority verdict was reached that the top two pre-requisites to learning TaTME were completion of training and accreditation in laparoscopic colorectal surgery and a minimum number of laparoscopic rectal cases performed independently, 97 and 95%, respectively (Fig. 1). The majority of the experts agreed (68%) that the number of laparoscopic rectal cases to be performed independently should be at least 30 cases (range 10–100). Comments from the experts suggested demonstration of surgical outcomes after laparoscopic rectal cancer surgery was preferred rather than solely counting cases performed, in particular with regards to the ultralow anterior resections. The vast majority of the expert group (92%), pro-posed a minimum of 5 TEMS and TAMIS cases prior to attempting TaTME.

The experts gave majority verdict for the top three desirable pre-requisites of an educational mentor or trainer for TaTME: (i) at least 30 TaTME cases performed independently, (ii) provision of training courses for the operation, and (iii) at least 5 years in the surgical specialty (Fig. 1). Most respondents (72%) recommended that each mentor should aim for at least 2 (0-10) papers per year in this field as academic output.

TaTME Training Centre

Availability of dry lab equipment, especially for pursestring practice, and running at least two workshops per year were deemed essential criteria to define a training centre in TaTME (68 and 69%, respectively) (Fig. 1). The majority of experts (76%) also felt that the most important and useful resource that a training centre should provide are cadaveric models.

Key elements of TaTME training curriculum

The expert group of respondents assigned with a positive majority verdict for clinical proctorship and multidisciplinary team (MDT) training as the most important components of a TaTME training curriculum (90 and 81%, respectively). The group also gave a majority positive verdict for training on indication and case selection (81%), technical skills training on cadavers and immersion courses (78%), and technical skills training on physical models (74%) as other important aspects of the training curriculum. The proposed structure of the TaTME training curriculum is outlined in Fig. 2.

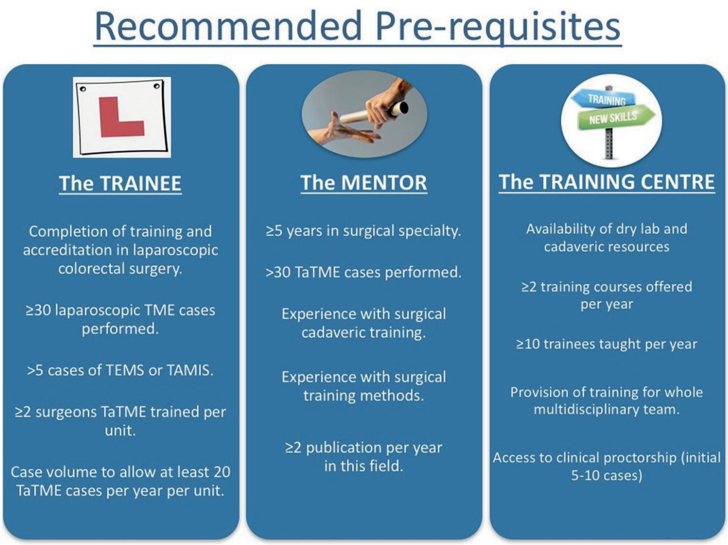

Fig. 1. Essential pre-requisites to learning transanal total mesorectal excision (TaTME), being a TaTME mentor and running a TaTME training centre

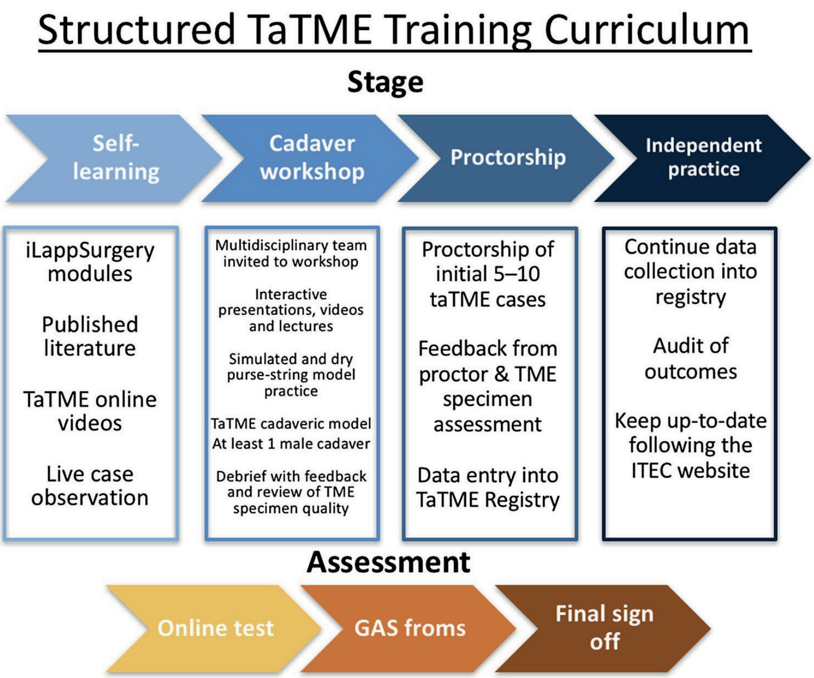

Fig. 2. Transanal total mesorectal excision (TaTME) structured training curriculum. TaTME transanal total mesorectal excision, ITEC International TaTME Educational Collaborative, GAS Global Assessment Score

Table 1. Objectives for the International TaTME Educational Collaborative

Aims and objectives
1) To develop consensus statements and recommendations aiming to enhance training and safe practice in TaTME
2) To propose a research agenda and establish evidence-based practice by conducting robust research in this field
3)To establish an international collaborative group led by surgeons with expertise in TaTME and education with local representation from each country
4) To establish a training curriculum for TaTME using validated teaching methods and developing assessment tools
5)To develop and maintain effective shared platforms of communication between the TaTME stakeholders with a web-based forum containing the training curriculum, published literature, educational materials, interactive forum and link to the registry
6)To promote networking with relevant industry in order to facilitate the accessibility of training resources to surgeons undergoing training in TaTME

Table 2. Recommendations on training and safe implementation of transanal total mesorectal excision (TaTME)

Recommendation	Level of agreement (%) 59 surgeons
TaTME must be adopted in a safe and sustainable manner	98
All transanal cases should be registered on the TaTME registry	91
Previous experience in laparoscopic or robotic rectal surgery, with a minimum volume of 20 cases per unit per annum is essential prior to learning TaTME	86
Dual consultant/specialist operating is recommended during the initial learning curve of the operation A	84
competency-based modular training is recommended which entails:	‘82
Online modules with web-based educational materials	
Dry lab workshop	
Cadaveric course	
Proctorship programme	
The minimum annual volume of TaTME cases per unit should be 10	74
TaTME can be considered for any patient requiring a full TME (total mesorectal excision)	68

TaTME assessment and data collection

A majority positive verdict felt that the two most important methods to assess competency in TaTME include reviewing the pathological quality of the resected TME specimens, and analysis of clinical outcome data including complications, mortality and oncological results, 97 and 91%, respectively (Fig. 2). Approximately 70% selected review of registry data, although comments were made that a central registry may be prone to selective data submission and hence reporting bias. Observation of unedited operative videos, either live or retrospectively, was deemed important by 55% of surgeons, whilst individual e-logbook assessment was considered the least efficient method.

Formative assessment

GAS forms were recommended by the experts to be used to monitor trainees’ progress and highlight areas that require more focused attention and practice during the initial cadaveric training and subsequent mentored live cases (Online Appendix 1).

Summative assessment and accreditation

Assessment of operative competency can be achieved using objective assessment tools. The majority of the experts (66%) felt that between 1 and 10 mentored cases should be sufficient to achieve safe independent TaTME practice.

Data entering and TaTME registry

Amongst expert surgeons who are performing TaTME, 80% are recording their cases on the TaTME registry [12]. The majority (80%) of surgeons recording cases on the TaTME registry commented that the database is useful, easy to use and takes no longer than 5 min once used to the system. A few responders (10%) find the registry too complex and time consuming, especially since "time to enter data is at a premium".

Formation of 'International TaTME Educational Collaborative'

The 'International TaTME Educational Collaborative' (ITEC) was selected by the experts as the name for the group of experienced surgeons forming the advisory committee (Online Appendix 2). There was a final con-sensus on the mission of the collaborative is "to promote the safe introduction of TaTME by driving the educational standard of the procedure through professional communications with relevant societies and collaborating with a wider international representation and stakeholders". Shared platforms of communication to build and maintain links amongst expert surgeons and educationalists in TaTME will also be created.

The agreed objectives and recommendations of the international collaborative group are outlined in the order of importance in Tables 1 and 2, and Fig. 1.

Discussion

Transanal total mesorectal excision is a novel access technique which has attracted substantial interest amongst colorectal surgeons throughout the world due to the perceived benefits for both shortand long-term outcomes in patients with rectal cancer. The introduction and adoption of this procedure, however, should be carefully planned, and surgeons need to be trained and confident to optimize patient outcomes. The essential elements of the training curriculum for this novel technique, although important and needed, have not yet been defined. Since there is currently no evidence of an established training pathway that can assist surgeons who wish to commence TaTME, it was important to obtain a consensus from all relevant stakeholders including, early adaptors, innovative and the potential learners of this technique to guide training of this technique.

To our knowledge, this is the first project to provide a cohesive and agreed training curriculum that can guide learners on all aspects of TaTME training. The proposed curriculum encompasses clear guidance on case selection, different methods of teaching that include online modules, dry lab purse-string simulators, cadaveric training and clinical proctoring as well as assessment and data collection.

This project has achieved its aim in outlining the important and key items of the training curriculum and education in TaTME. Although the practical steps of TaTME have been generally standardized by surgeons around the world, there is a lack of clarity about the indications for this approach. A consensus was achieved on the indications for TaTME, specifically for patients (both male and female) with mid and low rectal cancer. One could argue that female patients could be competently and safely treated using a conventional laparoscopic TME approach. However, the experts felt that the level of experience of the surgeon will also influence patient selection, as more 'straightforward' cases (female with higher tumour) are more likely to be selected at the start of the surgeon's learning curve. Interestingly BMI was felt to be less important than other parameters such as girth size, amount of visceral fat and waist-to-hip ratio.

Optimal prior training in laparoscopic and rectal surgery was proposed as a pre-requisite for TaTME training. This agrees with the UK National Institute for Health and Care Excellence guidelines, which recommend "TaTME should only be done by surgeons who are experienced in laparoscopic and transanal rectal resection and who have had specific training in this procedure" [13]. NICE guidelines also encourage clinicians to enter all patients undergoing TaTME onto the clinical registry, which was reported to be easy to use and provides the surgeon a complete record of patient cases and individual hospital outcomes.

Technical skills training was deemed to be essential to learn TaTME by the experts. In TaTME, there are several technical challenges such as the unfamiliar view and interpretation of the anatomy from below, with possible difficulty in identifying correct tissue plans. In addition, operating through a single port requires advanced level of technical skills and the availability of up-to-date imaging and insufflation equipment.

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Due to the complex anatomy of the human pelvis, human cadavers are the best training models available to practice the full operation, since simulated reconstructions at present are unable to capture all the intricate detail required [14].

In a recent study evaluating TaTME in the UK and the USA [15], those authors reported that the key lessons learnt by running the TaTME cadaveric workshops were the importance of team training with two surgeons together with their scrub team, the preferential use of male cadavers and immediate expert feedback and assessment of TME quality. They also found that simulated pursestring practice prior to the cadaveric procedure resulted in a more secure rectal closure with fewer leakages. In addition, Aigner et al. have recently stressed the importance of simulated cadaveric training on the identification of proper dissection tissue planes, particularly with anterior dissection around the prostate to avoid urethra injury [16].

These findings are in line with our proposed multimodal training in the curriculum for TaTME, as each component has a unique purpose and enables different skills to be accomplished. Cadaveric training was proposed by the expert group in our study as an essential pre-requisite to clinical training. The importance of MDT training also along with post-course mentorship were considered the most important aspects of the training curriculum for TaTME.

The proposed elements of the training curriculum for TaTME in this study are mostly in agreement with McLemore's six key elements [17], who found expertize in TME surgery, laparoscopic and/or robotic surgery, transanal approaches and intersphincteric dissection to be essential components. They also recommend training on human cadaver models as well as data collection of clinical outcomes.

Our study, however, has gone one step further to quantify each factor, such as the number of previous laparoscopic TME cases, in order to provide even more detailed guidance. However, experts commented that the number of cases would depend on the previous surgical experience of the trainee and this needs to be evaluated on a case-by-case basis.

Furthermore, the importance of clinical proctorship was highlighted in our study as a key component of the training curriculum and is estimated to be required for at least the first five cases. Knowledge of key operative steps is not enough to avoid intra-operative complications. Identifying errors and knowing how to 'rescue' the situation before harm occurs is an essential role of the proctor. It is not uncommon to enter into the wrong dissection plane in TaTME, but an experienced surgeon would be able to recognize the error at an early stage and safely find the correct plane again, whereas inexperienced surgeon without proctorship is more likely to lead to complications. Aided by the GAS scores, the mentor and trainee will discuss when the time has come for the trainee (likely to vary between surgeons) to perform an independent TaTME case without the presence of the proctor, and retrospective review of the unedited video capture. New technology that allows remote mentoring is currently being developed and will be potentially a useful adjunct for both proctoring and general teaching [18].

We feel that a traditional Delphi approach to reach consensus was not appropriate for this project, given the novel nature of the technique and the complexity of developing the service within the current challenges in health care service. The consensus process in this project, therefore took a trainees' centred approach. This study commenced with "training need analysis" by surveying the learners and building from their views the consensus statements to develop themes that were then discussed by a group of experts at the workshop prior to the final consensus process by a wider group of international experts in TaTME. A limitation of this study was the response rate of 18% in the initial survey (the learners) which may limit the generalisability of learners' views. TaTME, however, is a novel technique, and it is anticipated that not all colorectal consultants would be interested in training for this novel technique, and hence responding to this survey. We feel that the 148 responders may represent the potential learners of this technique in the UK. The response of the experts nevertheless was much higher (76%), which shaped the final statements and training framework.

Certain aspects of the outcome of this project have already started to be put into action. A structured training programme based on the agreed framework of the training curriculum has been proposed and agreed on by the ACPGBI to run a pilot TaTME pilot training programme in the UK in the near future. In addition, an interactive online website for the International TaTME Educational Collaborative (http://www.tatme.com) was launched at the European Association for Endoscopic Surgery congress in June 2016 [19]. The site provides excellent educational material with animated videos as well as published literature and access to the TaTME registry [12]. The iLappSurgery Foundation has also designed a superb App to deliver extensive educational modules in a clear modern and user-friendly way [20]. Live congress talks and TaTME operations can be viewed via the Advances In Surgery (AIS) channel which also offers further educational material and courses [21]. These online platforms have created a shared platform for communication amongst colorectal surgeons worldwide and stimulated collaboration and support.

In conclusion, a detailed framework for a structured TaTME training curriculum that promotes a competent performance has been proposed to ensure that the introduction of a new technique occurs in a safe and controlled manner to protect both the patient and the surgeon. The framework encompasses various training modalities and assessment, as well as having the potential to provide quality control and future research initiatives for this novel technique.

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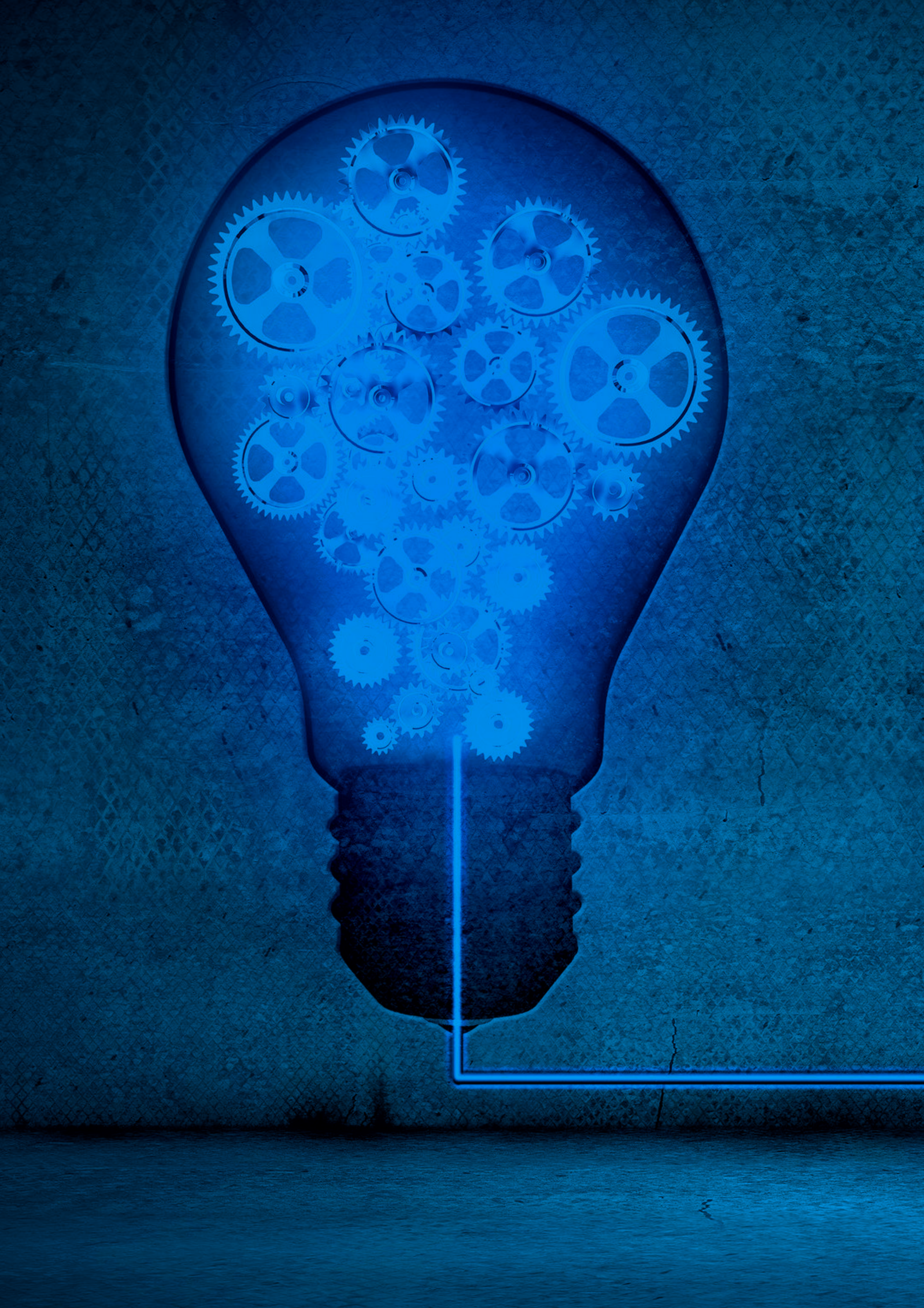

Chapter 13

St.Gallen consensus on safe implementation of transanal total mesorectal excision

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Surg Endosc. 2018 Mar;32(3):1091-1103.

Abstract

Background

The management of rectal cancer has evolved over the years, including the recent rise of Transanal Total Mesorectal Excision (TaTME). TaTME addresses the limitations created by the bony confines of the pelvis, bulky tumours, and fatty mesorectum, particularly for low rectal cancers. However, guidance is required to ensure safe implementation and to avoid the pitfalls and potential major morbidity encountered by the early adopters of TaTME. We report a broad international consensus statement, which provides a basis for optimal clinical practice.

Methods

Forty international experts were invited to participate based on clinical and academic achievements. The consensus statements were developed using Delphi methodology incorporating three successive rounds. Consensus was defined as agreement by 80% or more of the experts.

Results

A total of 37 colorectal surgeons from 20 countries and 5 continents (Europe, Asia, North and South America, Australasia) contributed to the consensus. Participation to the iterative Delphi rounds was 100%. An expert radiologist, pathologist, and medical oncologist provided recommendations to maximize relevance to current practice. Consensus was obtained on all seven different chapters: patient selection and surgical indication, perioperative management, patient positioning and operating room set up, surgical technique, devices and instruments, pelvic anatomy, TaTME training, and outcomes analysis.

Conclusions

This multidisciplinary consensus statement achieved more than 80% approval and can thus be graded as strong recommendation, yet acknowledging the current lack of high level evidence. It provides the best possible guidance for safe implementation and practice of Transanal Total Mesorectal Excision.

Introduction

The management of rectal cancer has evolved over the years with several options available to physicians taking care of cancer patients, including refined neoadjuvant and adjuvant therapies and various surgical techniques. Among the newly developed surgical approaches to rectal cancer, transanal total mesorectal excision (TaTME) proposes to address the anatomical limitations of the bony confines of the pelvis, bulky tumours, and fatty mesorectum through a new approach. Indeed, while taking advantage of the magnification of a laparoscope, performing a total mesorectal excision through the anus may confer a number of benefits. In particular a different viewpoint with a facilitated excision of the lower third of the mesorectum, better visualization of the endangered structures during dissection, and potentially a safer anastomosis by avoiding the multiple stapler firings too often required in a conventional complete anterior approach. Following the first live case in 2009 and inspiring experience of the pioneers [1, 2], dissemination of TaTME is taking place swiftly with many institutions having adopted this technique and published encouraging results. A large, international registry documents the adoption and practice of TaTME, with more than 2500 procedures from 39 different countries and 128 active centres recorded so far [3]. Furthermore, two international randomised controlled trials from the COLOR [4] and GRECCAR [5] investigators have recently started, randomising patients between TaTME and conventional laparoscopic TME. COLOR III [4] and GRECCAR 11 [5] are expected to help define the place and true value of TaTME in the surgical armamentarium for mid and low rectal cancer. Meanwhile, guidance is required to ensure safe implementation of TaTME, avoiding the pitfalls and intra-operative complications encountered and overcome by the pioneers and early adopters of this promising technique. The objectives of this international and interdisciplinary consensus statement are three-fold:

1. to provide a framework and guidance to those embarking on TaTME, including patient selection and surgical indication, technique, and educational opportunities;
2. to highlight the challenges, benefits, and distinctive dangers of this technique, capitalizing on a large international experience of early adopters of TaTME;
3. to promote prospective outcomes analysis and participation into clinical trials and registries.

Hence, it is hoped that the present international consensus guidelines will provide a basis for optimal clinical practice.

Materials and Methods

Sponsor and potential conflict of interest

The consensus was sponsored by the European Colorectal Congress of St.Gallen, Switzerland (http://www.colorectalsurgery.eu), which covered all costs associated with the entire consensus process with no support or involvement from the medical industry. The European Colorectal Congress is organizing one of the three largest colorectal congresses worldwide with an attendance of over 1400 participants from 80 countries (2016). It has no corporate sponsor, no member of the medical industry on its Board, and it does not own stock or participation to any medical company.

The four core authors of the consensus ensured scientific integrity. They completed the International Committee of Medical Journal Editors (http://www.icmje.org) form for disclosure of potential conflict of interest, reporting nothing to disclose. They were not paid for their time and efforts. The single benefit granted to the 40 consensus experts beyond collaborative authorship was not having to pay to attend the European Colorectal Congress in 2016.

Importantly, all statements referring to devices and instruments used to perform TaTME have been generated by the four core authors, in agreement with the current literature and routine practice of most experts. Referring to a given product and its alternatives does not imply endorsement of any manufacturer, it does solely provide the technical guidance based on the experience of a large group of international experts that may be expected by readers of the consensus.

Consensus Development

The consensus process was based on current recommendations for guideline developments adapted to the question at hand [6]. The core authors of the consensus drafted its agenda and formulated the initial questions with a focus on current practice, areas of controversy, and educational perspective. They identified and invited a group of international experts based on their clinical and academic achievements in the field of rectal cancer surgery and TaTME. Experts had performed at least 20 TaTME cases and reported their results in peer-reviewed publications and registries. They were major contributors to the international Low Rectal Cancer taTME registry (http://www.lorec.nhs.uk) having reported together more than 1000 TaTME procedures. An expert pathologist, radiologist, and medical oncologist were invited to participate to ensure the highest standard of care from a multidisciplinary team in the recommendations of the consensus.

The consensus statements were developed using a Delphi methodology [7] incorporating three successive rounds. The first two consecutive rounds were web-based with anonymous voting, and explicitly asked for feedback and suggestions from the international experts. The comments recorded were included into the iterative development of the consensus statements.

The third round was a dedicated expert meeting during the European Colorectal Congress in St.Gallen on November 30th, 2016 with face-to-face open discussion and finalisation of the consensus document. Consensus was defined as agreement by 80% or more of the experts. The final manuscript was then drafted by the four convenors of the consensus with only minor editing of the consensus statements if required. The discussion further developed practical advice, including perspectives from the expert radiologist and oncologist. The final consensus document was reviewed and approved by all involved experts.

Regarding the paucity of clinical data published on TaTME, no formal grading of evidence was provided. The authors of most major cohort series on TaTME were experts of the present consensus. Recommendation strength of the consensus statements was graded according to the Grading of Recommendations, Assessment, Development and Evaluation system (GRADE) [6]. Unresolved controversies and discussion points complete each section of the consensus. An update of the present consensus and systematic review of the literature is planned within three years by the core authors.

Results

Forty international experts were invited to participate in the consensus process. Two experts delegated participation to another senior staff surgeon who fulfilled the expertise criteria defined. A total of 37 colorectal surgeons from 20 countries in 5 continents (Europe, Asia, North and South America, Australasia) contributed to the work. The percentage reported in the consensus statements refers to those 37 (100%) expert colorectal surgeons. Participation to the first 2 web-based Delphi rounds was 100%, while 30 of 37 (81.1%) colorectal surgeons attended the third round live. The remaining 7 experts who could not attend the third round in person, televoted on the revised statements, achieving 100% participation to the third round. The consensus panel included three additional experts from the fields of clinical histopathology, radiology, and medical oncology. All 40 experts approved the final version of the manuscript.

Consensus statements

Patient Selection and surgical indications

Both genders can be operated on by a transanal approach. The female pelvis tends to be broader and therefore allows for an easier mesorectal excision. Obesity, especially visceral obesity with a fatty mesorectum, is an important limitation. Lastly, bulky mid/distal rectal tumours are very challenging, in both female and male patients. Hence, a TaTME may be technically easier than an abdominal TME in patients with a narrow pelvis, obese patients, and patients bearing a bulky mid/distal rectal tumour.

37/37 = 100%

In males, the prostatic urethra is at risk during the dissection of the lower third of the rectum. Injury to the prostatic urethra, especially when the pelvis has been irradiated, is a major complication.

37/37 = 100%

In females, the vagina is at risk of injury during the dissection of the lower third of the rectum. This lesion can be directly repaired with simple sutures, even in an irradiated pelvis. Caution must be taken when fashioning the anastomosis to avoid the dreaded complication of a neorectovaginal fistula.

37/37 = 100%

Prior pelvic surgeries make any total mesorectal excision more difficult, irrespective of the abdominal or transanal approach. Operating on patients with a prior prostatectomy, especially for an anterior rectal cancer with close circumferential resection margin (CRM), can be challenging. Prior mesh rectopexy may also pose greater surgical challenges. A prior hysterectomy is usually not a limitation.

34/37 = 91.9%

No further gender limitation/preference were felt relevant. 37/37 = 100%

There are no given body mass index (BMI) or limitation in BMI which make TaTME much better than open/laparoscopic/robotic TME.

37/37 = 100%

There is no given hip-waist ratio which makes TaTME much better than open/laparoscopic/robotic TME.

37/37 = 100%

Rectal cancer height

Transanal total mesorectal excision is best for lower rectal resections. It can be performed for partial mesorectal excision, e.g. for a cancer of the upper third of the rectum, although the need for an endoscopic purse-string placement on the long rectal stump increases the technical challenges. Caution should be taken not to perform unnecessary total mesorectal excision. The minimum distal margin of 1 cm applies to lower third cancers, whereas upper and middle third cancers require a distal margin of 5 cm. A partial mesorectal excision can be safely performed for cancer of the upper third of the rectum, whereas a total mesorectal excision is required for cancer of the mid and lower third.

32/37 = 86.5%

When an abdominoperineal excision is indicated, a "transperineal TaTME approach" may be undertaken once the surgeon has sufficient expertise in TaTME.

32/37 = 86.5%

Potential benefits of a "transperineal TaTME approach" include tailoring the dissection to the oncologic needs and avoiding the need to flip the patient in prone position in order to obtain an accurate view of the anterior plane.

34/37 = 91.9%

An intersphincteric TaTME can also be performed, thereby preserving some of the sphincter function. The known benefits of TaTME then apply, particularly better visualization of the lower two-thirds of the rectum when dissecting upwards. An intersphincteric TaTME requires, however, a coloanal or colo-pouch-anal handsewn anastomosis and the corresponding surgical expertise. Furthermore, the anterior dissection can be very difficult in an intersphincteric resection placing the urethra at risk.

37/37 = 100%

Surgical indications beyond rectal cancer

Beyond the classical surgical indication for neoplastic disease, TaTME can be performed in the context of inflammatory bowel disease. A proctectomy alone or a proctocolectomy can be performed, with or without ileal pouch anal anastomosis. For benign diseases, especially when a pouch reconstruction is considered, dissection of the rectum close to the bowel wall is an option that offers better function.

36/37 = 97.3%

Pouch advancement procedures, the dissection/removal of a neorectum in cases of chronic anastomotic sinus/anastomotic leak, and proctectomy for rectovaginal fistula are advanced procedures which can be performed transanally if appropriate technical and surgical expertise is available. The underlying disease, local inflammation, and dissection through scar tissue and obscured planes may be challenging.

37/37 = 100%

Perioperative management

Enhanced recovery

The recommendations for the perioperative management of TaTME patients follow the principles of enhanced recovery pathways (ERAS). The ERAS society has published in 2013 its guidelines for perioperative care in elective rectal/pelvic surgery [8], which the present group of experts endorses and recommends for the safe practice of TaTME.

36/37 = 97.3%

Mechanical bowel preparation

Full mechanical bowel preparation in all patients in whom a total mesorectal excision is planned is recommended, irrespective of the use of a diverting ostomy [9, 10].

33/37 = 89.2%

Pelvic drain

Evidence is scarce to use a routine pelvic drain after TaTME. Its use depends mainly on the surgeon's preference.

34/37 = 91.9%

Urinary catheter

A urinary catheter can be removed safely on the first postoperative day with low catheter reinsertion rates, including in elderly males. Epidural analgesia does not prevent early catheter removal. A suprapubic catheter is a good option whenever prolonged postoperative urinary drainage is anticipated.

30/37 = 81.1%

Perioperative antibiotic prophylaxis

Perioperative antibiotic prophylaxis and its repetition during the operation are mandatory and follow institutional guidelines. There is no evidence to support an extended perioperative antibiotic prophylaxis beyond 24 h.

37/37 = 100%

Patient positioning and operative room set-up

Patient preparation

The standard set-up may vary. However, a lithotomy position (or modified Lloyds-Davies position) is mandatory to allow a good position and exposition for the abdominal and perineal teams.

37/37 = 100%

Insertion of a urinary catheter, particularly in males, is advised. It may help to achieve a safer anterior dissection. In addition, by withdrawing the transanal platform, it allows palpation of the prostatic urethra in case of doubt.

34/37 = 91.9%

A generous rectal washout is advised after completing the pursestring and before starting the transanal dissection.

30/37 = 81.1%

One versus two team approaches

A one or two-team procedure can be performed and both have their advantages and disadvantages [11]. The two-team approach is costlier, at least in terms of personnel (two surgical and scrub teams). However, it should save at least 30 min of operative time and in case of difficult dissection it allows a better visualization and the two operating surgeons can help each other.

33/37 = 89.2%

The consensus panel advises to operate with two teams simultaneously whenever possible. Yet, a single operating team switching between abdominal and transanal approaches can also be very effective.

37/37 = 100%

On the other hand, a two-team approach requires a good collaboration between the abdominal and perineal teams. An integrated operative theatre should be advised to assure a good view of the screens. Space around the patient may be, however, an issue when two complete operative teams work synchronously.

30/37 = 81.1%

For a one-team approach, the benefits of starting the TaTME abdominally include exclusion of a peritoneal carcinomatosis, early splenic flexure mobilization and vascular control, and easier identification of the left ureter and autonomic nerves at the promontory level. In addition, the risk of massive distension of the colon (due to insufficiency of the rectal purse-string) is reduced.

32/37 = 86.5%

In a one-team approach, initiating the pelvic dissection from above does not seem to limit the extent and quality of the pneumopelvis.

35/37 =94.6%

When starting the TaTME transanally, a crucial point in the operation is swiftly securing an air-tight purse-string. This avoids stool contamination, cancer cell spillage, and bowel dilatation.

37/37 =100%

Starting the TaTME transanally allows for an exact transection point of the rectum assuring correct assessment of the distal margin.

32/37 =86.5%

Devices and instruments

Scope

A 10 mm high definition scope is preferred as it offers a broader visual field. For the transanal dissection, a 30° scope is recommended. A 3D system allows superior depth visualization; however, it is routinely used only in a few centres as there is a lack of data on reported clinical benefits.

32/37 = 86.5%

For the abdominal part, a 5 mm or a 10 mm scope may be used. Ten millimetres scopes offer a broader and brighter view.

37/37 = 100%

Transanal access platforms

A stable transanal access platform is required to ensure a pneumorectum and insertion of three ports. Most experts use a GelPOINT Path access platform (Applied Medical, Rancho Santa Margarita, CA, USA) inserted transanally [12]. Many alternative platforms from major suppliers exist (DalimSurgNet, Ethicon, Medtronic, Olympus, Storz, Wolff, etc).

34/37 = 91.9%

When performing an abdominoperineal excision, a transanal access platform is inserted when the dissection reaches the depth of the levator ani.

32/37 = 91.1%

Alternative platforms may be used depending on the surgeon's preference. The expert panel has limited experience with alternative platforms, and hence specific recommendation on these cannot be made (e.g. some experts supported TEO Storz (59.5%, Tuttlingen, Germany), TEM Wolff (40.5%, Knittlingen, Germany), Octo-Port (21.6%, DalimSurgNet, Seoul, Korea), etc).

Anal retraction sutures or an anal retractor system (most experts used a Lone Star retractor, CooperSurgical, Trumbull, CT, USA) may prove useful, especially when performing a handsewn anastomosis.

36/37 = 97.3%

Insufflation

Transanal CO_2 insufflation should ensure a stable pneumorectum/pneumopelvis under continuous smoke evacuation, a much helpful feature as the transanal dissection occurs close to the scope [13]. Most experts used an Airseal system (CONMED, Utica, NY, USA) for this purpose.

The abdominal part of the procedure may use a standard insufflator. Alternatively, two standard air insufflators can be used concurrently for the transanal and the transabdominal stages. However, the transanal insufflator should be able to deliver high insufflation pressure to compensate for frequent to constant smoke evacuation.

33/37 = 89.2%

The pneumorectum is typically initiated through an access port using low pressure/low smoke evacuation levels. It is important to occlude the rectal lumen with an abdominal clamp until the pursestring is completed and the rectal dissection is started. Upon progression of the rectal dissection a higher CO_2 pressure and smoke evacuation level are required, up to 20 mmHg. For a standard high insufflation pressure the recommended abdominal pressure is 12–15 mmHg.

32/37 = 86.5%

Laparoscopic instruments

Standard laparoscopic instruments are used for the transanal dissection. Monopolar cautery is used most frequently; alternatively, an energy device can be used, although this may further increase the procedure cost.

31/37 = 83.8%

The panel selected monopolar and bipolar cautery as the preferred energy source for the transanal dissection. Of all other energy sources (bipolar sealing device, ultrasonic shears, or a combination thereof in a single instrument), ultrasonic shears were used by a minority (2/37=4.6%) for transanal dissection.

35/37 =94.6%

Curved/angulated instruments may be useful. 30/37=81.8%

Transanal extraction of the specimen using a wound protector may be envisaged, depending on the size of the tumour and the bulkiness of the specimen. However, avoiding an abdominal extraction incision must be balanced against the risk of damage to both the sphincter complex and the specimen in a transanal extraction.

When extracting the specimen through an abdominal incision, a wound protector should be used to prevent port site metastases and wound infection.

37/37 = 100%

Pelvic anatomy revisited: the transanal perspective

Recognizing visual clues and orientating oneself are at the core of a safe surgical procedure [14]. The pelvic anatomy seen through the transanal perspective is novel even to experienced surgeons. Several pitfalls may arise from leaving the correct plane. Early recognition of errors and return to the correct plane are crucial to a safe TaTME dissection.

37/37 = 100%

In females, the anterior dissection carries the risk of entering the vagina. Usually, this injury can be easily recognized and repaired as required.

36/37 = 97.3%

The urethra in males may be injured during the initial anterior dissection.

35/37 = 94.6%

If in doubt, the transanal platform should be removed and the prostate/prostatic urethra/urinary catheter palpated to confirm the correct dissection plane.

34/37 = 91.9%

There is a risk of following a perimuscular plane and therefore being too close to the rectum and/or cancer. This is especially true at the beginning of the transanal dissection, when caution should be undertaken to identify and proceed early within the TME plane.

36/37 = 97.3%

Pneumopelvis may create areolar planes beyond the dissection point thus leading the surgeon astray.

36/37 = 97.3%

The ureters are particularly at risk of injury during the anterolateral dissection, especially when the lateral dissection is carried out too widely without control from an abdominal surgeon.

32/37 = 86.5%

Caution should be undertaken to avoid too lateral a dissection during the transanal approach, because of the risk of injury to the pelvic side wall and its structures.

37/37 = 100%

Posteriorly, too deep a plane runs the risk of entering the presacral space with possible subsequent injury to the presacral venous plexus.

36/37 = 97.3%

For low rectal tumours, an (total or partial) intersphincteric dissection may be required but carries the risk of poor function.

35/37 = 94.6%

TaTME training

Courses, proctoring, mentoring

TaTME represents an important addition to the contemporary treatment of rectal pathologies. In particular, it has the potential to improve the outcomes in rectal cancer surgery. However, the safe and successful introduction and development of TaTME requires adequate training. Participation in dedicated courses, including hands-on/cadaveric courses, taking part in a mentoring/proctoring program, and performing initial TaTME cases under supervision are crucial steps in the safe learning and implementation of TaTME.

37/37 = 100%

The consensus panel advises to participate in a TaTME course prior to performing any TaTME cases in the clinical setting. A TaTME course should include peer-reviewed materials covering pelvic anatomy from the transanal perspective, surgical technique of TaTME, pitfalls, and technical troubleshooting.

37/37 = 100%

Furthermore, it is important for the whole multidisciplinary team to know the particulars of TaTME. Case observation and hospital visit, involving one's complete theatre team, are very useful prior to starting one's first TaTME.

37/37 = 100%

In addition to case observation, mentoring/proctoring with an expert surgeon available is strongly advised.

36/37 = 97.3%

An important further prerequisite is adequate experience in oncological rectal surgery, including an annual centre volume of at least 10 cases.

36/37 = 97.3%

The learning curve for safe and independent practice of TaTME is yet to be established but progress is slow even for the experienced laparoscopic colorectal surgeon. Depending on previous laparoscopic TME and TEM/TAMIS experience, 1–5 TaTME cases should be proctored/supervised before embarking on solo practice.

35/37 = 94.6%

The panel agrees that the overall learning curve is long and demanding, with more than 20 cases required. No consensus could be reached on a given number of procedures to reach proficiency.

37/37 = 100%

Prospective monitoring and benchmarking one's own outcomes is advised, as well as participation in clinical studies. In particular, perioperative clinical outcomes, oncological outcomes, and function/quality of life should be monitored in an effort to continuously improve quality.

37/37 = 100%

Surgical technique step by step

The consensus panel endorses a standardized surgical technique to allow for safe and reproducible outcomes. Several publications have described ad hoc surgical techniques and variations in performing TaTME. In the context of an upcoming randomised controlled trial evaluating TaTME vs laparoscopic TME (COLOR III), a step by step TaTME procedure has been validated and published. This conse sus panel recommends adherence to the surgical technique described in the COLOR III protocol [15].

34/37 = 91.9%

TaTME starts with either the transabdominal or transanal phase. In the abdominal phase the sigmoid and the splenic flexure are mobilised by multiport laparoscopy or through single port surgery with the single port located in the future ileostomy site. The inferior mesenteric artery is centrally ligated after identification of the left ureter. After mobilisation of the descending colon, sigmoid and the proximal rectum, the transanal phase is initiated.

In a two-team approach, the lumen of the distal sigmoid colon is occluded early with a grasper to minimize colonic distension while the perineal surgeon completesthe pursestring.

31/37 = 83.8%

The transanal phase starts with a washout of the rectum with a povidone-iodine solution [16, 17]. Use of anal retraction sutures and/or an anal retractor are advised.

37/37 = 100%

For distal tumours (< 5 cm from the anal verge), an intersphincteric dissection is performed with the use of an anal retractor. The transanal dissection is continued as proximal as possible in open fashion. Thereafter, the open rectum is closed with purse-string suture to prevent spillage of bacteria and tumour cells.

33/37 =89.2%

In case of tumours above 5 cm from the anal verge, a transanal platform is inserted and sutured to the perineal skin. The rectal stump is then closed with a pursestring suture with a recommended minimum distance of 1 cm from the distal end of the cancer. This pursestring suture can be placed through the transanal platform under direct vision or endoscopically, especially for more proximal tumours.

32/37 = 86.5%

A pneumorectum is created with carbon dioxide at a pressure of 14 mmHg and a relatively low flow of 5 l per minute to minimise rectal contractions. When dissection progresses, insufflation settings can be increased and air evacuation controlled to allow for the best possible visualization. Use of a dedicated insufflation management system, which provides a stable pneumopelvis under continuous smoke evacuation, is advised.

34/37 = 91.9%

Dissection starts by marking the distal resection level with the diathermy hook, then proceeding to a full thickness incision of the rectal wall. The dorsal plane is then developed proximally using blunt and cautery dissection along the TME plane. The ventral dissection comes next, taking great care not to injure the vagina and to preserve the prostatic urethra. The lateral dissection comes last after progression of the dorsal and ventral parts, in order to minimize the risk of damaging neurovascular structures. Lastly, the peritoneal reflection is opened. This step should be carried out last as it may markedly impair the ability to maintain a pneumopelvis.

30/37 = 81.1%

Whenever restoration of bowel continuity is envisaged, construction of a diversion ileostomy is advisable to protect against and minimize the risk of anastomotic leak [18, 19].

33/37 = 89.2%

There are different techniques to perform a low anastomosis after TaTME. If an intersphincteric dissection was performed, a handsewn coloanal anastomosis is the best option.

37/37 = 100%

On the other hand, if there is enough distal rectum to perform a pursestring, a stapled anastomosis can be safely performed.

35/37 = 94.6%

Different anastomotic techniques have been published [20] and seem feasible and safe. To date, there is no strong evidence supporting one particular technique. All stapled anastomoses use a double pursestring technique placed at the rectal stump and at the colonic end. Multiple stapler firings with crossing staple lines is thus avoided. The diameter of the stapler varies from 28 to 33 mm.

36/37 = 97.3%

The type of reconstruction depends on the surgeon's preference and the patient's anatomy (end-to-end or side-to-end anastomosis, or colonic J pouch). There is limited data suggesting better short-term functional outcomes with a sideto-end or colonic J pouch reconstruction.

35/37 = 94.6%

Depending on the size of the specimen, an abdominal or a transanal extraction can be performed. A transanal extraction reduces the risk of postoperative abdominal wall compl cations (pain, wound infection, incisional hernia). It may, however, put additional stretch on the anal sphincter and can cause trauma to the rectal specimen.

34/37 = 91.9%

However, there are cases where a transanal extraction is not possible or suitable (short mesentery, bulky specimen, risk of specimen injury). In this situation, a suprapubic or short midline incision is advised.

33/37 = 89.2%

In all cases, a wound protector should be used to reduce the potential risk of wound infection and tumour cell implantation.

35/37 = 94.6%

Outcome analysis

Outcome research

Several publications from expert centres have shown promi ing results and have supported the dissemination of TaTME. The consensus panel encourages the prospective monitoring of perioperative clinical outcomes, histopathology results, oncological outcomes, and function/ quality of life.

37/37 = 100%

Clinical outcomes of interest include operative time, oneteam or two-team procedure, conversion to laparoscopy, conversion to open surgery, 30-day post-operative morbidity taking advantage of a validated grading system (e.g. the Dindo-Clavien classification [21]), length of hospital stay, and readmission. Anastomotic leaks should be graded according to the international grading system (A–C) [22]. Whether a case has been proctored should also be recorded.

37/37 = 100%

Oncologic outcomes of interest include quantification of resection margins (proximal, distal, and circumferential resection margins), Quirke/Mercury TME quality grading [23], TNM staging [24], including the number of lymph nodes retrieved, and both neoadjuvant and adjuvant treatment. Recurrence rates shall be monitored prospectively as well.

37/37 = 100%

Functional outcomes of interest include generic and colorectal cancer specific assessment of quality of life (e.g. EORTC QLQ-C30 & CR-29 [25]), urinary function (e.g. IPSS [26]), gender specific sexual function (e.g. IIEF-5 [27]/ FSFI-6 [28]), bowel function (e.g. LARS [29], Vaizey [30]), and health utility (e.g. EQ-5D [31]).

36/37 = 97.3%

Lastly, econometric analysis may be of interest, including assessment of health utilities (e.g. EQ-5D [31]), procedure and hospital costs, and hospital reimbursement.

37/37 = 100%

Registries and clinical trials

The consensus panel strongly advises participation in the international TaTME registry [3] (http://www.TaTME.surgery) and in the randomised controlled trials COLOR III [4] and GRECCAR 11 [5] (TaTME vs laparoscopic TME). 37/37 = 100%

MRI staging and prognosis information

Gina Brown, Consultant Radiologist

Multidisciplinary review of MRI rectal cancer findings leads to improved outcomes [32]. Thus, MRI is the investigation of choice for local staging of rectal cancer. It shows the extension of the tumor through the rectal wall and to the mesorectal fascia, and the involvement of local nodes and vessels [33, 34]. Further, MRI enables an objective assessment of the tumour with respect to the sphincter and the anal verge, guiding management decisions regarding potential sphincter preservation [35]. Understanding the relationship of the tumour to the distal TME plane at or just above the puborectalis sling prevents inadvertent surgical perforation and dissemination of tumour during distal TME dissection. Also, it allows selective use of extralevator abdominoperinal excision for those tumours where the invasive border lies within 1 mm of the intersphincteric plane, levator muscle, or lower prostate [36, 37]. Last, MRI assessment reveals the area or quadrant of maximal tumour at risk of margin involvement [36].

Other prognostic and predictive factors that are assessed include depth of extramural spread (mrT substage) [38, 39] and the presence or absence of tumour signal into extramural veins [40–42]. High resolution MRI technique enables characterisation of nodes based on breach of the nodal capsule and/or replacement of nodal tissue by tumour resulting in border irregularity and mixed signal intensity respectively. Size criteria should not be used [34, 43]. Compared with the assessment of mrCRM (TME plane), millimetre assessment of the extramural depth of spread, and MRI assessment of venous invasion, MRI assessment of nodes do not hold prognostic significance [44]. Reporting standards for MRI staging are shown in Table 1.

Table 1 Reporting standards for MRI staging

MRI reporting standards
Site of tumour—upper/mid/lower third
Height from puborectalis sling and anal verge and craniocaudal length
For tumours arising at or within 2 cm above the level of the puborectalis sling—assessment of the safety of the total mesorectal excision (TME) surgical plane
Relationship to important landmarks, e.g., peritoneal reflection/seminal vesicles
Morphology: e.g. annular/semi-annular/mucinous
Infiltrating border—smooth or nodular infiltration
Presence or absence of extramural venous invasion
Presence or abscence of vascular mediate tumour deposits (N1c)
Maximum depth of extramural spread
Presence or absence of malignant lymph nodes (smooth border/uniform signal = benign irrespective of size)
Minimum distance to mesorectal fascia or intersphincteric plane > 1 mm = mrCRM clear
In the final assessment, the TNM stage and an assessment of potential resection margin involvement/safety of the TME plane (classified as potentially involved if tumour < 1 mm to the mesorectal fascia/ intersphincteric plane) should be made

A word of caution by the pathologist

Philip Quirke, Consultant Pathologist

As any new technique, TaTME needs rigorous evaluation and its safety needs to be proven. Pathology is helpful in evaluating its effectiveness and optimizing surgical technique. Major changes in local recurrence and survival in rectal cancer have been achieved by considering the anatomy of the rectum, careful selection of the appropriate planes on MRI, assessing the surgeon's ability to deliver the appropriate anatomical package and quality assurance by the pathologist through describing the involved margin rate [45] and the quality of the surgery [23, 46, 47].

The anatomy is difficult as posteriorly there are complex changes in the angulation of the mesorectal fascial plane and the mesorectum is initially a thin fatty layer. Anteriorly there is very little mesorectum and the anterior surgical margin is in juxtaposition to the urethra. In the male important nerves run at the height of the prostate, so surgery needs to be very precise. It is essential that the surgeon finds and develops the correct plane around the tumour and stays within it. Since the height of the tumour is an important factor with lower tumours generating worse surgical planes [47] there may well be a place for excellent TaTME but this needs to be proven. The degree of increased operative difficulty caused by preoperative therapy also needs to be determined.

Auditing of key pathology features safeguards the quality of the surgical planes, especially anteriorly in the low rectum, and the frequency of CRM positivity. Photography of the anterior and posterior surfaces of all TaTMEs is essential to alert surgeons to suboptimal planes and ensure their correction in future cases. Photography allows for external audit and evidence rather than opinion based audit. Early, self-declared registry information looks optimistic [48] but this is no substitute for proper cohort studies with central pathology evaluation and MRI stratified randomised trials.

Multimodal therapy and role of the multidisciplinary team
Ulrich Güller, Consultant Medical Oncologist

Multimodal therapy and multidisciplinary tumour board discussions resulted in a quantum leap regarding outcomes of rectal cancer patients. However, major challenges still lay ahead: First, while local relapses have become a rare phenomenon in patients undergoing neoadjuvant chemo-radiotherapy and proper TME, distant metastases remain an unsettling problem. Hence, further efforts must focus on improving systemic treatment. Second, not all patients need the trimodal therapy including radiation, surgery, and chemotherapy. Currently, randomised trials are evaluating whether patients with good response to neoadjuvant chemotherapy can do without additional radiation (PROSPECT Trial, Alliance) [49]. Moreover, the use and time point of chemotherapy are further evaluated as it is hypothesized that systemic treatment is used too late in the treatment sequence leading to a higher risk of distant relapse. Contemporary randomised controlled trials now evaluate total neoadjuvant treatment (e.g. Rapido Trial [50]), in which patients receive chemotherapy in a neoadjuvant setting. Finally, not all patients must undergo surgery. As pioneered by Habr-Gama [51], a relevant fraction of patients having a complete clinical response after neoadjuvant therapy can be followed without immediate operation, with good outcomes, including improved quality of life and decreased morbidity, as the recent presentation at ASCO GI 2017 of the International Watch and Wait Database (IWWD) for Rectal Cancer confirms [52]. To further advance care and knowledge in treating rectal cancer patients, it is of cardinal importance to nurture an ongoing collaboration with all actively involved disciplines including surgery, radiation oncology, gastroenterology, pathology, radiology and medical oncology.

Discussion

The primary objective of this interdisciplinary consensus statement was to provide guidance to those embarking on TaTME. Secondary, it was aimed to highlight the challenges, benefits, and distinctive dangers of this technique, and to promote prospective outcomes analysis.

Seven different aspects were analysed including: patient selection and indication, perioperative management, patient positioning and operating room set up, devices and instruments, pelvic anatomy, TaTME training, and outcomes analysis. Globally, the statements achieved more than 80% approval for most of these items, which were graded as strong recommendations. However, it is acknowledged that there is a current lack of high level evidence in support of this recommendation, which is based only on expert opinion. On the other hand, the panel of experts found a large agreement on all the different questions.

As for recommendations, the GRADE guidelines [6] state: 'Strong recommendations indicate that the panel is confident that the desirable effects of adherence to a recommendation outweigh the undesirable effects. Weak recommendations indicate that the desirable effects of adherence to a recommendation probably outweigh the undesirable effects, but the panel is less confident'. Recommendations were based not only on the quality of evidence but also on the balance between wanted and unwanted effects, and on values and preferences [53]. The latter implies that, in some instances, strong recommendations may be reached from low-quality data and *vice versa*.

The introduction of a new technique must occur in a safe and controlled manner to protect both the patient and the surgeon. The expert panel agreed that the earlier stages of the learning curve are best overcome by initially selecting easier cases, although no agreement was reached on gender selection with 60% of the panel favouring the broader pelvis of female patients to begin with TaTME. However, the panel acknowledges that the greater the BMI and/or more unfavourable the hip-waist ratio the more TaTME helps to overcome the challenges of an oncologic low pelvic dissection. This is particularly true in male patients with low rectal cancer.

The adoption of TaTME has seen an exponential growth worldwide. The largest cohort to date includes recently published results from the International TaTME registry, suggesting an oncologically safe and effective technique with acceptable short-term clinical outcomes [48]. However, surgeons did experience intra-operative equipment and technical difficulties in up to 40% of cases, with incorrect plane dissection, pelvic bleeding, unstable pneumopelvis and, more worryingly, visceral injuries such as urethral division. Indeed, one of the most dreaded specific complication of TaTME is the injury of the urethra during initial anterior dissection. The TaTME surgeon has to recognize new landmarks in dissection and think in different planes. The prostate may initially appear as a vertical wall in front of the dissection and inadvertently be dissected en bloc with the anterior mesorectum or 'dug' into, causing urethral injury. Removing the platform to palpate and help define the anatomy of the prostate/urethra or vagina is a key step in case of doubt. Similarly, for very low tumours where dissection is initiated in an intersphincteric plane the platform may be inserted once a classical transanal dissection using a conventional retractor has clarified the surgical/oncological plane. Later during the high lateral dissection, the autonomic nerves, ureters, and pelvic vessels are at risk. In case of major bleeding, tamponade by a transanally inserted gauze and positioning the patient in reverse Trendelenburg help control and repair vascular injury, which may be completed laparoscopically.

This consensus strongly recommended proper training, including participation in dedicated courses and proctoring of the first cases before embarking on independent practice of TaTME. Guidance from surgeons experienced in TaTME help new adopters of the technique avoid mistakes made in the past and progress at an efficient pace with more appropriate and specialised equipment becoming widely available. To start a TaTME practice, a minimal annual volume of 10 complete TME dissections for cancer was agreed on. This figure, although low, was felt the least to achieve but many voiced concerns that more may be required to obtain best possible results. A minimum learning curve of 20 cases performed within about 2 years was felt reasonable, while it was recognized that individual variability may influence the length and steepness of the learning curve. Experience of the surgeon and his team should be considered when reporting and appraising outcomes. Importantly, participation to an international registry and/or clinical trial is encouraged to share experience and benchmark one's practice with other surgeons and institutions.

Whilst this consensus did focus on malignant pathologies requiring TME, this new approach may be applied for benign conditions as well, although this emerging indication was beyond the scope of the present consensus. Several reports have shown benefits of a transanal approach beyond cancer [54–58], with 11.9% of the cases reported in the TaTME registry [48] addressing benign conditions. Most benign procedures were an intersphincteric amputation or a proctectomy with ileal-pouch-anal reconstruction for inflammatory bowel disease. A transanal approach facilitates proctectomy, especially in obese patients with narrow pelvis. Also, it allows an exact transection of the rectum at the top of the anal canal, leaving no rectal mucosa behind, and avoids multiple stapler firings and cross-stapling. Further benign indications include complex fistulae [59, 60], anastomotic complications (stenosis or leakage) [61–63], completion proctectomy [64–66], deep pelvic endometriosis [67], and reversal of Hartmann [68].

Conclusion

A broad international consensus statement is presented herein, which provides a basis for optimal clinical practice. This multidisciplinary consensus statement achieved more than 80% approval and can thus be graded as strong recommendation, yet acknowledging the current lack of high level evidence. It provides the best possible guidance to safe implementation of Transanal Total Mesorectal Excision.

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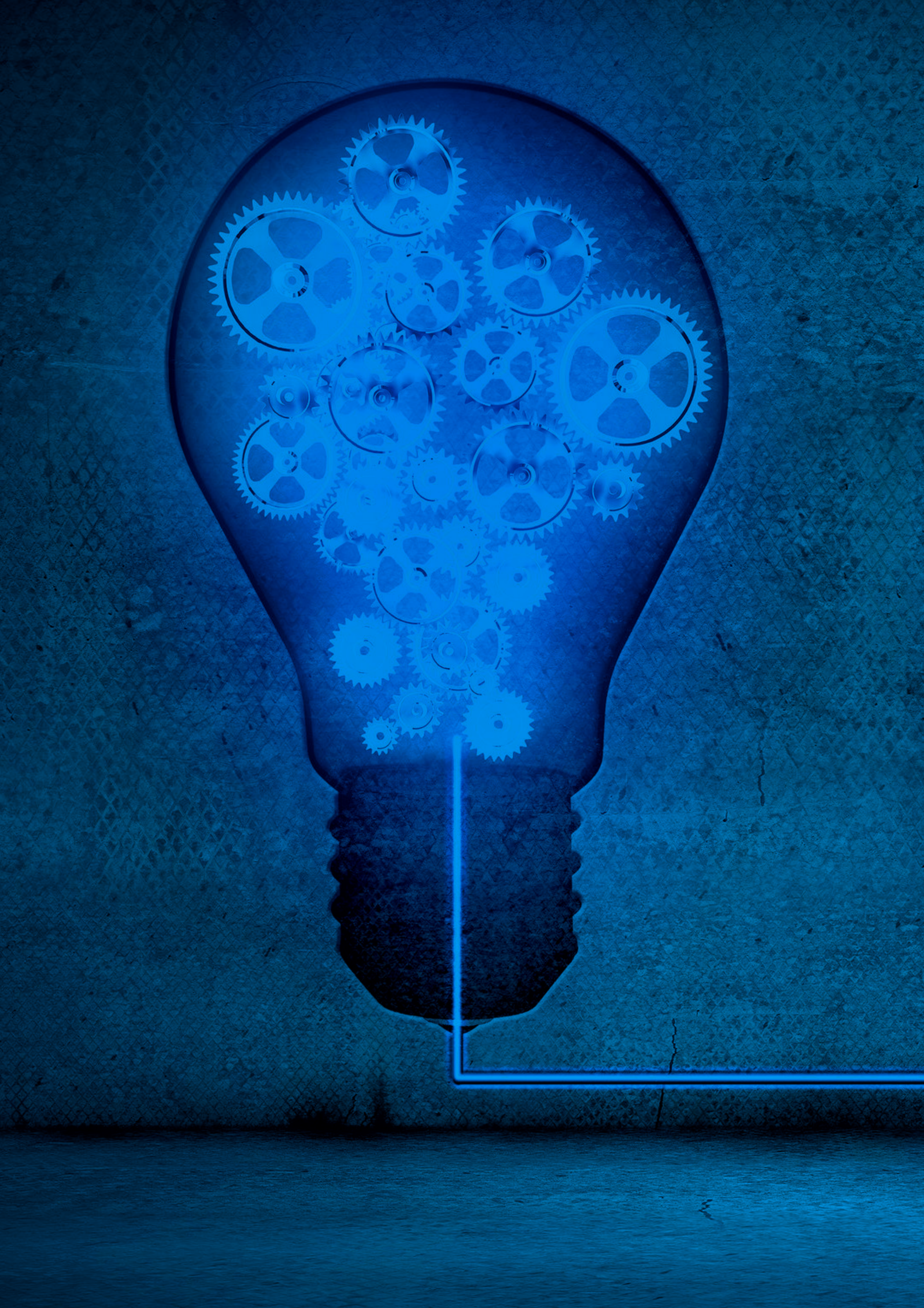

Chapter 14

Transanal Total Mesorectal Excision: International Registry Results of the First 720 Cases

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Abstract

Objective

This study aims to report short-term clinical and oncological outcomes from the international transanal Total Mesorectal Excision (taTME) registry for benign and malignant rectal pathology.

Background

TaTME is the latest minimally invasive transanal technique pioneered to facilitate difficult pelvic dissections. Outcomes have been published from small cohorts, but larger series can further assess the safety and efficacy of taTME in the wider surgical population.

Methods

Data were analyzed from 66 registered units in 23 countries. The primary endpoint was "good-quality TME surgery." Secondary endpoints were short-term adverse events. Univariate and multivariate regression analyses were used to identify independent predictors of poor specimen outcome.

Results

A total of 720 consecutively registered cases were analyzed comprising 634 patients with rectal cancer and 86 with benign pathology. Approximately, 67% were males with mean BMI 26.5 kg/m^2. Abdominal or perineal conversion was 6.3% and 2.8%, respectively. Intact TME specimens were achieved in 85%, with minor defects in 11% and major defects in 4%. R1 resection rate was 2.7%. Postoperative mortality and morbidity were 0.5% and 32.6% respectively. Risk factors for poor specimen outcome (suboptimal TME specimen, perforation, and/or R1 resection) on multivariate analysis were positive CRM on staging MRI, low rectal tumor <2 cm from anorectal junction, and laparoscopic transabdominal posterior dissection to <4 cm from anal verge.

Conclusions

TaTME appears to be an oncologically safe and effective technique for distal mesorectal dissection with acceptable short-term patient outcomes and good specimen quality. Ongoing structured training and the upcoming randomized controlled trials are needed to assess the technique further.

Introduction

Colorectal cancer is the third most common cancer in the world[1]. Rectal cancer in particular poses unique challenges and major changes have occurred over the past few decades. The gold standard approach to rectal cancer surgery is total mesorectal excision (TME) as popularized by Heald in 1979 [2]. Neoadjuvant therapy and accurate dissection along the fascia propria obtaining intact mesorectum with negative distal (DRM) and circumferential resection margins (CRM), can improve local recurrence rate and cancer-free survival [3-5]. Oncological benefits were originally shown with open surgery [4-7]. After increasing adoption of laparoscopy, randomized controlled trials (RCT) showed largely equivalent outcomes [6,7]. However, two recent RCTs, ACOSOG Z6051[8] and ALaCaRT [9], failed to show noninferiority of laparoscopy compared with open surgery for oncological outcomes. Patient-related factors predicting intraoperative difficulty and potentially increased risk of local recurrence include male sex, high body mass index (BMI), visceral obesity, and a narrow pelvis [10]. Bulky tumors and advanced T-stage have also been identified as risk factors for a positive CRM [11]. These anatomical features pose technical challenges during both laparoscopic and open surgery, with poor visualization of mesorectal planes and difficult introduction of instruments into a narrow pelvis; increasing the risk of an incomplete mesorectal excision and poor oncological outcomes. High conversion rates have also been reported for laparoscopy—16% and 11.3% in COLOR II [7] and ACOSOG Z6051 [8] trials, respectively—indicating technical challenges of achieving a successful laparoscopic TME.

Transanal approaches to pelvic dissection have attracted attention with expectations to improve clinical, oncological, and functional outcomes by providing better visualization and more accurate distal TME dissection. Transanal TME (taTME) is not a completely new concept, but rather, an amalgamation of important surgical techniques; transanal endoscopy microsurgery (TEM) [12], transabdominal transanal (TATA) approach [13], and transanal minimally invasive surgery (TAMIS) [14]. Since Sylla and Lacy reported their early experience in 2010 [15], numerous case series have been published, showing encouraging results in terms of safety and efficacy of taTME [16-18].

The aim of the current study is to report short-term outcomes of initial cases reported on the international taTME registry [19]. These data give insight into the experience with this new technique in everyday practice from a wide community of rectal surgeons across the globe.

Methods

The taTME Registry

The registry is a secure online database funded by Pelican Cancer Foundation[19] and accessed via the Low Rectal Cancer Development (LOREC) website (http://www.lorec.nhs.uk). Registration is voluntary and surgeons performing taTME worldwide are invited to join. The dataset collected consists of nine sections: patient demographics, staging and neoadjuvant treatment, operative details, postoperative clinical and histological outcomes, readmissions details, late morbidity, and long-term oncologic follow-up. Ethical approval for the registry and publication of results was obtained from the UK Health Research Authority (REC reference 15/LO/0499, IRAS project ID 156930).

Study Design and Patient Population

Cases registered between July 2014 and December 2015 were analyzed. These results were recorded in 66 surgical units from 23 different countries (Appendix 1, http://links.lww.com/SLA/B80). Three months before data analysis, registered surgeons were invited via email to update their records with two subsequent reminders to minimize missing data. Surgeons were individually contacted to clarify unexpected or possibly erroneously entered results. Data were gathered on rectal cancer and benign cases that underwent taTME. Data from cancer cases focused on preoperative staging, neoadjuvant treatment and histopathological results. Definitions of variables and outcomes are outlined in Appendix 2, http://links.lww.com/SLA/B80. Missing data did not exceed 15% for each variable and percentages shown represent data available excluding missing values. The primary endpoint of the study was "good-quality TME surgery" defined as a TME dissection that was classed as intact or with minor defects and with clear CRM and DRM (R0 resection). Quality of the TME specimens was categorized using descriptions by Quirke et al.[20] Secondary endpoints included short-term patient and procedure-related adverse events.

Statistical Analysis

Categorical data are presented as number of cases and percentages, whereas continuous data are shown as either mean standard deviation (range) or median with range. Univariate and multivariate analyses were performed to identify possible risk factors associated with poor histological features (composite of R1 resection and poor TME/perforated specimen). Dependent variables were subdivided into patient-related, tumor-related, and technical risk factors. Univariate analysis comparing categorical variables was performed using the Pearson χ^2 test, and continuous variables were analyzed using Mann-Whitney *U* test. Multivariate analysis was subsequently performed using logistic binary regression for variables that achieved a *P* 0.100 on univariate analysis. On multivariate analysis, $P < 0.05$ was considered statistically significant. The Statistical Package for Social Sciences (SPSS) of IBM Statistics, version 20, was used for the statistical analysis.

Results

A total of 720 cases were recorded on the taTME registry during an 18-month period. Caseload distribution was as follows: 0–5, 6–10, 11–20, and >20 cases in 33 (50%), 12 (18%), 8 (12%), and 13 (20%) units, respectively. The indication for surgery was rectal cancer in 634 cases (88.1%), whereas 86 patients (11.9%) had benign pathology. Patients' characteristics are outlined in Table 1.

Cancer Cases: Preoperative Staging and Neoadjuvant Therapy

Preoperative tumor characteristics and neoadjuvant therapy are outlined in Table 2. Low rectal cancer, 6 cm from anal verge, accounted for 62% of cases. Mid (7–10 cm) or high (>10 cm) rectal cancer was present in 37% and 1%, respectively. Preoperative MRI revealed threatened (CRM) in 115 cases (21.1%); 8.3% showed nodal involvement, 11% tumor involvement, and 1.8% both nodal and tumor involvement. Baseline MRI staged 185 (33.1%) as T1–T2 rectal cancer, 343 (61.4%) T3, and 31 (5.5%) T4 cancer. Nodal status. was reported as N0, N1, and N2 in 232 (41.8%), 221 (29.8%), and 102 (18.4%) cases, respectively. Synchronous metastatic disease was present in 40 patients (6.6%).

Table 1. Patient characteristics

PATIENT CHARACTERISTIC Factor Category	TaTME registry data results Total: 720 cases
Gender, n (%)	
Male	489 (67·9)
Female	231 (32·1)
Age in years, mean ± SD (range)	62·4 ± 13·0 (18–91)
ASA score, median (range)	2·0 (1–4)
BMI in kg/m^2, mean ± SD (range)	26·5 ± 4·3 (16·5–42·7)
Smoking, n (%)	
Smoker	90 (12·5)
Non-smoker	630 (87·5)
Presence of co-morbidities, n (%)	
Diabetes mellitus	85 (11·8)
Ischemic Heart Disease	97 (13·5)
Active Inflammatory bowel disease	42 (5·8)
Steroid use at time of surgery	13 (1·8)
Previous abdominal surgery, n (%)	
Non-cancer related surgery	134 (19·0)
Hysterectomy	23 (3·2)
Prostatectomy	12 (1·7)
Laparoscopic ventral mesh rectopexy	1 (0·1)
Previous pelvic radiation therapy, n (%)	15 (2·1)

SD: standard deviation. ASA: American Society of Anesthesiologists. BMI: Body Mass Index.

Table 2. Cancer cases: Pre-operative staging and neoadjuvant therapy.

PRE-OPERATIVE STAGING Factor Category	**TaTME registry data results** Total: 634 cancer cases
Clinical tumor height from anal verge on rigid sigmoidoscopy in cm, median (range)	6·0 (0–13)
Tumor height from anorectal junction on MRI in cm, median (range)	3·0 (0–11)
Predominant tumor location, n (%)	
Anterior	243 (43·3)
Posterior	233 (41·5)
Lateral	85 (15·2)
Missing	*73 (11.5)*
Circumferential extent of tumor, n (%)	
1 to 2 quadrants	399 (70·1)
3 to 4 quadrants	170 (29·9)
Missing	*65 (10.3)*
Pre-operative MRI staging, n (%)	
≥ T3	374 (66.9)
N+	323 (58·2)
Pre-operative CRM involvement on MRI, n (%)	115 (21·1)
NEOADJUVANT THERAPY	
Received neoadjuvant therapy, n (%)	355 (57·1)
Short course radiotherapy	56 (15·8)
Long course chemoradiotherapy	255 (71·8)
Long course radiotherapy alone	27 (7·6)
Chemotherapy alone	48(13·5)
Contact radiotherapy	1 (0·3)
TRG response post neoadjuvant therapy, n (%)	
mTRG 1 & 2 (No or small residual tumor)	136 (38·3)
mTRG 3 (Mixed fibrosis and tumor)	103 (29·0)
mTRG 4 & 5 (Mainly or only tumor)	116 (32·7)

MRI: Magnetic Resonance Imaging. CRM: Circumferential Resection Margin. N+: Positive nodal status (N1 or N2). TRG: Tumor regression grading on MRI Percentages for *Missing* values use the total number of cancer cases as the denominator (i.e. 634). Percentages for the variables are calculated out of the total number of actual results available excluding the missing values.

Table 3. Operative details.

OPERATIVE CHARACTERISITC Factor Category	**TaTME registry data results** n (%)
Total number of cases	720
Indication	
Benign	86 (11·9)
Cancer	634 (88·1)

Operations performed		
Cancer cases:		
High anterior resection	30 (4·8)	
Low anterior resection	537 (86·2)	
Abdominoperineal excision	14 (2·2)	
Intersphincteric APE	42 (6·8)	
Missing	*11 (1.7)*	
Benign cases:		
Low anterior resection	3 (3·7)	
Standard APE	4 (4·9)	
Intersphincteric APE	48 (58·5)	
Proctectomy (close rectal) + IPAA	3 (3·7)	
Proctectomy (TME plane) + IPAA	24 (29·2)	
Missing	*4 (4.7)*	
Simultaneous abdominoperineal operating	227 (32·3)	
Surgical approach		
Abdominal phase:		
Open	21 (3·1)	
Laparoscopic	553 (82·4)	
SILS	93 (13·9)	
Robotic	4 (0·6)	
Missing	*49 (6.8)*	
Transanal phase:	**Benign**	**Cancer**
Mucosectomy	3 (3·9)	49 (8·2)
Total intersphincteric	29 (28·2)	37 (6·2)
Partial intersphincteric	2 (2·6)	120 (20·0)
Pursestring	40 (52·6)	375 (62·5)
Other*	2 (2·6)	19 (3·2)
Missing	*10 (11.6)*	*34 (5.4)*
Conversion		
Abdominal	40 (6·0)	
Perineal	20 (2·8)	
Stoma		
No stoma	51 (7·3)	
Ileostomy	580 (83·3)	
Colostomy	65 (9·3)	
Missing	*24 (3.3)*	
Specimen extraction site		
Pfannenstiel	99 (14·7)	
Umbilical	61 (9·0)	
Right or Left Iliac Fossa	75 (11·1)	
Transanal	340 (50·4)	
Other**	92 (13·6)	
Missing	*53 (7.4)*	

Anastomotic technique	**Benign Cancer**
Manual	3 (13·6) 249 (44·7)
Stapled	19 (86·4) 308 (55·3)
Missing	*8 (26.7) 10 (1.8)*
Height of anastomosis from anal verge in cm, median (range)	**Benign Cancer**
Manual	2 (1–4) 3 (0–5)
Stapled	4 (2–6) 4 (0–10)
Operative time in minutes, mean ± SD (range)	
Total operative time	277 ± 83 (62–685)
Perineal phase time	128 ± 70 (15–467)
Intra-operative adverse events	
Technical problems	283 (39·3)
Incorrect dissection plane	56 (7·8)
Pelvic bleeding	50 (6·9)
Visceral injury	11 (1·5)

APE: Abdomino-perineal excision. IPAA: Ileal Pouch-Anal Anastomosis. TME: Total mesorectal excision. SILS: Single incision laparoscopic surgery. SD: Standard Deviation

*Other transanal phase surgical approaches include extra-levator dissection and abdomino-perineal excision.

**Other sites of specimen extraction: Single port incision (n=44, 6.1%), midline laparotomy incision (n=40, 5.6%), and previous stoma site (n=8, 1.1%).

Percentages for *Missing* values use the total number of cases as the denominator (i.e. 720). Percentages for the variables are calculated out of the total number of actual results available excluding the missing values.

Table 4. Post-operative short-term clinical outcomes.

POST-OPERATIVE CLINICAL OUTCOMES	**TaTME registry data results**
Factor	Total: 720 cases
Category	
Length of hospital stay in days, median (range)	8·00 (2–97)
Post-operative morbidity at 30 days, n (%)	213 (32·6)
Clavien-Dindo classification at 30 days, n (%)	
I or II	142 (21·7)
III	66 (10·1)
IV	5 (0·8)
V	3 (0·5)
Missing	*68 (9.4)*
Overall Mortality Rate*, n (%)	17 (2·4)
Pelvic sepsis, n (%)	
Anastomotic leak:	
Early	32 (5·4)
Delayed	8 (1·3)
Intra-abdominal / pelvic abscess	17 (2·4)
Surgical re-interventions	44 (6·1)
Unplanned hospital readmissions	50 (6·9)

* Overall mortality rate refers to reported deaths occurring at any time point during the study period.

Table 5: Histopathological data.

HISTOPATHOLOGICAL DATA Factor Category	TaTME registry data results
Total number of cancer cases	634
Pathological T stage, n (%)	
T0	82 (14·1)
T1	70 (12·1)
T2	197 (34·0)
T3	222 (38·3)
T4	9 (1·6)
Missing	*54 (8.5)*
Pathological N stage, n (%)	
N0	406 (69·2)
N1	122 (20·8)
N2	59 (10·1)
Missing	*47 (7.4)*
Quality of TME specimen, n (%)	
Intact	503 (85·0)
Minor defects	65 (11·0)
Major defects	24 (4·1)
Rectal perforation	12 (2·0)
Missing	*42 (6.6)*
Number of lymph nodes harvested	
Mean ± SD	16·5 ± 9·2
Median (range)	15 (0–70)
Maximum tumor size in mm	
Mean ± SD	27·6 ± 16·7
Median (range)	25 (0–95)
Distal margin in mm	
Mean ± SD	19·0 ± 14·3
Median (range)	15 (0–97)
Positive DRM, n (%)	2 (0·3)
Missing	*45 (7.1)*
Circumferential resection margin in mm	
Mean ± SD	9·19 ± 8·6
Median (range)	8 (0–90)
Positive CRM, n (%)	14 (2·4)
Missing	*45 (7.1)*
Composite poor pathological outcome:	
R1 + poor TME specimen	44 (7·4)
Missing	*42 (6.6)*

TME: Total mesorectal excision. SD: Standard Deviation. DRM: Distal resection margin. CRM: Circumferential resection margin. Percentages for *Missing* values use the total number of cancer cases as the denominator (i.e. 634). Percentages for the variables are calculated out of the total number of actual results available excluding the missing values.

Table 6: Multivariate analysis of risk factors for poor composite histological features (R1 resection + poor TME specimen).

MULTIVARIATE ANALYSIS Factor Category	Event Rate %	Adjusted Odds ratio	95% Confidence Interval	P value
Tumor height from anorectal junction				
> 2 cm	3.8			
0 to 2 cm	11.6	4·561	1·167–17·826	0·029
Positive CRM on staging MRI				
Clear CRM	4.4			
Positive CRM	12.3	4·930	1·364–17·816	0·015
Abdominal extent of posterior pelvic dissection				
> 4 cm	3.1			
≤ 4cm	10.4	5·849	1·424–24·024	0·014

CRM: circumferential resection margin; MRI: Magnetic Resonance Imaging

Operative Details

A total of 634 cancer and 86 benign taTME operations were performed. Table 3 outlines operative features.

Abdominal Phase

A minimally invasive approach was adopted for the abdominal phase in 650 (96.9%) patients, with splenic flexure mobilization in 72%. In cancer resections, the anterior extent of pelvic dissection in males reached the pouch of Douglas (POD), seminal vesicles and prostate in 53%, 38%, and 9%, respectively. In female patients, most surgeons (67%) terminated anterior dissection at the POD, whereas the lowest level reached was mid-vagina in 7.1% of cases. Posterior abdominal TME dissection in cancer cases reached a level of 8 to 10 cm, 5 to 7 cm, and <5 cm from anal verge in 56%, 31%, and 13%, respectively. In benign cases, pelvic dissection was continued to a lower level more frequently: 42% to POD, 53% seminal vesicles, and 5.6% down to the prostate level. Female anterior dissection reached mid-vagina in 8%, but most surgeons (68%) stopped at the POD. Posterior dissection reached 8 to 10 cm, 5 to 7 cm, and <5 cm from anal verge in 44%, 36%, and 20% of cases, respectively. A defunctioning stoma was created in 538 patients (91%) who underwent anterior resection with primary anastomosis.

Perineal Phase

Rigid and flexible transanal access platforms were used in 14.4% and 85.6%, respectively. A rectal purse-string technique was adopted before full rectotomy in the majority of cancer and benign cases, 62.5% and 52.6%, respectively. Median purse-string height from anorectal junction was 4.0 cm (range 0–9) in cancer cases and 4.0 cm (range 0–7) in benign cases. Anterior dissection in males was performed anterior to Denonvilliers fascia in 66.7% of patients with an anterior tumor.

Bowel anastomosis was performed manually in 252 cases (43.6%) and stapled in 327 cases (56.5%). In cancer cases with a stapled anastomosis, the configuration was side-to-end, end-to-end, colonic-J-pouch, and ileal pouch-anal anastomosis (IPAA) in 49.2%, 46.9%, 3.3%, and 0.7% of cases, respectively. The stapler diameters used were 28/29 mm in 30.6%, 31 mm in 12.4%, and 33 mm in 57% of cases. For manual anastomoses in cancer patients, configurations performed included end-to-end, side-to-end, colonic-J-pouch, and IPAA in 67.9%, 27.3%, 4.4%, and 0.4%, respectively. In benign cases, side-to-end or IPAA were performed in 10.5% and 89.5% of stapled cases. Three different stapler diameters were used: 28 mm (5.3% cases), 29 mm (73.7%), and 31 mm (21.1%). Manual anastomosis configurations recorded for 3 benign cases were one end-to-end and two IPAA.

Adverse Events

Intraoperative Difficulties and Complications

Abdominal conversion (Appendix 2, http://links.lww.com/SLA/B80) occurred in 40 cases (6.3%): strategic conversion in 31 cases and reactive in 9 cases. Significant adverse events reported during the abdominal phase included two ureteric transections, iatrogenic enterotomy on insertion of a laparoscopic instrument, splenic injury, and bladder injury during simultaneous laparoscopic hysterectomy for myomatosis.

Perineal conversion (Appendix 2, http://links.lww.com/SLA/ B80) to a more extensive abdominal dissection was required in 20 cases (2.8%): strategic and reactive conversions in 11 and 9 cases, respectively. There were 4 cases (0.6%) of reported failure of the pursestring, with leakage, requiring a repeat pursestring. Problems encountered during perineal dissection included difficulty maintaining a stable pneumopelvis (15.6%), excessive smoke obscuring the view (21.9%), incorrect planes (7.8%), and problematic pelvic bleeding difficult to control (6.9%). Visceral injuries during perineal dissection included 5 urethral injuries (0.7%), 2 bladder injuries (0.3%), 1 vaginal perforation (0.1%), 1 unilateral resection of hypogastric nerves (0.1%), and 2 rectal tube perforations (0.3%). Intraoperative blood loss of <100 mL occurred in 61.2%, with 6 cases (1%) losing more than 1 litre.

Postoperative Clinical Outcomes

Table 4 outlines the short-term outcomes with overall post-operative mortality rate of 2·4% (n=17) and morbidity rate of 32·6% (n=213). All deaths occurred in cancer patients; three of which occurred during index admission. Median time of death following surgery was 248 days (range 4–1857). Specific causes of death were not recorded, but categorised as cancer-related (n=6), not cancer related (n=5), post-operative (n=3) or unknown (n=1), with 2 missing results.

Anastomotic leaks were recorded in 40 cases (6·7%); 32 (5.4%) were identified early, the remaining eight identified at a later stage (>30 days). Surgical or radiological re-intervention was required in 14 (44%) of the 32 patients, and 10 (31%) of these patients required unplanned re-admission. An abdominal or pelvic abscess was recorded in an additional 17 patients without evidence of anastomotic leak.

Unplanned surgical or radiological interventions were required in 66 (10·1%) patients. Re-operations during the index admission included three laparotomies for ischemic left colon, one laparotomy for fecal peritonitis, three examinations under anesthesia for anastomotic leak, two evacuations of hematoma, one negative laparotomy for severe sepsis on day 1 post resection, one incarcerated hernia repair and one case requiring bilateral fasciotomies for compartment syndrome.

Fifty patients (6·9%) had unplanned re-admissions into hospital. Thirty (60%) readmitted patients were treated either conservatively or medically for general malaise, abdominal pain, high stoma output with acute kidney injury, pulmonary embolism, prolonged ileus and delayed anastomotic leak diagnosed during chemotherapy. Fifteen patients underwent a surgical intervention during their re-admission: one laparotomy for small bowel obstruction requiring small bowel resection, one laparotomy for a coloplasty leak, one parastomal hernia repair, one drainage of a perineal abscess, one abdominal wound debridement, one pull-through procedure for anastomotic leak and nine examinations under anesthesia; with re-suturing of partial anastomotic dehiscence (3 cases), re-do of coloanal anastomosis (1 case), dilatation of a strictured handsewn anastomosis (1 case), placement of endo-VAC therapy (2 cases) for pelvic abscess and chronic presacral sinus, transanal lavage of the presacral collection following anastomotic dehiscence (1 case) or no further action (1 case). The remaining five re-admitted patients underwent radiologically guided drainage of pelvic collections.

Histopathological Results

A total of 634 (88%) cancer cases were analyzed. Table 5 outlines key pathological outcomes. R0 resection was obtained in 97.3% of cases. Sixteen cases (2.7%) were reported as R1 because of positive DRM, positive CRM by tumor, and positive CRM by an adjacent malignant lymph node in 2 (0.3%), 10 (1.7%), and 4 (0.7%) cases, respectively. A poor TME specimen was reported in 24 (4.1%) cases. Twelve specimens were found to have a rectal tube perforation but only 6 of these were recorded as poor TME specimens. Although the perforation was not necessarily at the tumor site or through the mesorectum, we have included all rectal perforations into the "poor TME specimen" category for further analysis.

Risk factors for a poor pathological composite outcome: Univariate and Multivariate analysis

R1 resections were combined to those with a poor TME specimen to form a composite endpoint of poor pathological features (n=44, 7·4%). Possible risk factors were divided into patient–related, tumor–related and technical variables. On univariate analysis the following factors achieved a p-value ≤ 0·100: Patient–related factors: None; Tumor–related factors: (1) tumor height from anorectal junction, (2) tumor location, (3) pre-operative T-staging on MRI, (4) positive CRM on pre-operative MRI, (5) metastatic disease on staging CT, (6) neoadjuvant long course radiotherapy; Technical factors: (1) simultaneous abdomino-perineal operating, (2) anterior resection vs. abdomino-perineal excision (APE), (3) abdominal and perineal conversion, (4) blood loss over 1L, (5) extent of posterior pelvic dissection abdominally, (6) total transanal operative time.

Multivariate analysis identified three statistically significant risk factors (table 6). Poor pathological features are more likely to occur when the posterior pelvic dissection performed by the abdominal 'top-down' approach extends to less than 4cm from the anal verge. Lower tumors, with a tumor height of ≤2cm from the anorectal junction, and pre-operative positive CRM on staging MRI significantly increase the risk of obtaining a poor histological outcome.

Discussion

The taTME registry is an international database with strong collaboration between 66 surgical units in 23 different countries. The present study reports the initial 720 taTME cases recorded, which represent the largest patient cohort published to date. Low anterior resection was performed in 77% of cases with most surgeons adopting a laparoscopic approach for the abdominal phase. The conversion rate from laparoscopic to open or transanal was 6·3% with an even lower perineal conversion rate of 2.8%, which is encouraging given the higher rates reported in earlier studies [7,8,21,22]. This may be due to increased experience in laparoscopic surgery. However, the three commonest reasons for conversion in the COLOR II trial were a narrow pelvis (22%), obesity (10%) and tumor fixation (9%). Similar risk factors for conversion were also apparent in the more recent ROLARR (RObotic versus LAparoscopic Resection for Rectal Cancer) trial[23] with 471 patients randomised to either laparoscopy (234) or robotic (237) TME. The overall conversion rates were 12·2% and 8·1%

for laparoscopic and robotic TME surgery respectively. However, 27·8% of obese patients undergoing laparoscopic TME and 18·9% in the robotic arm required conversion. Lower rectal cancer and male gender were also associated with increased conversion rates. These risk factors can be potentially overcome by taTME as constraints and challenges posed by anatomical features are reduced when approached from below. Veltcamp–Helbach et al.[24] reported on 80 taTME cases and reported a conversion rate of 5%; unlike Lacy's group who had no conversions in 140 cases [16].

The most frequently reported intra-operative problems during the transanal phase were an unstable pneumopelvis and poor smoke evacuation. In these cases conventional laparoscopic insufflation devices were used which are unable to evacuate smoke effectively and prevent bellowing. This emphasizes the importance of using optimal equipment available for taTME [25]. Failure of the pursestring with subsequent spillage was also reported, potentially leading to sepsis and even tumour implantation. This hypothesis will require further evaluation and long term follow up. Eleven visceral injuries, including three urethral injuries during taTME alone were recorded. Two further urethral injuries occurred during combined rectal and partial prostatic resections. Urethral injury has not been reported with abdominal approaches and, even in APE, is an uncommonly reported event. Likewise, 12 (2%) rectal perforations were documented on histological analysis, of which 2 were identified intra-operatively. This clearly is a serious concern that must be addressed. Every operation carries risks; just as ureteric injury can occur during abdominal anterior resections, urethral injury has been identified as an important risk during taTME. Therefore it is crucial for surgeons who wish to adopt taTME to have appropriate education and training. Surgeons must inform patients of specific risks as part of the consenting process.

Post-operative morbidity and mortality at 30 days, 32·6% and 0·5% respectively, were similar to those reported in previous rectal surgery trials[7,21] and to other large taTME studies [16,26,27]. The 6·3% overall anastomotic leakage rate compares favourably to the rate observed in other series (7% in CLASICC [21], 13% in COLOR II [7], 8·6% in Lacy's series[16]). A hospital stay of 8 days is acceptable, although the use of enhanced recovery protocols was not recorded.

Histopathological results are comparable to the best published literature, with an incomplete specimen in only 4·1% and R1 resection in 2·7% (16 cases). R1 was secondary to a positive CRM in 14 cases. In COLOR II [7], using the limit of 1 mm for comparison, positive margins were seen in 7% of laparoscopic and 9% of open resections; most of which were cases with more proximal tumors. ROLARR [23] found no statistically significant oncological or clinical advantage to robotic over laparoscopic TME surgery, with positive CRM rates of 5·1% and 6·3% respectively. In taTME series by Lacy [16], Burke [26] and Veltcamp–Helbach [24] CRM positivity was 6·4%, 4% and 2·5% respectively. Small cohorts and registry data do have limitations outlined below, and caution should be exercised when comparing to well stratified

RCTs. A RCT comparing laparoscopic TME to hybrid-taTME in 100 patients with low rectal cancer, showed significantly lower positive CRM rates (18% versus 4%, p=0·025), with similar surgical morbidity (14% vs. 12%, p=0·766). It is important to note that most surgeons performing taTME are still at the early stage of their learning curve and despite this, results are very promising. Also, most registry patients had risk factors for difficult pelvic dissections [10], being predominantly overweight males (61.2% overweight and obese) with low rectal tumors receiving neoadjuvant chemoradiotherapy.

Interestingly, none of the patient characteristics, including increased BMI or male gender, were significant risk factors for poor histological results. This suggests the transanal approach may overcome patient characteristics that traditionally created a difficult pelvic dissection from the abdominal approach. On multivariate analysis, three risk factors for poor histological features were significant: positive CRM identified on staging MRI, tumor height less than 2cm from the anorectal junction and a posterior dissection to less than 4cm from the anal verge performed transabdominally. The first two of these findings agree with results from the observational, multicenter MERCURY II study that predicted a positive pathological CRM by anteriorly located tumors, presence of extra-mural venous invasion, tumors either within 4 cm of anal verge or 1mm from the CRM [3,28]. Further analysis of long-term registry data will allow assessment recurrence and survival rates.

The only technical risk factor for poor quality specimens identified on multivariate analysis was extensive trans-abdominal dissection and the chances of obtaining a worse specimen is six times greater than if the dissection is performed transanally. The extent of transanal dissection did not increase the risk of poor histological outcome, suggesting that a better oncological resection is likely to be achieved for low rectal tumors via the transanal approach.

Limitations of registry data include the potential for selection bias and relying on accurate, reliable and all-inclusive data recording from centers in different countries. This is a voluntary registry with no formal documentation of the total denominator of all rectal cancer cases performed in each unit during the time-period of the study. Thus, the outcomes cannot be applied to all patients with rectal cancer and further work is needed to establish exact indications and outcomes. Recording data is also time consuming and needs to be inputted at different intervals following the patient's progress. Perioperative outcomes in particular may therefore be under-reported. However, at present, the registry is the largest data source available and its results add to the current body of evidence that is needed in order to establish an identity for this new procedure. The advantages of an international registry are that it assesses the therapeutic effectiveness and safety of taTME in the 'real world', with surgeons at different stages in their learning curve. It also offers a rapid evaluation of new technologies with data from a large number of patients. Furthermore, an open and transparent collaborative is formed amongst contributing centers that are able to share experiences and advice.

Further analysis of registry data will form a prognostic model for key pathological outcomes, pelvic sepsis and other major complications. Once short-term clinical and oncological safety has been confirmed in randomised controlled trials, such as the upcoming COLOR III trial [29], the focus will shift to long-term oncological results, functional outcomes and quality of life after taTME. The online registry continues to record these long-term outcomes and will be reported at three years follow up. The opportunity to record quality of life and functional survey data will also be available. As the interest and uptake in taTME continues to grow, monitoring of outcomes remains vitally important in order to provide patients with the best possible care.

In conclusion, the initial results of the international TaTME Registry suggest that TaTME is predominantly an oncologically safe and effective technique, resulting in low involved marginrates s and good specimen quality with acceptable short-term patient outcomes. Structured training, standardization of the technique and reducing the learning curve are all necessary. Well-designed trials are needed to assess the efficacy of taTME compared with laparoscopic, robotic and open TME surgery.

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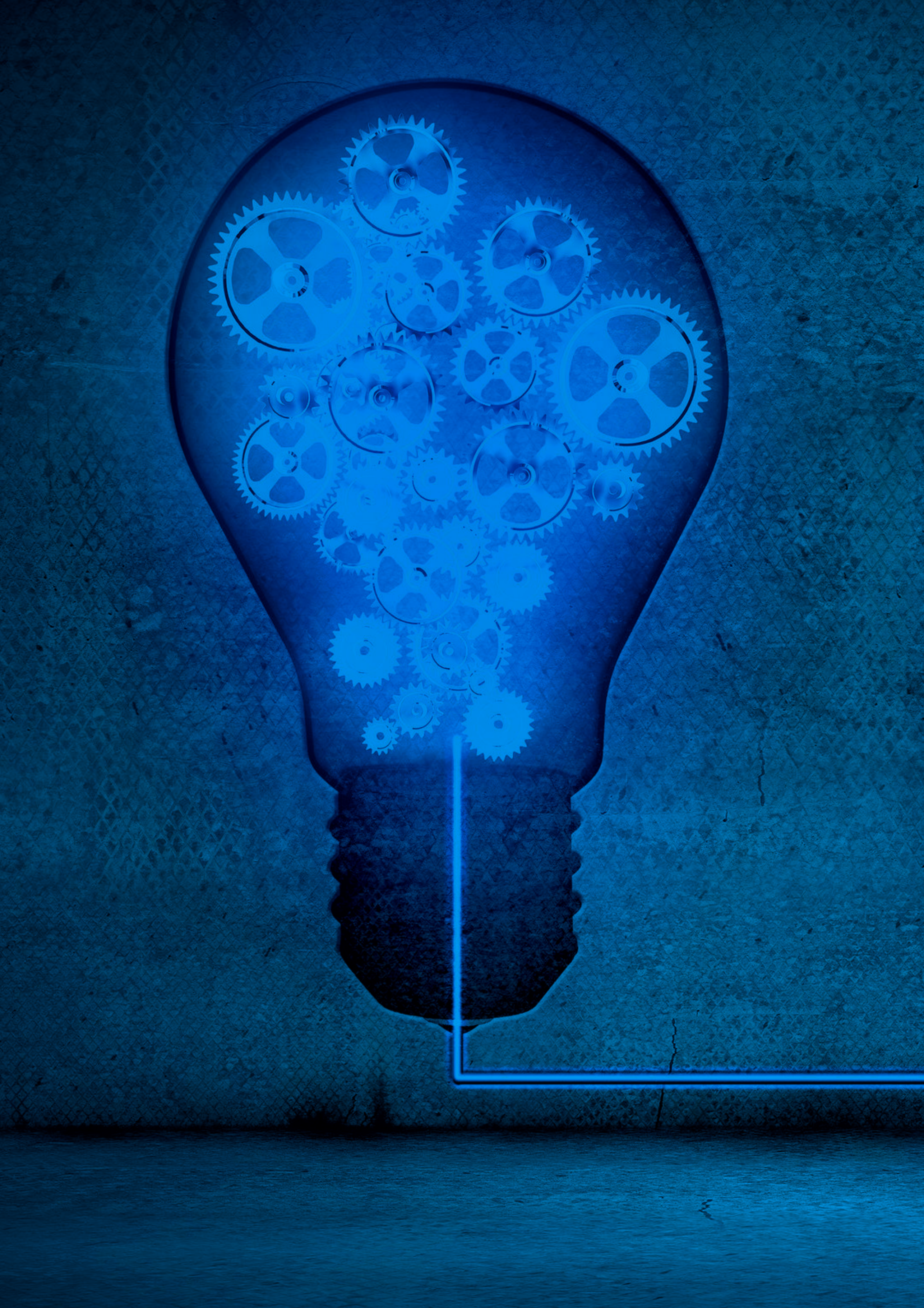

Chapter 15

Incidence and Risk Factors for Anastomotic Failure in 1594 Patients Treated by Transanal Total Mesorectal Excision Results From the International TaTME Registry

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Ann Surg. 2018 Jan 5. doi: 10.1097/SLA.0000000000002653.

Abstract

Objective

To determine the incidence of anastomotic-related morbidity following Transanal Total Mesorectal Excision (TaTME) and identify independent risk factors for failure.

Background

Anastomotic leak and its sequelae are dreaded complications following gastrointestinal surgery. TaTME is a recent technique for rectal resection, which includes novel anastomotic techniques.

Methods

Prospective study of consecutive reconstructed TaTME cases recorded over 30 months in 107 surgical centers across 29 countries. Primary endpoint was "anastomotic failure," defined as a composite endpoint of early or delayed leak, pelvic abscess, anastomotic fistula, chronic sinus, or anastomotic stricture. Multivariate regression analysis performed identifying independent risk factors of anastomotic failure and an observed risk score developed.

Results

One thousand five hundred ninety-four cases with anastomotic reconstruction were analyzed; 96.6% performed for cancer. Median anastomotic height from anal verge was 3.0 ± 2.0 cm with stapled techniques accounting for 66.0%. The overall anastomotic failure rate was 15.7%. This included early (7.8%) and delayed leak (2.0%), pelvic abscess (4.7%), anastomotic fistula (0.8%), chronic sinus (0.9%), and anastomotic stricture in 3.6% of cases. Independent risk factors of anastomotic failure were: male sex, obesity, smoking, diabetes mellitus, tumors >25 mm, excessive intraoperative blood loss, manual anastomosis, and prolonged perineal operative time. A scoring system for preoperative risk factors was associated with observed rates of anastomotic failure between 6.3% to 50% based on the cumulative score.

Conclusions

Large tumors in obese, diabetic male patients who smoke have the highest risk of anastomotic failure. Acknowledging such risk factors can guide appropriate consent and clinical decision-making that may reduce anastomotic-related morbidity.

Introduction

Anastomotic leakage (AL) is a common and potentially devastating complication of a colorectal anastomosis and can result in severe morbidity and mortality, as well as long-term anorectal dysfunction [1]. Additionally, AL has been reported to increase the risk of local cancer recurrence [2], with reduction in overall and disease-free survival [3-5]. AL can markedly impair a patient's quality of life and is detrimental to the doctor–patient relationship [6], particularly as AL can result in prolonged sequelae including anastomotic fistulae, chronic sinuses, and anastomotic strictures. The reported incidence of AL after colorectal surgery is between 2 and 24% [7-10], with the highest rates after low anterior resection [11-12]. The clinical manifestations, and severity, of AL encompass a broad spectrum of symptoms, and signs, from minor symptoms, to major life-threatening events.

As a consequence of technical developments, particularly stapling instruments, but also minimal access techniques, in combination with widespread adoption of total mesorectal excision as the standard treatment for rectal cancer, the rate of sphincterpreserving surgery with low anastomoses has significantly risen. The reduction in abdominoperineal excision rates, with an increase in low anastomoses, has led to an increased overall leakage rate in patients with rectal cancer [13]. Technical drawbacks of minimal access intracorporal anastomosis include the lack of direct tactile sensation, inadequate exposure, and a suboptimal cutting angle of the endo-linear stapler. Crossing staple lines by repeated firings, or incorrect staple height in relation to tissue thickness increases the risk of AL, especially when 3 or more linear staple firings are needed [14-15]. Transanal total mesorectal excision (TaTME) is the latest advanced surgical access technique for pelvic dissection and facilitates different anastomotic techniques without the need for transabdominal rectal transection, particularly in a narrow pelvis. The standard TaTME technique incorporates an open rectal stump with continuity restored by a coloanal handsewn or double pursestring stapled anastomosis [16]. As TaTME adoption increases, careful monitoring and review of outcomes is crucial. Identification of risk factors for AL and overall anastomotic failure may guide preoperative optimization and intraoperative surgical decision-making, adopting measures to reduce risk and consequences of AL, such as selective defunctioning stomas. This is even more important when a novel anastomotic technique is being implemented into clinical practice.

The primary aim of this study was to report "anastomotic failure" rates and incidence of anastomosis-related morbidity in patients following TaTME surgical procedures recorded on the international TaTME registry. The secondary aim was to identify potential risk factors associated with anastomotic failure.

Materials and methods

Study design

Cases recorded on the international TaTME registry[17] between July 2014 and December 2016 by 107 surgical centers in 29 different countries (Appendix 1) were analyzed. The registry is a secure online database open to all international surgeons performing TaTME, as previously described [18]. All contributing surgeons were invited via emails to update their records with 2 subsequent reminders to obtain up-to-date data and minimize missing fields. Contributing surgeons were contacted individually to clarify any unexpected or ambiguous data. The primary endpoint of the study was "anastomotic failure" rate, defined as the overall incidence of anastomotic-related morbidity, including early and late AL, pelvic abscess, anastomotic-related fistula, chronic sinus, and persistent anastomotic stricture after primary rectal resection. "Early" anastomotic leak was defined as a symptomatic leak diagnosed and managed within 30 days of the primary resection. Anastomotic leaks were classified according to the "International Study Group of Rectal Cancer" definition and severity grading system (Appendix 2) [19].

Statistical analysis

All categorical data are presented as number of cases and percentages, whilst continuous data are shown as either mean ± standard deviation (range) or median with range. Categorical variables were compared by the Pearson Chi^2 test, and continuous variables by the two-sample t-test or Mann Whitney U test where appropriate. Risk factors were divided into patient, tumour-related factors, and technical intraoperative factors. Continuous variables were dichotomized using the median or the value at which a significant change occurred as a cut-off point. Variables that achieved a p-value of ≤ 0·100 on univariate analysis were selected for the multivariate analysis to identify independent predictors of anastomotic failure and early AL. Median and mean imputation was used to adjust for missing values where appropriate and first order interactions tested in the multivariate model. A p-value <0·05 was considered statistically significant and odds ratios (OR) and their 95% confidence intervals (CI) are reported. The β coefficients (log odds ratios) derived from the multivariate analysis were used as weights in the derivation of the anastomotic failure observed risk score. Multilevel logistic regression model was used to adjust for possible clustering of anastomotic failure within centers. The Statistical Package for Social Sciences (SPSS) of IBM Statistics, version 24, was used for the analysis.

Results

A total of 1836 cases were recorded on the TaTME registry over a 30-month period. The indication for surgery was rectal cancer in 1663 (90.6%) patients and benign pathology in 173 (9.4%). Overall, 1594/1836 (86.8%) cases had an anastomosis and will be the focus of the results presented in this paper. Of the remaining 242 non-restorative procedures, 236 were planned as such, leaving 6 (0.4%) cases in which the anastomosis was abandoned (Supplementary Table 1).

Table 1: Patient and tumor characteristics

Factor Category	TaTME registry data results Total: 1594 cases
Gender, n (%)	
Male	1080 (67.8)
Female	514 (32.2)
Age in years, mean ± SD (range)	63.7 ± 12.4 (19 – 93)
ASA score, n (%)	
I + II	1271 (80.7)
III + IV	303 (19.3)
Missing	20 (1.3)
BMI in kg/m², mean ± SD (range)	26.3 ± 4.4 (15.6 – 44.2)
Smoking, n (%)	
Smoker	230 (14.4)
Non-smoker	1364 (85.6)
Presence of co-morbidities, n (%)	
Diabetes mellitus	178 (11.2)
Ischemic Heart Disease	222 (13.9)
Active Inflammatory bowel disease	30 (1.9)
Steroid use at time of surgery	16 (1.0)
Previous unrelated abdominal surgery, n (%)	275 (17.3)
Clinical tumor height from anal verge on rigid sigmoidoscopy in cm, median (range)	6.0 (0–17)
Tumor height from anorectal junction on MRI in cm, median (range)	4.0 (0–14)
Pre-operative MRI staging, n (%)	
≥mrT3	930 (69.0)
mrN+	764 (57.3)
Pre-operative CRM involvement on MRI*, n (%)	274 (23.4)
Received neoadjuvant therapy, n (%)	895 (56.1)
TRG response post neoadjuvant therapy, n (%)	
mrTRG 1 & 2 (No or small residual tumor)	446 (52.0)
mrTRG 3 (Mixed fibrosis and tumor)	220 (25.6)
mrTRG 4 & 5 (Mainly or only tumor)	192 (22.4)

SD: standard deviation. ASA: American Society of Anesthesiologists. BMI: Body Mass Index. MRI: Magnetic Resonance Imaging. CRM: Circumferential Resection Margin. N+: Positive nodal status (N1 or N2). TRG: Tumor regression grading on MRI. *CRM involvement on MRI is defined as involved if the distance of tumor or malignant lymph node to the mesorectal fascia was less than 1 mm on MRI. Percentages for *Missing* values use the total number of cancer cases as the denominator (i.e. 1594). Percentages for the variables are calculated out of the total number of actual results available excluding the missing values.

Table 2. Operative details.

OPERATIVE CHARACTERISTICS	TaTME registry data results
Factor	Total = 1594 cases
Category	n (%)
Indication	
Benign	54 (3.4)
Cancer	1540 (96.6)
Operations performed	
Cancer cases:	
High anterior resection	122 (7.9)
Low anterior resection	1411 (91.6)
Total & subtotal colectomies	7 (0.5)
Benign cases:	
Low anterior resection	9 (16.6)
Proctectomy (close rectal) + IPAA	6 (11.1)
Proctectomy (TME plane) + IPAA	37 (68.5)
Completion proctectomy	1 (1.9)
Total colectomy	1 (1.9)
Synchronous 2 team operating	665 (41.7)
Transanal initial dissection:	
Mucosectomy	83 (5.8)
Total intersphincteric	78 (5.5)
Partial intersphincteric	208 (14.7)
Pursestring	1027 (72.5)
Other*	21 (1.5)
Missing	177 (11.1)
Conversion	
Abdominal	69 (4.3)
Perineal	21 (1.3)
Both abdominal and perineal	12 (0.8)
Stoma	
No defunctioning stoma	177 (11.7)
Ileostomy	1282 (85.0)
Colostomy	50 (3.3)
Missing	*85 (5.3)*
Anastomotic technique	
Manual	512 (34.0)
Stapled	996 (66.0)
Missing	*86 (5.4)*
STAPLED ANASTOMOSES	
Stapled configuration	485 (49.6)
End-to-end	433 (44.3)
Side-to-end	24 (2.5)
Colonic J pouch	36 (3.6)
Ileal pouch-anal anastomosis	*18 (1.8)*
Missing	

MANUAL ANASTOMOSES	
Manual configuration	
End-to-end	334 (65.2)
Side-to-end	136 (26.6)
Colo-anal J pouch	30 (5.9)
Ileal pouch-anal anastomosis	12 (2.3)
Height of anastomosis from anal verge in cm, median (range)	
Manual	2.0 (0-9.0)
Stapled	4.0 (0-11.0)
Operative time, mean ± SD (range)	
Total operative time, hours:minutes	4:12 ± 1:42 (0:30 – 12:13)
Perineal phase time, hours:minutes	2:03 ± 1:03 (0:14 – 7:47)
Intraoperative adverse events	
Technical problems during transanal phase	330 (18.0)
Incorrect dissection plane	91 (5.7)
Pelvic bleeding >100mls	67 (4.2)
Visceral injuries during transanal phase, total	28 (1.8)
Urethral injury	12 (0.8)
Rectal tube perforation	7 (0.4)
Vaginal perforation	5 (0.3)
Hypogastric nerve divisions	2 (0.1)
Bladder perforation	2 (0.1)

APE: Abdomino-perineal excision. IPAA: Ileal Pouch-Anal Anastomosis. TME: Total mesorectal excision. SILS: Single incision laparoscopic surgery. SD: Standard Deviation

*Other transanal phase surgical approaches include extra-levator dissection and abdomino-perineal excision.

Percentages for *Missing* values use the total number of cases as the denominator (i.e. 1594). Percentages for the variables are calculated out of the total number of actual results available excluding the missing values.

Patient and tumour characteristics

Table 1 outlines patient and tumour characteristics. The majority of registered cases were male patients with a median (range) age of 65 (19–93) years and median (range) body mass index (BMI) of 26.0 (15.6–44.2) kg/m^2. In total 275 patients (17.3%) had previous unrelated abdominal surgery, including 21 (1.3%) prior prostatectomy. Twelve patients (0.8%) had received pelvic radiotherapy prior to diagnosis of rectal cancer. The indication for surgery was rectal cancer in 1540 (96.6%) of reconstructed cases with a median tumour height from anorectal junction on staging MRI of 4.0 (0–14) cm. Radiological cancer staging was reported as stage 0, I, II, III and IV in 17 (1.2%), 267 (19.5%), 287 (20.9%), 689 (50.2%) and 112 (8.2%) cases respectively. Pre-operative involvement of the circumferential resection margin (CRM) was seen on 274 (23.4%) staging MRI scans and 895 (56.1) patients received neoadjuvant therapy; the majority as long course chemoradiotherapy.

Intraoperative details

Operative details are summarized in Table 2, showing that the commonest operation performed was a low anterior resection in 89%, with synchronous operating by two teams in 41.7%. The abdominal phase was performed laparoscopically in 1350 (86.3%); with SILS, open surgery and robotic approaches in 179 (11.4%), 26 (1.7%) and 10 (0.6%) respectively. The recorded estimated blood loss was 0-99mls in 42.3% and 100-499mls in 21.1%. In 32 (2.1%) blood loss > 500mls was reported, mainly due to pelvic bleeding and splenic hemorrhage following splenic flexure mobilization. The specimen was extracted transanally in 43.9%, whilst abdominal extraction was utilized in the remainder either via Pfannenstiel incision (26.6%), iliac fossa/stoma site (14.8%), umbilical opening (6.7%) or the laparotomy incision (8.0%). A pelvic drain was inserted in 1134 patients (71.1%).

The commonest anastomotic technique performed was mechanical stapling in 66% with an end-to-end or side-to-end configuration in 94% of cases (Table 2). The stapler diameters used included 25-28mm, 29mm, 31-32mm and33mm in 14.5%, 22.3%, 17.4% and 45.8% respectively.

Intraoperative adverse events occurred in 487/1594 (30.6%). Conversion to an alternative technique was required in 90 patients (5.6%). Abdominal access conversion was primarily required due to limited visualization secondary to excessive adhesions and obesity, whilst perineal conversions occurred after difficulty identifying the correct dissection plane leading to bleeding and/or visceral injuries. Twelve cases underwent both perineal to abdominal, and minimal access to open abdominal conversions, and were predominantly men (11/12) with a higher BMI (mean 27.1 ±3.9 kg/m^2). Table 2 outlines the incidence of technical transanal difficulties and adverse events. A total of 41 visceral injuries were recorded during both abdominal and transanal phases; 12 (0.8%) urethral injuries, 7 (0.4%) rectal tube perforation, 5 (0.3%) vaginal perforations, 5 (0.3%) ureteric injuries, 5 (0.3%) enterotomies, 3 (0.2%) bladder perforations, 2 (0.1%) hypogastric nerve divisions, 1 (0.06%) splenic injury with significant hemorrhage, and 1 (0.06%) diaphragmatic perforation during splenic flexure mobilization. Anastomosis-related technical difficulties included anastomotic defects requiring additional handsewn sutures (n=12), complete re-do of the anastomosis due to ischemia (2) or rectal tear (1). Further intraoperative complications included injury to the mesenteric vascular arcade during attempted transanal specimen extraction, carbon dioxide embolism with hemodynamic instability and intraoperative myocardial infarction.

Post-operative outcomes and Anastomosis-related morbidity

The median length of hospital stay was 8 days (range 2 to 94), with morbidity and mortality rates within 30-days of the primary resection of 35.4% and 0.6% respectively. Overall, 44 deaths (2.8%) have been reported over a mean follow up period of 14 months (range 3–68). Post-operative complications within 30-days, categorized according to the Clavien-Dindo classification [20] as I/II, III, IV and V, occurred in 354 (22.2%), 188 (11.8%), 13 (0.8%)

and 9 (0.6%) patients respectively. Emergency surgical re-intervention for any cause within 30-days or index admission was required in 128 (8.0%) (Supplementary Table 2: Summary of emergency operations).

Table 3: Anastomosis-related morbidity

POST-OPERATIVE COMPLICATIONS Factor Category	**TaTME registry data results** Total: 1594 cases n (%)
Anastomotic leak:	
Early*	124 (7.8)
Delayed^	32 (2.0)
Pelvic abscess	75 (4.7)
Anastomotic fistula	12 (0.8)
Anastomotic sinus	15 (0.9)
Anastomotic stricture	58 (3.6)
ANASTOMOTIC FAILURE§	
Number of events diagnosed	316
Number of patients affected	250 (15.7)
Management of anastomotic failure:	
Early anastomotic leak score	
A – Conservative management	23 (20.7)
B – Re-intervention without laparotomy	68 (61.3)
C – Laparotomy required	20 (18.0)
Missing	*13 (10.5)*
Total number of patients requiring re-interventions due to anastomotic failure / total number of patients undergoing a re-intervention at any time point	135 /311 (43.4)
Total number of re-interventions for anastomotic failure at any time point	141
Type of re-interventions for anastomotic failure	
Surgical	108 /141 (76.6)
Radiological	27 (19.1)
Endoscopic	6 (4.3)

*Early anastomotic leaks were diagnosed within 30-days of the primary colorectal resection.
^Delayed anastomotic leaks were diagnosed after 30-days of the primary colorectal resection.
§Anastomotic failure is defined as the defined as the overall incidence of anastomotic-related morbidity, including early and late AL, pelvic abscess, anastomotic-related fistula, chronic sinus and persistent anastomotic stricture following primary rectal resection.

Table 3 outlines the incidence of anastomosis-related morbidity, showing an overall anastomotic failure rate of 15.7%. Early AL, diagnosed within 30-days of the primary resection, occurred in 124 (7.8%) patients; 68 (61.3%) of these were managed by active therapeutic intervention without the need for a re-laparotomy (Grade B). Overall 311/1594 (19.5%) patients required a re-intervention (surgical, endoscopic or radiological) for any cause at some point during the study period, whilst 135/311(43.4%) of these patients required a re-intervention for anastomotic failure. A total of 141 re-interventions for failure were reported during the study period. The majority, 108/141 (76.6%), of re-interventions for anastomotic failure involved surgery under general anesthesia, with either examination of the anastomosis with washout ± vacuum therapy, re-suturing for anastomotic dehiscence, laparoscopic lavage ± defunctioning stoma or as a later re-operation with dilatation or anastomotic re-fashioning for anastomotic stricturing. Out of 250 patients diagnosed with anastomotic failure, 219 had a defunctioning stoma created at the index operation. Gut continuity was restored in 124 (56.6%). The median interval to stoma closure was 142 days (approx. 4½ months), range 5–1638 days. Twelve patients (0.8%) underwent a takedown of the anastomosis with an end stoma in the form of a Hartmann's procedure for anastomotic leak (11 cases) and a completion proctectomy with end colostomy for a tight anastomotic stricture (1 case). A further six patients (0.4%) with anastomotic leaks were managed with laparoscopic washout and formation of a defunctioning stoma.

Histopathological results for the 1540 cancer cases are described in supplementary table 3. In summary, a curative R0 resection rate was achieved in 95.7%. A positive CRM or distal resection margin (DRM) was reported in 60 (3.9%) and 10 (0.6%) cases respectively. Major defects in the TME specimen and rectal perforations were noted in 75 (4.9%) specimens.

Risk factors for early anastomotic leak

Univariate analysis identified eight patient–related and five technical risk factors (p value ≥0.100) for early AL (Table 4). On multivariate analysis, seven of these factors remained statistically significant. Patient–related risk factors included male gender, obesity, smoking (borderline significance), diabetes, larger tumors (>25mm maximum diameter), and tumor height >4 cm from anorectal junction on MRI. The only significant technical risk factor was excessive intraoperative blood loss of ≥500mls. Significantly more cases that did not have a defunctioning stoma developed an early symptomatic AL compared to those that were defunctioned (12.4% vs. 7.2%, OR 0.547, 95% CI 0.334–0.895, P=0.015). Although univariate results suggested that patients who did not receive neoadjuvant therapy were at higher risk of AL and failure (Tables 4 & 5), these findings were not significant on multivariate analysis and outcomes would have been confounded by the fact that significantly more patients who had neoadjuvant treatment were defunctioned (32.8% vs 58.1%, OR 2.846, 95% CI 2.042–3.967, P<0.001). Defunctioning stoma was not included in multivariate analysis as previous studies have shown that the presence of a defunctioning stoma may not prevent AL, but rather reduces the consequences should an AL occur [21]. Hence, a defunctioning stoma is proposed as a strategy to reduce the adverse effects of AL and is recommended in patients with identified risk factors.

Risk factors for anastomotic failure

Fourteen potential risk factors associated with anastomotic failure were identified on univariate analysis (Table 5). Eight of these (5 patient-related and 3 technical factors) remained statistically significant on multivariate analysis including male patients, obesity, smoking, diabetes, larger tumors over 25 mm, manual anastomoses, excessive blood loss of ≥500 milliliters, and longer perineal phase operative time of >1.5 hours. The manual technique significantly increased the risk of late stricturing (5.9% vs. 2.7%, OR 0.448, 95% CI 0.263–0.762, $p=0.002$). The presence of a defunctioning stoma did not appear to significantly influence the incidence of anastomotic failure in this cohort (no stoma 17.5% vs. stoma 15.6% OR 0.872, 95% CI 0.576–1.320, $p=0.516$). Multilevel regression analysis did not demonstrate any significant clustering between hospitals for anastomotic failure rates, nor alter the significant risk factors. Figure 1 shows the scoring of patient and tumour-related risk factors and the associated percentage risk of developing anastomotic failure observed in this cohort of 1594 patients treated by a TaTME technique with a low anastomosis.

PRE -OPERATIVE RISK SCORING		
RISK FACTOR	**SCORE**	
Gender	Female - **0**	Male - **1**
Body Mass Index	<30 kg/m^2 - **0**	≥30 kg/m^2 - **1**
Smoking	No – **0**	Yes - **1**
Diabetes	No – **0**	Yes - **2**
Tumo r size	≤25mm - **0**	>25mm - **1**
	Cumulative Score : ___________	

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Table 4. Univariate and multivariate analyses of patient-related and technical risk factors for early anastomotic leak.

Factor Category	Event Rate %	UNIVARIATE ANALYSIS Adjusted Odds ratio	95% Confidence Interval	P value	MULTIVARIATE ANALYSIS Adjusted Odds ratio	95% Confidence Interval	P value
PATIENT–RELATED FACTORS							
Gender	Female 4.1	1			1		
	Male 9.5	2.475	1.529–4.006	<0.001	2.173	1.331 – 3.548	0.002
BMI	$<30 kg/m^2$ 6.9	1			1		
	$\geq 30 kg/m^2$ 12.4	1.901	1.238–2.918	0.003	1.589	1.012 – 2.494	0.044
Smoker	Non-smoker 7.0	1			1		
	Smoker 12.2	1.831	1.172–2.861	0.007	1.576	0.991 – 2.506	0.055
Diabetic	Non-diabetic 6.5	1			1		
	Diabetic 18.0	3.154	2.037–4.883	<0.001	2.700	1.702 – 4.282	<0.001
Tumor height on MRI from ARJ	≥4cm 6.9	1			1		
	>4cm 9.8	1.466	1.010–2.127	0.043	0.607	0.401 – 0.920	0.019
Tumor size	≥25mm 5.5	1			1		
	>25mm 10.4	1.997	1.291–3.088	0.002	1.883	1.212 – 2.926	0.005
ASA	I-II 6.8	1					
	III-IV 12.2	1.917	1.275–2.881	0.002			
Neoadjuvant therapy	No 9.2	1					
	Yes 6.7	0.713	0.494–1.029	0.070			
TECHNICAL FACTORS							
Perineal dissection	Open dissection^	1					
	4.9	1.896	1.127–3.190	0.014			
Anastomotic height from AV	Endoscopic PS* 8.9	1					
	≥3cm 6.1	1.779	1.194–2.651	0.004			
	>3cm 10.4						
Pelvic bleeding	Negligible 7.5	1					
	Noticeable[b] 13.4	1.905	0.920–3.943	0.078	1		
Estimated blood loss	<500mls 6.8	1			4.334	1.900–9.888	<0.001
	≥500mls 25.0	4.551	1.971–10.506	<0.001			
Specimen extraction	Transanal 6.2	1					
	Abdominal 9.5	1.601	1.073–2.389	0.020			

BMI: Body Mass Index. ASA: American Society of Anesthesiologists. MRI: Magnetic Resonance Imaging. ARJ: Anorectal junction. AV: Anal verge.

^Open dissection includes total and partial intersphincteric and mucosectomy dissections performed open. *PS: Pursestring suture placed endoscopically. [β]Noticeable pelvic bleeding was >100 mls with 9% of cases with pelvic bleeding having >500 mls blood loss.

Table 5. Univariate and multivariate analyses of patient-related and technical risk factors for overall anastomotic failure.

		UNIVARIATE ANALYSIS			MULTIVARIATE ANALYSIS		
Factor Category	Event Rate %	Adjusted Odds ratio	95% Confidence Interval	P value	Adjusted Odds ratio	95% Confidence Interval	P value
PATIENT–RELATED FACTORS							
Gender	Female 12.1	1			1		
	Male 17.4	1.537	1.129–2.092	0.006	1.419	1.030–1.955	0.032
BMI	<30kg/m^2 14.6	1			1		
	≥30 kg/m^2 22.6	1.698	1.221–2.362	0.002	1.484	1.049–2.102	0.026
Smoker	Non-smoker 14.7	1			1		
	Smoker 21.7	1.617	1.142–2.288	0.006	1.506	1.054–2.153	0.025
Diabetic	Non-diabetic 14.2	1			1		
	Diabetic 27.5	2.296	1.600–3.295	<0.001	1.873	1.282–2.738	<0.001
Tumor size	≥25mm 11.5	1			1		
	>25mm 19.1	1.813	1.313–2.504	<0.001	1.648	1.198–2.268	0.002
ASA	I-II 13.7	1					
	III-IV 23.8	1.965	1.443–2.677	<0.001			
Ischemic heart	No IHD 14.7	1					
disease, IHD	IHD 22.1	1.650	1.162–2.343	0.005			
Neoadjuvant	No 17.5	1					
therapy	Yes 14.3	0.789	0.602–1.034	0.086			
TECHNICAL FACTORS							
Anastomotic	Manual 18.9	1			1		
technique	Stapled 14.7	0.735	0.554–0.975	0.032	0.745	0.559–0.993	0.045
Estimated blood	<500mls 13.9	1			1		
loss	≥500mls 34.4	3.232	1.525–6.848	<0.001	3.020	1.431–6.376	0.004
Perineal	≥1.5hrs 12.1	1			1		
operative time	>1.5hrs 17.9	1.576	1.033–2.404	0.034	1.554	1.031–2.343	0.035
Intraoperative	No 14.6	1					
problem	Yes 18.1	1.287	0.968–1.710	0.082			
Pelvic bleeding	Negligible 15.3	1					
	Noticeable[β] 23.9	1.734	0.972–3.092	0.059			
Conversion	No 15.2	1					
	Yes 23.3	1.695	1.019–2.817	0.040			

BMI: Body Mass Index. ASA: American Society of Anesthesiologists. [β]Noticeable pelvic bleeding was >100 mls with 9% of cases with pelvic bleeding having >500 mls blood loss.

Discussion

Anastomotic complications can lead to significant early and long-term morbidity, with a possible adverse impact on cancer outcomes [2,22,23]. Identifying high-risk patients and implementing appropriate reduction strategies, through pre-operative patient optimization, technical considerations and focused post-operative management with early recognition of adverse signs, are key to improving patient outcomes.

In contrast to abdominal rectal resections that usually employ a stapled distal transection, TaTME involves a transanal endoscopic full rectotomy, with an open rectal stump. A number of stapled and handsewn techniques have been reported to perform an anastomosis after TaTME [16]. Most reports have small patient numbers with little data on the morbidity associated with anastomoses following TaTME.

Results from the recently commenced randomized controlled trials comparing TaTME with laparoscopic TME may provide some robust data in the future, should sufficient numbers be enrolled [24,25]. Currently, the international TaTME registry[17] provides the largest cohort of TaTME cases performed in the wider surgical community, allowing analysis and monitoring of outcomes, and incorporating outcomes from units with different levels of surgical experience. In this study 1594 TaTME cases with an anastomosis were analyzed, with an early leak rate of 7.8%. This value is higher than the previously published rate of 5.4% in the initial 720 registry cases [18] and could be explained by an increased complexity of cases performed transanally, wider adoption of TaTME by surgeons at the start of their learning curve or improved recording and reporting of adverse events on the registry. Over the last year, the number of surgical centers joining the registry has almost doubled with approximately 32 cases recorded per month and 35% of centers having performed less than 5 TaTME cases.

Nonetheless, the leak rate remains within an acceptable range comparable to previously reported incidences in colorectal surgery [7-10]. Similarly, the overall morbidity rate of 35.4% is within recognized rates comparable to conventional abdominal TME surgery, especially when we take into account the majority of cases selected for TaTME are the more difficult low rectal cancer cases.

Although higher leak rates have been attributed to low surgical volume [26,27], Hyman et al [28], found that even in a group of high-volume surgeons, leak rates still ranged from 1.6–9.9%; despite more surgical experience and high caseload. This variation may be due to the multifactorial etiology and contributing factors that lead to AL, including both non-modifiable and modifiable patient and tumor–related risk factors. Independent risk factors identified in previous studies include male gender, smoking, obesity, pre-operative radiotherapy, emergency surgery, and tumor-related factors such as distal infraperitoneal tumors, larger tumor size, and advanced tumor stage [13,19,29–31]. Our study found similar factors to be significant for AL and overall anastomotic failure, in particular male diabetic smokers with large tumors. Sorensen et al. [32] reported that smoking impairs tissue healing through nicotine-induced vasoconstriction, reduced perfusion, and carbon-monoxide induced cellular hypoxia, leading to reduced tissue oxygen and collagen deposition. Diabetes also impacts wound healing as uncontrolled hyperglycemia leads to vascular damage, resulting in decreased blood flow and cellular accumulation of toxic glucose-derived metabolites [33].

A recent meta-analysis by Qu et al reported four intra-operative factors significantly associated with increased risk of AL, including longer operative time, number of stapler firings >2, intra-operative transfusions/blood loss >100 mL, and anastomotic level of <5 cm from anal verge [31]. In TaTME, the distal rectal transection does not involve multiple stapler firings and so eliminates this potential risk factor. However, excessive blood loss and longer operative time were also found to be important factors following TaTME. Interestingly, anastomotic height appeared to be associated with AL only on univariate analysis (but not overall anastomotic failure) and a higher rate of AL occurred in anastomoses at a level of >3 cm from anal verge. Similarly, higher tumors located >4 cm from the anorectal junction on MRI were found to pose a greater risk of leakage than lower tumors, and this remained significant on multivariate analysis. Colorectal surgeons are likely to have less experience in performing a transanal pursestring on an open rectal stump at a higher distance from the anal verge prior to stapled anastomosis in their early phase of the learning curve for TaTME. The lower stapled anastomoses can also be reinforced with additional handsewn sutures that would be difficult to place more proximally, and any leakage through a lower anastomosis is more likely to discharge transanally rather than accumulating intra-abdominally with symptomatic sepsis.

The evidence regarding manual versus stapled techniques is more conflicting with no significant differences in AL rates, stricture and mortality in colorectal anastomoses reported in a Cochrane review and recent meta-analysis [34,35]. Cong et al.[36] did find significantly lower rates of AL and stricture formation following stapled compared with handsewn coloanal anastomoses after intersphincteric resection. Similarly, our results suggest that the odds of developing anastomotic failure, in particular anastomotic stricture, is 30% less likely if a stapled anastomosis is performed; although no association was noted with early AL. Depending on the degree of anastomotic stricturing, multiple interventions may be required including anastomotic dilatation, re-do anastomoses or even conversion to a permanent stoma; all of which contribute to long-term morbidity and increased healthcare costs.

Reassuringly, 82% of TaTME patients diagnosed with an early AL were successfully managed without the need for a laparotomy. Overall 20.7% were managed conservatively and 61.3% underwent active re-intervention without requiring laparotomy. Similar findings were reported by Kim et al [37] in patients with AL following minimally invasive (laparoscopic and robotic) anterior resection, with 19.7% undergoing a second open operation, whilst 69% and 11.3% had laparoscopic re-intervention and transanal surgery respectively. The benefits of a less invasive approach, where feasible, compared with a laparotomy for AL after initial laparoscopic surgery were reported in two retrospective cohort studies [38,39] with shorter intensive care stay, shorter time to first diet and earlier stoma functioning.

Reduction strategies and treatment algorithms for anastomotic failure have been developed and proposed by numerous authors and surgical societies [7,21,40,41]. The risk factors and the pre-operative observed risk scoring reported in this study can aid the perioperative planning for patients undergoing TaTME. The observed risk score does however require validation which is planned on an external patient cohort in the future. Pre-operative optimization with tighter glycemic control for diabetics, weight loss for the obese and active smoking cessation programs can be initiated immediately, especially if more time is available during neoadjuvant treatment or prior to non-urgent benign resections. Operative strategies, such as the formation of a defunctioning stoma, pelvic drain placement, and use of fluorescence angiography [42], if available to assess bowel perfusion, should be considered intra-operatively especially if the risk score proposed here is high. Although accurate prediction of risk is impossible, appreciation of these factors may help with the discussion and decision-making with the patient as to whether an anastomosis should even be attempted, especially in the context of poor pre-existing bowel function and/or poor physiological reserve to cope with anastomotic failure.

The limitations of this study include the potential for reporting bias and human error in recording registry data. Post-operative complications, in particular, may be difficult to capture, especially if patients attend a different hospital or are treated in the community. Thus, longer term outcomes are likely to be under-reported. Differences in the investigative methods to diagnose anastomosis-related pathology may further under-report the true incidence or increase heterogeneity amongst groups. Early leaks were also more likely to have been identified clinically and, we therefore cannot address the question of occult or subclinical leaks. However, the main intention was to determine the incidence of symptomatic leaks and to identify potential risk factors. Although the TaTME registry captures over 200 variables, certain factors that may influence anastomotic healing, such as perioperative fluid management and use of vasopressors, are not recorded. Nonetheless, at present, this registry is the largest TaTME database available and encompasses the wider surgical community performing the technique worldwide with an open and transparent collaborative.

In conclusion, anastomosis-related complications cause significant morbidity and are an ongoing challenge. New and modified anastomotic techniques have been developed to address the open stump following TaTME [16]. Analysis of the risk factors identified in this study for AL and longer–term anastomotic failure aids perioperative management and decision making tailored to the patient to reduce and mitigate complications. Further research is required to determine the learning curve associated with TaTME and the optimal training pathway [43-45] to further reduce the occurrence of adverse events and to optimize the benefits of this novel access technique.

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APPENDICES

Summary

The objective of this thesis was the present how Transanal Total Mesorectal Excision (TaTME) was introduced into daily clinical practice while adhering to the IDEAL framework recommendations for surgical innovation.

In **Chapter 1**, we describe the routine use of the "glove port" for Single Incision Laparoscopic surgery (SILS). In comparison with more conventional multiport laparoscopic approaches, SILS minimizes the surgical trauma even further to facilitate improved cosmesis as well as reduced likelihood of trocar wound complications and incisional pain. However, the necessity for expensive disposable equipment may hamper uptake and technique advancement as benefits are as yet unclear. The glove port is a cheap, useful and readily available tool whereby a surgical glove is snapped onto a conventional wound protector. The choice of a low cost equivalent, will allow surgical units to embrace SILS throughout the spectrum of their clinical case-load ranging from introductory level to complex interventions.

Going forward, in Chapter 2 we introduce the concept of "SOLE" surgery: sealed orifice laparoscopic or endoscopic surgery. The concept of SILS using a glove port described in chapter one is broadened to a wider pallet of applications. The authors postulate that for single-incision laparoscopic devices, the access modality should not only facilitate SILS but also support multiport laparoscopy as well as facilitate transanal working and natural orifice specimen extraction (and thereafter potentially transluminal surgery). In this way, technical skills and instrumentation can overlap between approaches in order to obviate parallel learning-curve requirements and simplify economics. The access device that best fits these criteria is the surgical glove port and we demonstrate the global applicability of this simple access device for laparoscopic procedures but also transanal resections in a manner that is reliable, reproducible, ergonomical and economical.

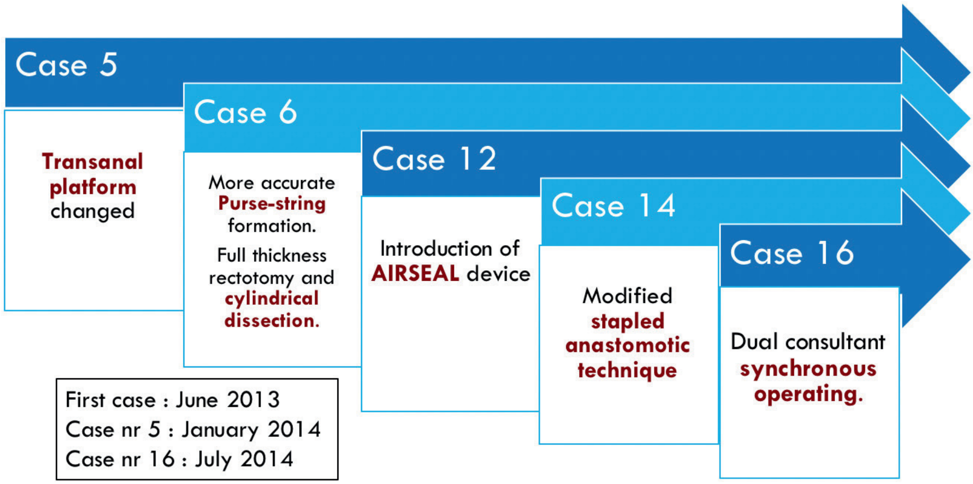
In **Chapter 3** we describe the clinical application of a modified technique for transanal endoscopic resection using the transanal glove port. Over a 3-month period, consecutive non-selected patients eligible for standard Transanal Endoscopic Microsurgery (TEM) were offered a procedure performed via a 'glove TEM port'. This access device was constructed on-table using a circular anal dilator (CAD), wound retractor and standard surgical glove, along with standard, straight laparoscopic trocar sleeves and instruments. Fourteen patients underwent full-thickness resection of benign (n=8) or malignant (n=6) rectal pathology. CAD insertion failed in one patient and conventional TEM assistance was needed in another, leaving 12 procedures completed successfully by glove TEM alone as planned. The median (range) duration of operation and resected specimen area were 93 (30– 120) min and 12 (3– 152) cm^2 respectively. There was no intraoperative and minimal postoperative morbidity, with a median follow-up of 5·7 (2·7–9·4) months. This study has shown that the glove TEM

port is a safe, inexpensive and readily available tool that can be used in combination with regular laparoscopic tools for transanal resection of rectal lesions.

In **Chapter 4** we explored whether it was possible to integrate the robot (da Vinci® Surgical System) into transanal work. Following the initial experiments in an ex vivo model, cadaveric experiments were completed. The Cadaveric work revealed that Robotic transanal surgery using the glove transanal platform was feasible, and that the set-up developed was ready to be reproduced and tested in patients. The Robotic integration offered an improved magnified three-dimensional view, excellent ergonomics, tremor elimination, motion scaling, and the availability of instruments with multiple degrees of freedom. All these features are ideal for working in a confined space, where conflicts between instruments or between instruments and optics are otherwise common.

The initial clinical application of Robotic TAMIS for local excision of rectal lesions is described in **Chapter 5**. Sixteen patients underwent robotic TAMIS for rectal lesions with a median (range) distance from the anal verge of 8 (range 3– 10) cm. The median size of the resected specimen was 5·3 (0·5–21) cm^2. The median docking time and duration of operation were 36 (18– 75) and 108 (40– 180) min respectively. One conversion to regular (non-robotic) TAMIS was needed owing to difficulties accessing the rectum. Glove puncture necessitated replacement in four procedures, an unstable pneumorectum arose during one operation and one patient developed a pneumoperitoneum. One patient required catheterization for urinary retention. The median hospital stay was 1·3 (0– 4) days. This first report on robotic TAMIS established feasibility and the intraluminal versatility of the platform would also lend itself to more advanced extraluminal transanal procedures. However the cumbersome, time-consuming set-up and prolonged operative times are drawbacks and cost-effectiveness needs further exploration. As we gained more experience with TAMIS through various platforms we broadened the application to TaTME, and in **Chapter 6** we report our very early experience with this new technique as early adopters. From June 2013 to September 2014, 20 selected patients underwent TaTME for malignant and benign rectal pathologies. Of the 20 patients (14 male), seventeen (85%) had rectal cancer lying at a median distance of 2 cm (range 0–7) from the anorectal junction. The benign conditions consisted of a rectovaginal fistula after a total colectomy and ileorectal anastomosis for ulcerative colitis, rectal erosion after ventral mesh rectopexy and rectal stenosis after TEM for a large villous adenoma. The operations included Low Anterior Resection (n=16), Abdominoperineal excision (n=2), and completion proctectomy (n=2). Three conversions (15%) occurred, including one due to bleeding from the pelvic side wall, another due to dense abdominal adhesions, and one due to access problems with the glove port. The mean operation time was 315.3 (180-480) min, which reflects the steep learning curve and could be further shortened by a two-team approach. There were six postoperative complications of which two (10%) were Clavien–Dindo Grade IIIb (pelvic haematoma and a late contained anastomotic leakage). The median length of stay was 7 days.

The TME specimen was intact in 94.1% of cancer cases. The mean number of harvested lymph nodes was 23.2. There was only one positive circumferential resection margin (tumour deposit; R1 rate 5.9%). One patient developed a distant recurrence after a short median follow-up of 10 (6-21) months. This small series confirmed that TaTME was feasible with benefits for the distal rectal dissection, but also highlighted the steep learning curve associated with the procedure, even in experienced hands. Several technical changes were implemented during this study period (see figure below), which led to further standardization of the technique, some of which are described in chapters 7-9.



In **Chapter 7** the use of a conventional laparoscopic insufflation unit is compared to the AirSeal® System in TaTME cases. Using a conventional insufflator, two notable obstacles in attaining a perfect transanal endoscopic surgical field are encountered: 1) excessive diathermy-induced smoke in an already restricted operative field and 2) bellowing or oscillation of the rectum ('unstable pneumorectum'). The AirSeal® System consists of an Intelligent Flow System (iFS) control unit, one valveless access port and one contiguous trilumen filter tube set which provides constant smoke evacuation and a stable operative field (" stable pneumopelvis "). The adoption of this technology allows the operator to focus on the more important aspects of surgical dissection rather than being distracted by the need for continually venting smoke, loss of insufflation, pausing to clean the endoscope, and having the assistant battling to maintain an optimal view in a confined space with fluctuating levels of pressure.

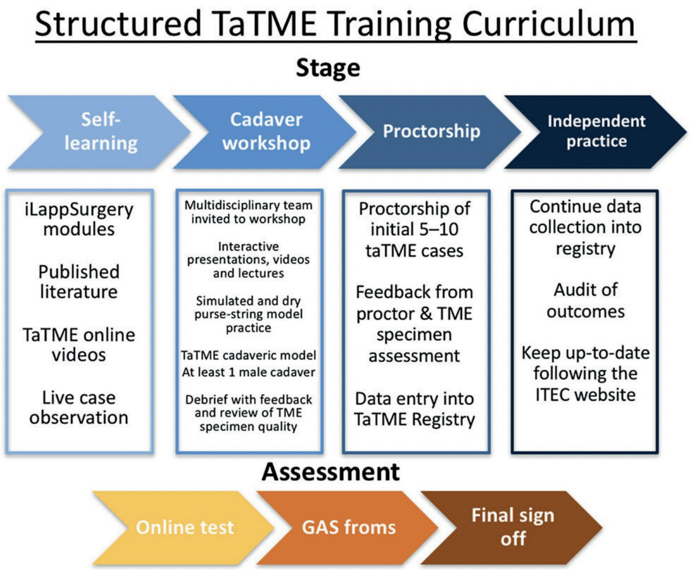
In **Chapter 8,** the authors describe two distinct visual features that may facilitate adherence to the correct and safe dissection plane for TaTME: Triangles and 'O's. The surgeons' interpretation and visual appreciation of the appropriate dissection plane differs from a pure abdominal approach. The misperception of the actual anatomy and surgical planes is further enhanced by the visible effects imposed upon the operative field by CO2 insufflation. Deviations from the TME plane, if not recognized and corrected can lead to autonomic nerve injury, visceral injury (vagina/urethra/bladder/rectal wall) and troublesome hemorrhage. Any violation or incursion into a new fascial plane will lead to the formation of an 'O' or 'halo' sign. This occurs as the insufflation of CO_2 leads to pneumatic dissection which evenly distributes pressure forces and blows the fascial defect into the shape of a circle. A 'triangle' represents a tethering point of a deeper plane which has not been released. The apex indicates the correct dissection plane between that deeper plane and the current plane of dissection. Understanding and recognizing these visual clues should alert the surgeon that if they appear, to slow down and carefully ascertain the correct plane of dissection to avoid collateral damage and imperfect TME specimens.

A crucial and difficult step is the formation of a stapled low colorectal or coloanal anastomosis. At the start of the procedure the rectum is divided without a stapler leaving an open rectal stump, different from a surgeons' standard practice with a pure abdominal approach. In **Chapter 9** we describe in detail the different anastomotic techniques, and how each technique should be tailored according to the length of the anal canal and height of anastomosis. From personal experience of the authors, the advantages and disadvantages of each technique are discussed. Outcomes of anastomotic healing are described later in chapter 15.

After reporting our own initial experience, in **Chapter 10** we systematically reviewed all the available literature reporting early experience on the use of TaTME. The aim was 1) to assess the perioperative outcome and 2) the oncological quality of resections using a TaTME approach. Thirty-six studies with 627 patients were included; 510 patients underwent TaTME and 117 patients Laparoscopic TME. Mean operative times ranged from 143 to 450 min. The reported conversion rate was 2.3% (n=12), primarily due to tumour related factors and abdominal adhesions. Of the studies reporting on the anastomotic technique, 66% of the anastomoses were hand-sewn coloanal and 34% were stapled, giving a ratio of handsewn coloanal to stapled anastomoses of 2:1. The peri-operative morbidity rate of 35% for TaTME is comparable to that of open and Lap TME. The most frequently reported postoperative complication was acute anastomotic leaks, at 6.1%. However a urethral injury occurred in three patients, which is a serious complication specifically related to TaTME, unseen in open or Lap TME. The oncological quality of resection for TaTME appeared comparable to that of open and laparoscopic TME; the CRM was positive in 5% of cases, the DRM was positive in 0.3% and the reported mean number of harvested lymph nodes ranged from 11.5 to 33. In regards to the mesorectal quality, the mesorectal excision was described as complete in 88% of cases, as nearly complete in 6% of cases and as incomplete in 6%. Based on the quality of the studies included in this systematic review, which were mostly case reports and case series, we can only conclude that TaTME is feasible and a reproducible technique.

To ensure adequate numbers for evaluation of this new procedure, a UK registry has been set up which is introduced in **Chapter 11**. The registry was set up through support of the Pelican Cancer Foundation and the Oxford Colon Cancer Trust, which could be accessed online via the LOREC (Low Rectal Cancer Development Program) portal (http://www.lorec.nhs.uk). The data set within the registry consists of several sections including patient demographics, procedural/technical data and postoperative outcomes (early/late morbidity, readmissions, pathology, oncological follow-up and functional outcomes). The main set aims for the registry were: 1) monitor the uptake of TaTME within the surgical community 2) compile data on the technique to allow further standardization 3) assess peri-operative morbidity, oncological safety and functional outcomes 4) drive/enable future research.

Aside from data collection in a registry there was a need for a structured training curriculum specifically for TaTME to support the safe the introduction of TaTME in selected patients with mid or distal rectal cancer, which is described in **Chapter 12**. A consensus process was conducted, seeking the views of 207 surgeons across 18 different countries worldwide, including 52 international experts in the field of TaTME. The consensus process was conducted in three phases: 1) learners survey 2) expert workshop and 3) final expert consensus.



Through the consensus process, the recommended pre-requisites were determined for the trainee, the mentor and the training centre. The proposed training curriculum (shown below) encompasses clear guidance on case selection, different methods of teaching that include online modules, dry lab purse-string simulators, cadaveric training and clinical mentoring as well as assessment and data collection.

With a registry and a formal structured training pathway in place, the next step was to establish a broad international consensus statement as a guide for optimal clinical practice. This is presented in **Chapter 13.** The objectives of this international and interdisciplinary consensus statement were three-fold: 1) provide a framework and guidance to those embarking on TaTME, including patient selection, surgical indication, technique, and educational opportunities 2) highlight the challenges, benefits, and distinctive dangers of this technique, capitalizing on a large international experience of early adopters of TaTME 3) promote prospective outcomes analysis and participation into clinical trials and registries. The consensus process was based on current recommendations for guideline developments adapted to questions with a focus on current practice, areas of controversy, and educational perspective. The final consensus statements were developed using a Delphi methodology incorporating three successive rounds. Although the final statements achieved more than 80% approval and can thus be graded as strong recommendation, the current lack of high level evidence needs to be acknowledged.

In the final two chapters, the first two analysis from the Internal TaTME registry are presented. In **Chapter 14** the short-term outcomes of the first 720 cases are analysed, and represented the largest dataset at the time of publication. The cases were registered between July 2014 and December 2015, by 66 surgical units from 23 different countries. The conversion rate from laparoscopic to open or transanal was 6.3% with an even lower perineal conversion rate of 2.8%. Postoperative morbidity and mortality at 30 days, was 32.6% and 0.5%, respectively. A total of 634 (88%) cancer cases were analyzed. R0 resection was obtained in 97.3% of cases. Sixteen cases (2.7%) were reported as R1 because of positive DRM, positive CRM by tumor, and positive CRM by an adjacent malignant lymph node in 2 (0.3%), 10 (1.7%), and 4 (0.7%) cases, respectively. A poor TME specimen was reported in 24 (4.1%) cases. Twelve specimens were found to have a rectal tube perforation. On multivariate analysis, two tumor related factor for poor histological features were significant: positive CRM identified on staging MRI and tumor height less than 2 cm from the anorectal junction. The only technical risk factor for poor quality specimens identified on multivariate analysis was extensive trans-abdominal dissection and the chances of obtaining a worse specimen is 6 times greater than if the dissection is performed transanally. The extent of transanal dissection did not increase the risk of poor histological outcome, suggesting that a better oncological resection is likely to be achieved for low rectal tumors via the transanal approach.

Finally, in **Chapter 15,** the "anastomotic failure" rates and incidence of anastomosis-related morbidity following TaTME are reported. Potential Risk factors associated with anastomotic failure were also analysed. A total of 1836 cases were recorded on the TaTME registry between July 2014 and December 2016, and overall 1594 of 1836 (86.8%) cases had an anastomosis. Median anastomotic height from anal verge was 3.0 ± 2.0 cm with stapled techniques accounting for 66.0%. The overall anastomotic failure rate was 15.7%. This included early (7.8%) and delayed leak (2.0%), pelvic abscess (4.7%), anastomotic fistula (0.8%), chronic sinus (0.9%), and anastomotic stricture in 3.6% of cases. Independent risk factors of anastomotic failure were: male sex, obesity, smoking, diabetes mellitus, tumors >25 mm, excessive intraoperative blood loss, manual anastomosis, and prolonged perineal operative time. A scoring system for preoperative risk factors (shown below) was associated with observed rates of anastomotic failure between 6.3% to 50% based on the cumulative score.

Discussion and Future perspective

A colleague once told me " surgical innovation is either born out of boredom or necessity ", and I believe the latter to be the case for Transanal Total Mesorectal Excision (TaTME). The widespread acceptance and adoption of Total Mesorectal Excision (TME) surgery, combined with multimodal therapy, revolutionized the management of rectal cancer with demonstrable reduced local recurrence rates and improved overall survival. [1-5] The next logical step forward in surgical innovation for rectal cancer was to transition from an open TME to a laparoscopic approach, making even further gains by improving short term perioperative outcomes. However, unlike the obvious "buzz" around laparoscopy for colon cancer which quickly transformed colon surgery into a minimally invasive field, laparoscopy for rectal cancer has been plagued by a slow adoption rate and underutilization – for all practical purposes, laparoscopy for rectal cancer could be labeled a failure. And when we were promised an improved solution with the robot, the reality proved far less attractive, and access even more difficult due to expensive costs and prolonged operative times. Hence, the necessity was born - not just for new technology, but a complete rethinking of the approach for minimal invasive rectal cancer surgery. And, here, was the start of TaTME.

The effective scientific evaluation of modern surgical innovation can prove quite difficult given the technical complexity, patient heterogeneity, and lack of consistent step-wise algorithms. However, this is becoming increasingly important as valid evidence of safety, efficacy and cost-effectiveness is crucial to obtain prior to widespread adoption by practitioners and subsequent implementation of evidence-based guidelines by regulators. The IDEAL framework and recommendations provide a valid, and internationally recognized evaluation template, which can be applied to novel invasive procedures and surgical techniques. [6-9] The focus of this thesis was to assess whether the introduction of TaTME was conducted in alignment with the IDEAL framework. The steps taken for the pre-IDEAL, Idea and Development phases, fall completely within the frameworks' recommendations and are a credit to the innovators and early adaptors. However, the promising early results achieved by early adaptors from expert centers were insufficiently juxtaposed by warnings of the procedure complexity, challenging "down-to-up" anatomy and potential for severe procedure specific complications. The TaTME "hype" that ensued meant the procedure moved prematurely into the exploration phase with rapid uptake by the early majority without complete standardization of patient indications, crucial procedural steps, established training pathways, and entry criteria for surgeons. The uptake by lower volume and less experienced surgeons, which skipped essential steps from the IDEAL pathway, clearly contributed to high complication rates and overexposure of patients to new procedure specific morbidity.[10, 11] The high anastomotic failure rate presented in chapter 15 attests to this exact problem, as this step of the procedure was not yet fully standardized before more widespread implementation. Further insights were obtained, and crucial modifications were made, to optimize the double pursestring stapled anastomotic technique, unfortunately not utilized in the armamentarium of the early majority.[12] This reflects a problem of the ongoing unregulated nature of surgical innovation even through a framework of existing recommendations, similar to the implementation of laparoscopic cholecystectomy and laparoscopic colorectal surgery and their known early challenges. [13, 14] Some might argue that a novel treatment should not be withheld from patients and that a balance needs to be struck between waiting for sufficient safety/efficacy data and allowing potential improved therapies to be administered. However, we need to be mindful that "the new" is not always better, and too rapid widespread adoption of a new technique may actually prove harmful. In TaTME, aside from the peri-operative complications, we remain uncertain about the oncological implications of dividing the rectal wall distal to the tumor and its subsequent potential for local tumor cell dissemination. The upcoming analysis from the international TaTME registry on 3 year oncologic follow-up will shed further light on this question.

Furthermore, mastering any new technique requires a steady case volume to both optimize technical skill and improve clinical judgement. These attributes will undoubtedly improve the performance along the learning curve. Hence, centralization for complex procedures in high-volume centers with high-volume surgeons SHOULD become an area for debate. This is particularly true for highly complex procedures where the number to achieve proficiency is high, as is the associated morbidity rate along the learning curve. From personal experience and evolving data on the learning curve, this holds true for TaTME. If we take into account that the role for TaTME will most likely be for predominantly low rectal cancers, then we should at least strive for centralization in this subgroup of rectal cancers. Although controversial and challenging to implement (inter)nationally, action is required to prevent a moratorium on TaTME, similarly to what we saw after the initial improper use of laparoscopy for colon cancer surgery. Not because TaTME is a bad technique, but rather a complex procedure performed badly by poorly trained, low volume surgeons which will not result in optimal patient outcomes. Specialization therefore should foster a better state-of-the-art and elevate practice standards among high volume centers.

As this process will be slow, requiring cautious and thoughtful implementation, national and international societies can, in the meantime, suggest stricter entry criteria for individual surgeons and surgical departments. The St. Gallen consensus statements (chapter 12) represent the first attempt to provide possible guidance for safe implementation and practice of TaTME by an international group of early adaptors. Interestingly, reading these statements again now, they are clearly too soft and lack sufficient focus on the two main aspects to guide surgeons; 1. Clear indications for TaTME and 2. Safe implementation and Training. New guidance statements are about to be published on these two particular topics, under the umbrella of the ESCP guidelines committee, and supported by representatives of all the major colorectal societies from across the world. Very clear succinct statements delineate the role for TaTME in rectal cancer surgery, and distinctly separate patients into those who can be treated in starting level centers (standard indications) and those who should be treated in expert centers.

Expert centers are defined by their demonstrable expertise in all aspects of rectal cancer surgery, case volume and infrastructure, independently validated outcomes and educational efforts. The guidance statements also focus on a structured training pathway for TaTME, based on the work presented in chapter 12. Surgical simulation is an essential part of the pathway, as it replicates the operative steps, potential points of risk, and provides situational awareness. It facilitates acquisition and assessment of technical skills in a safe, controlled setting, of which cadaveric based simulation is currently the most commonly used, although expensive and not always readily accessible. New technologies for future simulation-based training for TaTME are augmented reality (AR), virtual reality (VR) and the 3-dimensional models engaging the trainee during skills acquisition. Combination of these technologies will allow novice surgeons planning and pre-operative simulation, as well as locating essential structures to avoid injury during TaTME. New software platforms that combine artificial intelligence and telehealth are also being applied to clinical mentorship, another essential step within the training framework. This allows real-time fast and seamless transfer of expertise during the steep part of the learning curve and shortens the time consuming and expensive physical presence of a mentor. Finally, more stringent entry criteria are put forward that articulate the required prerequisites and case volume needed for surgeons embarking on TaTME. These guidance statements have a broad support base and will hopefully be adopted by regulatory bodies to avoid further unwarranted and more controlled implementation.

Ultimately, "optimal surgery" for rectal cancer is not about being an expert in one technique, but rather combining the best of all approaches based on the surgeons own experience and expertise. The surgical approach and/or platform needs to be tailored to the characteristics of the patient and tumor specific features. And while it is impossible to expect surgeons to master all available techniques, I predict that future advances in technology will foster a combination of robotics and transanal surgery to facilitate an optimal approach for the most distal and challenging rectal cancers. Robotic platforms will likely become more accessible as competitive markets drive down costs and thereby provide greater access. Standard robotic systems are currently being applied to complete the transanal part of TaTME procedures, although they were not specifically designed for transanal access. However, innovative endoluminal robotic platforms are in pre-clinical and clinical use (i.e Flex® Robotic System, the da Vinci SP® surgical system) and through further innovation, their applicability will improve and widen. Surgeons performing TaTME should be driving this technologic innovation, troubleshooting the optimal hybrid approach, as the ultimate end users. Complimentary developing technologies, such as new bio-fluorophores for structure localization (i.e. urethra, ureters, nerves) and the primary tumour will help improve accuracy, drive down wrong plane surgery and ultimately improve outcomes of TaTME. Similarly, stereotactic image-guided navigation surgery is under development and will provide surgeons with an augmented working environment for complex rectal cancer surgery. There is no doubt that the era of digital surgery is upon us, and integration with the "best" surgical techniques will be a game changer for not only us as surgeons but more importantly our patients.

Once the oncological safety has been settled, the focus will shift to the evaluation of long term functional outcomes for patients that undergo transanal surgery. Meticulous surgery with clear view of the neurovascular bundles, and an improved anastomosis at the appropriate height should theoretically provide better bladder, sexual and bowel function. Actually, for benign indications this will be the main focus for research as there are no oncological factors to be examined. The transanal approach provides an excellent alternative to the pure top-down dissection, particularly for the complex pelvis in IBD patients with fistulating disease or redo procedures for chronic pelvic sepsis. Under these conditions the access from above is severely hampered secondary to sepsis, adhesions, fibrosis and radiation effects and distorted anatomy. No top-down approach can compete in these circumstances and the role for transanal surgery might become even more prominent than TaTME for cancer. Clearly, many of these procedures should be restricted to expert centers with high volume, and well trained surgeons.

Benjamin Carson, a pioneer in neurosurgery said " a good surgeon doesn't just concentrate on technical ability but also on the appropriateness of what you're doing", and I truly believe this to be the case for TaTME surgery in the present and going forward.

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Nederlandse Samenvatting

In dit proefschrift toetsen we hoe Transanale TME chirurgie (TaTME) werd geïntroduceerd in de dagelijkse klinische praktijk, en met name als dit is verlopen volgens de 'IDEAL' aanbevelingen voor veilige introductie van chirurgische innovatie.

In hoofdstuk 1 beschrijven we het routinematig gebruik van een 'glove port' voor laparoscopische chirurgie door een kleine incisie in de buikwand (Single Incision Laparoscopic surgery; SILS). In vergelijking met de conventionele laparoscopische benadering via meerdere toegangspoorten minimaliseert SILS het chirurgische trauma nog verder, met betere cosmese, minder pijn en minder wond complicaties. Het expliciet gebruik van dure, commerciële SILS poorten kan echter de implementatie en verdere ontwikkeling van deze technologie belemmeren. De 'glove port' is een goedkoop alternatief, waarbij er een chirurgische handschoen met een wondbeschermer wordt verbonden om zo een SILS poort te creëren. Zo kunnen chirurgen SILS makkelijker introduceren en gebruiken in het hele gamma van ingrepen, variërend van simpele procedures tot complexe interventies.

In hoofdstuk 2 wordt het concept van "SOLE" chirurgie geïntroduceerd. Het concept van SILS met een 'glove port' beschreven in hoofdstuk 1 wordt uitgebreid naar een breder pallet van toepassingen. Hierbij stellen we voorop dat SILS poorten niet alleen SILS procedures moeten faciliteren maar ook nuttig kunnen zijn voor multi-poort laparoscopische ingrepen, preparaat extracties (waaronder ook Natural Orifice Specimen Extractie, NOSE) en uiteindelijk ook transluminale en transanale chirurgie. Zodoende kunnen technische vaardigheden en instrumenten overlappen tussen benaderingen en daarbij de leercurve inkorten en de procedure kosten verminderen. In het hele gamma van SILS poorten voldoet de 'glove port' het meest aan deze vooropgestelde criteria en we demonsteren verder in dit hoofdstuk de klinische toepassingen.

In Hoofdstuk 3 beschrijven we de klinische toepassing van een alternatieve techniek voor een transanale endoscopische resectie met behulp van de transanale 'glove port'. Gedurende een periode van 3 maanden werden opeenvolgende, niet-geselecteerde patiënten die in aanmerking kwamen voor transanale endoscopische microchirurgie (TEM), een procedure aangeboden die werd uitgevoerd via deze transanale 'glove port'. Bij veertien patiënten werd een goedaardige (n = 8) of kwaadaardige (n = 6) rectale poliep verwijderd. In twee patiënten was er ondersteuning noodzakelijk met de conventionele TEM poort. De mediane duur van de operatie, en het oppervlak van het resectie preparaat waren respectievelijk 93 (30-120) minuten en 12 (3-152) cm^2. Er waren geen intraoperatieve complicaties en minimale postoperatieve morbiditeit, met een mediane follow-up van 5,7 (2,7-9,4) maanden. Deze studie toont aan dat de transanale "glove port" een werkbaar en goedkoop platform is dat kan worden gebruikt in combinatie met reguliere laparoscopische instrumenten voor transanale resectie van rectale poliepen.

In hoofdstuk 4 onderzoeken we of het technisch mogelijk is om een chirurgische robot (da Vinci® Surgical System) te gebruiken voor transanale procedures. Na initiële experimenten in een ex-vivo model, werden experimenten op menselijke kadavers verricht. Het bleek mogelijk om via de transanale 'glove port' procedures in het rectum te verrichten met de robot en dat klinische translatie opgestart kon worden. Het robot platform biedt de chirurg een optimale driedimensionale weergave van het operatie gebied, uitstekende ergonomie, tremor-eliminatie, en instrumenten met superieure bewegingsvrijheid. Al deze kenmerken zijn ideaal voor het werken in een kleine ruimte, waar conflicten tussen instrumenten of tussen instrumenten en de camera anders gebruikelijk zijn.

De klinische toepassing van robot TAMIS (transanale minimaal invasieve chirurgie) voor de lokale excisie van rectale poliepen wordt beschreven in hoofdstuk 5. Zestien patiënten ondergingen een robot TAMIS voor rectale poliepen met een mediane afstand tot de margo ani van 8(3-10) cm. De mediane grootte van het resectie preparaat was 5,3 (0,5-21) cm^2. De mediane tijd om de robot te installeren en de duur van de operatie waren respectievelijk 36 (18-75) en 108 (40-180) minuten. Eén conversie naar een reguliere TAMIS procedure was noodzakelijk vanwege problemen met de toegang tot het rectum. Eén patiënt ontwikkelde een pneumoperitoneum zonder klinische consequentie en één patiënt ontwikkelde een blaasretentie waarvoor eenmalige catherisatie. De mediane opname duur was 1,3 (0-4) dagen. Deze unieke case serie toont aan dat robot transanale chirurgie mogelijk is, en dat meer complexe procedures theoretisch ook tot de mogelijkheden behoren, waaronder TME chirurgie. Maar er waren ook nadelen, met name de tijdrovende installatie van de robot transanaal en de lange operatie duur. Er is tevens verder onderzoek noodzakelijk naar de kosten efficiëntie van deze techniek.

In hoofdstuk 6 rapporteren we onze eerste klinische ervaring met TaTME. In de periode van juni 2013 tot september 2014 ondergingen 20 geselecteerde patiënten een TaTME procedure voor een rectale tumor of goedaardige pathologie. Van de 20 patiënten (14 mannen) hadden zeventien (85%) patiënten een rectum tumor, op een mediane afstand van 2 (0-7) cm van de anorectale ring. De goedaardige aandoeningen betroffen een rectovaginale fistel na een totale colectomie en ileorectale anastomose voor colitis ulcerosa, erosie van een mesh in het rectum na een procedure voor rectale prolaps en een rectale stenose na een TEM procedure. In 16 patiënten werd een lage anterior resectie verricht, en in twee patiënten elk een abdominoperineale excisie en een intersphincterische proctectomie. In totaal waren er 3 conversies naar een open of laparoscopische techniek, omwille van een bloeding uit de bekken zijwand, dense verklevingen in de buik en vanwege toegangsproblemen tot het rectum met de transanale 'glove port'. De gemiddelde operatieduur was 315 (180-480) minuten en weerspiegelt de steile leercurve voor TaTME. Er waren zes postoperatieve complicaties, waarvan twee (10%) Clavien-Dindo Graad IIIb (bekkenhematoom en een late naadlekkage). De mediane opname duur was 7 dagen. Het TME preparaat was intact in 94,1% van de patiënten met een rectum tumor, met gemiddeld 23 lymfeklieren. Er was slechts één positieve circumferentiële resectiemarge (CRM), en dit op basis van een tumordepostie ter hoogte van de resectie marge (5,9%). Eén patiënt ontwikkelde een levermetastase, na een korte mediane follow-up van 10 (6-21) maanden. Deze initiële resultaten toen aan dat TaTME technisch mogelijk is met goede histopathologische uitkomsten, maar benadrukt ook de steile leercurve van deze procedure. Tijdens de studie periode werden verschillende technische veranderingen doorgevoerd wat leidde tot verdere verbetering en standaardisatie van de techniek, waarvan enkele worden beschreven in de hoofdstukken 7-9.

In Hoofdstuk 7 wordt het gebruik van een conventionele laparoscopische insufflator vergeleken met het AirSeal®-systeem in TaTME. Bij het gebruik van een conventionele insufflator treden twee specifieke problemen op die het chirurgisch zicht belemmeren: 1) overmatige diathermie geïnduceerde rook in een reeds beperkt operatieveld en 2) 'bellowing' of oscillatie van het rectum ('onstabiele pneumopelvis'). Het AirSeal®-systeem daarentegen zorgt voor een constante rookevacuatie en een stabiel werkveld ("stabiele pneumopelvis"). De toepassing van deze technologie stelt de operateur in staat zich te concentreren op dissectie in plaats van te worden afgeleid door het continu ventileren van rook met verlies van werkruimte en suboptimaal zicht.

In hoofdstuk 8 beschrijven we twee visuele kenmerken die de chirurg kunnen helpen om het juiste vlak te vinden en te volgen bij een TaTME: "Triangles" and "O's". De perceptie van de anatomie en het juiste dissectie vlak verschilt van een puur abdominale benadering en kan dus makkelijk leiden tot dissectie in het verkeerde vlak. De verkeerde interpretatie van de werkelijke anatomie en chirurgische vlakken wordt versterkt door de impact van de CO2-insufflatie op het operatiegebied. Belangrijk hierbij is dat als de chirurg van het TME vlak afwijkt, meestal te lateraal, dit kan leiden tot autonome zenuwletsels, visceraal letsels (vagina / urethra / blaas / rectumwand) en complexe bloedingen uit de bekken zijwand. Nu, als de chirurg een nieuw vlak opent en hierbij dus een fascia blad insnijdt zal er een "O" of "halo sign"ontstaan, door influx van CO2. De "triangles" ontstaan door unidirectionele tractie op het weefsel waarbij de onderliggende fascia opgetrokken wordt, en er een driehoek ontstaat ("Triangles"). Het juiste vlak is meestal ter hoogte van de apex van deze driehoeken. Het begrijpen en onderkennen van deze visuele aanwijzingen moet een waarschuwingssignaal zijn voor de chirurg dat hij mogelijk buiten het juiste vlak is geraakt, en eventueel moet corrigeren.

Een cruciale stap bij elke restoratieve rectum resectie, is het aanleggen van een colorectale of coloanale anastomose. In tegenstelling tot een puur abdominale benadering wordt het rectum aan het begin van de procedure geopend, waarbij een rectale cuff ontstaat die op het einde van de procedure gebruikt wordt voor de anastomose. In hoofdstuk 9 beschrijven we in detail de verschillende technieken voor de anastomose bij een TaTME en hoe elke techniek moet worden afgestemd op de lengte van het anale kanaal en hoogte van de anastomose. Resultaten met betrekking tot lekkage en andere complicaties gerelateerd aan de anastomose worden later in hoofdstuk 15 beschreven.

Na het rapporteren van onze eigen initiële ervaring, presenteren we in hoofdstuk 10 een systematische analyse van de gepubliceerde literatuur met betrekking tot TaTME. Het doel was 1) om de peri-operatieve resultaten te presenteren en 2) de kwaliteit van de resectie preparaten te analyseren na een TaTME. In totaal werden 36 studies met 627 patiënten geselecteerd; 510 patiënten ondergingen een TaTME en 117 patiënten een laparoscopische TME. Gemiddelde operatietijden varieerden van 143 tot 450 minuten. Conversie naar een open procedure werd gemeld in 12 patiënten (2,3%), voornamelijk als gevolg van tumor gerelateerde factoren en abdominale verklevingen. Uit de studies waarin gegevens met betrekking tot de anastomose gerapporteerd werden, bleek dat slechts 34% van de anastomosen met een stapler werden aangelegd (hand gelegde anastomose vs anastomose met stapler; 2:1). De peri-operatieve morbiditeit van 35% voor TaTME is vergelijkbaar met die van een open en Laparoscopische TME. In 3 patiënten trad er echter een letsel op van de urethra, een ernstige complicatie die specifiek gerelateerd is aan TaTME. De oncologische kwaliteit op basis van de analyse van het resectie preparaat lijkt voor TaTME vergelijkbaar met die van een open en laparoscopische TME; de circumferentiële resectie marge (CRM) was positief in 5% van de gevallen, de distale resectie marge (DRM) was positief in 0,3% en het gerapporteerde gemiddelde aantal lymfeklieren varieerde van 11,5 tot 33. Een incompleet TME preparaat werd beschreven in 6% van de gevallen. Op basis van de kwaliteit van de geïncludeerde studies in deze systematische analyse, kunnen we alleen maar concluderen dat TaTME technisch mogelijk is en een reproduceerbare techniek is.

Om een groter aantal van deze procedures te analyseren vanuit verschillende chirurgische centra is er een internationaal register specifiek voor TaTME opgezet; hoofdstuk 11. Demografische gegevens van de patiënten, operatie details en uitkomsten van de operatie worden hierin prospectief verzameld. De vooropgestelde doelen waren : 1) evalueren van de implementatie van TaTME binnen de colorectale gemeenschap 2) gegevens verzamelen over de techniek om verdere standaardisatie mogelijk te maken 3) beoordelen van de peri-operatieve morbiditeit, oncologische veiligheid en functionele uitkomsten 4) stimuleren van onderzoek.

Naast een register, was er verder behoefte aan een gestructureerd opleidingsprogramma, ter ondersteuning van de veilige introductie van TaTME. De ontwikkeling hiervan via een gevalideerd consensus proces wordt beschreven in hoofdstuk 12. Het voorgestelde trainingsprogramma omvat duidelijke richtlijnen voor selectie van geschikte patiënten, verschillende educationele modules, klinische mentoring, gestructureerde evaluatie van procedures en verzamelen van gegevens via het TaTME register.

In hoofdstuk 13 beschrijven we de volgende stap naar veilige implementatie, met name het opstellen van een internationale consensusverklaring als richtlijn voor chirurgen die TaTME willen opnemen. Dit wordt gepresenteerd in hoofdstuk 13. De doelstellingen van deze internationale en interdisciplinaire consensusverklaring waren drieledig: 1) bieden van een kader waarin TaTME veilig kan worden geïntroduceerd 2) toelichten van voordelen, mogelijke nadelen en gevaren 3) bevorderen van prospectieve registratie en publicatie van resultaten. De definitieve consensusverklaringen werden ontwikkeld met behulp van een Delphi-methodologie met drie opeenvolgende ronden. Hoewel de eindverklaringen meer dan 80% goedkeuring hebben gekregen en dus kunnen worden beoordeeld als een sterke aanbeveling, moet het huidige gebrek aan kwalitatief hoog bewijs worden erkend.

In de laatste twee hoofdstukken worden de eerste twee analyses van het internationale TaTME register gepresenteerd. In hoofdstuk 14 worden de korte termijn resultaten van de eerste 720 patiënten geanalyseerd die werden geregistreerd tussen juli 2014 en december 2015 door 66 chirurgische eenheden uit 23 verschillende landen. Conversie van een minimaal invasieve ingreep naar open chirurgie of transanale assistentie was 6,3%, met een perineale conversie in 2,8% van de patiënten. Postoperatieve morbiditeit en mortaliteit na 30 dagen was respectievelijk 32,6% en 0,5%. In 634 patienten (88%) werd een TaTME verricht voor een tumor in het rectum. Een R0-resectie werd in 97,3% van de gevallen verkregen, met in 16 (2,7%) patienten een R1 resectie vanwege een positieve DRM (n=2), positieve CRM op basis van tumor (n=10) en positieve CRM op basis van een positieve lymfeklier (n=4). Een slecht TME resectie preparaat werd beschreven in 24 (4,1%) patienten, waarbij 12 patienten een perforatie hadden van het preparaat. Bij multivariate analyse waren twee tumor gerelateerde factoren voor slechte histologische kenmerken significant: positieve CRM op de preoperatieve MRI en tumorhoogte minder dan 2 cm van de anorectale overgang. De enige technische risicofactor die uit deze analyse representatief bleek was een dissectie die te ver van abdominaal verricht werd. De uitgebreidheid van de transanale dissectie daarentegen verhoogde het risico op een slechte histologische uitkomst niet, wat suggereert dat een betere oncologische resectie waarschijnlijk kan worden bereikt voor lage rectale tumoren via de transanale benadering.

Ten slotte wordt in hoofdstuk 15 de anastomose gerelateerde problemen gerapporteerd bij 1594 patiënten in het TaTME register, waarbij ook potentiële risicofactoren werden geanalyseerd. In tegenstelling tot het artikel in hoofdstuk 10, werden nu meer van de anastomosen mechanisch verricht (66%). Het risico op een probleem gerelateerd aan de anastomose was 15,7%. Dit betrof een vroegtijdige (7,8%) of laattijdige lekkage (2,0%), abces in het kleine bekken (4,7%), fistel vanuit de anastomose (0,8%), chronische sinus (0,9%) en strictuur van de anastomose in 3,6% van de gevallen. Onafhankelijke risicofactoren voor falen van anastomose waren: mannelijk geslacht, obesitas, roken, diabetes mellitus, tumoren> 25 mm, bloedverlies > 500ml, handmatige anastomose en verlengde perineale operatieve tijd. Een scoresysteem op basis van de preoperatieve risicofactoren werd opgesteld, waarbij op basis van de cumulatieve score het risico geschat kan worden tussen 6,3% en 50%.

ACKNOWLEDGEMENTS | DANKWOORD

It has taken me a while, but the last words are written and I'm very proud to present this doctoral thesis. Similar to innovation in surgery, there are only twists and turns, no straight lines.

Only thanks to the support of many amazing people that crossed my path throughout my private and professional life I've been able to initiate and complete this project. Some of them I would like to thank below.

First my two promotors, both giants in the world of colorectal surgery; prof. dr. N.J. Mortensen and prof. dr. W.A. Bemelman.

Thank you, Prof Mortensen! I still find it difficult to call you Neil, even after we became colleagues in Oxford, and for me (and I suppose for everyone who has ever worked for you as a fellow in Oxford) you will always be " Prof ". You are a true innovator in the purest meaning of the word. Not only did you introduce/implement TEM in the U.K. but you also fiercely supported laparoscopy early on when outcomes were suboptimal. You provided me with the opportunity to master transanal surgery and pushed me to look beyond the standard applications and available platforms. The lab sessions we had to develop Robotic TAMIS, accompanied by the numerous discussions and the clinical translation of that project is something I'll never forget and a very valuable experience. You also allowed me to take the first steps in TaTME for rectal cancer, and as a young starting surgeon I could not have done this without your support. You are a true gentleman, a mentor of many now established colorectal surgeons and I will always be grateful for the opportunities you have provided me with.

Willem, where to start when trying to thank you ? As a young surgeon, visiting the ESCP meeting for the first time, I was so impressed with your stage presence and amazing research output. And of course, a bit intrigued whether that special jacket actually existed (and I now know it does…). When the opportunity arose to join your team, it was a difficult decision, but impossible to resist for many good reasons. But mainly because of the excellent and wonderful team you gathered around you. From the beginning I have felt at ease and I have evolved as a surgeon and researcher under your guidance. And although I regularly think back of my time in Oxford, I can truly say that I have found "mijn plekje". Willem, thank you for your tremendous support, endless energy, abundance of ideas, and your friendship. And, thank god for good Russian vodka !

And when talking about the best colorectal unit in the world to work in, brings me automatically to my two other colleagues, dr. C.J. Buskens and dr. P.J. Tanis.

Dear Christianne, I fondly think back of our time together as fellows in Oxford. And I'm certain Cato still remembers her "Dikkie Dik" backpack you gave her, and that she wore proudly for many years. Your spontaneity, contagious enthusiasm and critical, bur refreshing view on research have not changed a bit since then. And these are characteristics why I admire you as a person and a colleague. Having you as part of the team that I would join in Amsterdam, made my decision to move definitely easier. You are such a wonderful woman, my go-to person for "non-work" related advise and someone I look up to in many aspects. And of course, I could not have wished for a better paranimf, thank you!

Dear Pieter, when trying to describe you a term that Prof. Mortensen uses comes to mind, a "Surgeon Scholar". You are truly gifted, not only in the field of colorectal surgery and research but also in the arts. Some surgeons might feel insecure or intimidated when they would have to work with someone of your caliber, but I thrive on this and I praise myself lucky to be your colleague. I look forward to working many more years alongside you; completing research projects, operate together on challenging cases, and work on your pool skills.

My sincerest gratitude goes out to prof. dr. M.G.H. Besselink, prof. dr. M.I. van Berge Henegouwen, prof. dr. T.A. Rockall, dr. P. Tanis, prof. dr. J. Torkington and dr. J.B. Tuynman for taking the time to critically assess my thesis and to sit in my doctoral thesis jury. A special thank you for my two external jury members.

prof. Rockall, Tim, I have always admired you as a surgeon, particularly your attention to detail and laparoscopic skills, especially for TME surgery. Discussing together the landscape of rectal cancer management and where TaTME fits in, helped me immensely in my research and doctoral thesis concept.

Prof. Torkington, Jared, I just wish I could "own" a podium like you can; funny and yet thoughtful and knowledgeable. The implementation of TaTME in your unit was exemplary, and proves it can be done well and safely. Our conversations regarding the implementation of new technology in daily surgical practice were extremely valuable for this project. I look forward to a closer relationship of our respective units in the future and exciting combined research projects.

I'm very grateful to all co-authors that contributed to these chapters. This doctoral thesis spans a long period from 2011 to 2018, and over that time I've been lucky to work with some wonderful people. Without their enthusiasm and innovative mindset these manuscripts would not have been realized. I would also like to thank all surgeons who contributed their data to the Internal TaTME registry. Only through that collaborative effort we were able to gather important early data and present this to the wider colorectal community. I would especially like to thank prof. R.A. Cahill and Mrs. M. Penna.

Ronan, you are one of the most innovative surgeons I know, always "thinking outside the box", and you really inspired me during my first years in Oxford. The "glove port" that you introduced was a catalyst for many projects and finally also facilitated the introduction of TaTME in Oxford. Thank you for your friendship and career advice over the last 10 years.

Marta, sometimes you know immediately if someone is going to be a good surgeon, and you have that ability. I'm proud to supervise your doctoral thesis project, and it will reflect the outstanding work you have done to gain better insight into TaTME and allow for safer implementation. Your organizational and people skills really helped to expand and drive the registry forward. Thank you !

Dear Fred, thank you for being my paranimf together with Christianne. Very fondly, I think back of the times when we were fellows in Oxford. Together with Farhat Din we ruled the wards and theatres in Oxford for nearly two years, an unforgettable experience. I don't think I can remember a day when you were not upbeat, full of energy and laughing! You built an incredible career in Geneva and recently even turned into a real Professor! I'm proud of what you have achieved and to call you my friend.

Aside from surgeons mentioned above, I would also like to thank a few other surgeons who impacted my career and made me into the surgeon I am today.

Dr. Vansteenkiste, beste Franky, thank you for igniting my interest in colorectal surgery. You thought me the basics in surgery, and stimulated me to get the most out of myself. The ad hoc clinics at your home with dinner afterwards and endless discussions are unforgettable moments. The journeys to the meetings in Minneapolis and visits to the Mayo Clinic really stimulated me during surgical training and made me a more critical surgeon, questioning why we do things like we do them.

Prof. dr. A. D'hoore, you are a minimal invasive wizard and a pioneer of laparoscopy in Europe. Thank you for inspiring, and training me in my early years of residency and during my fellowship year in Leuven. You stimulated me to go abroad for a fellowship in Oxford, and without that guidance I would not stand here today.

Mr. B. Moran, dear Brendan, I have learned so much from you in the short period I worked with you in Basingstoke, the home of TME surgery. Even though you are an "open" surgeon, you pushed me to do laparoscopic TME surgery, but made me think how to do it better and safer for our patients. Similarly, you supported the introduction of TaTME, and I remember very well the very first case I ever did under your watchful eye. Thank you.

And finally, Mr. Cunningham, dear Chris, I truly miss the near daily interactions we had in Oxford. Our offices in Oxford were opposite each other with the doors always open, so easy enough for daily coffee together and a chat. You trained me in TEM surgery and together we mastered TAMIS and finally also TaTME. Your fresh and clear opinion on many surgical controversies, particularly early rectal cancer were an inspiration to me and I consider you to be one of my main mentors.

I am also very thankful of my colleagues, fellows, residents, nurses, secretaries and PhD students both in Oxford and Amsterdam. I truly appreciate all your hard work, our daily interactions and your wise words and friendship.

Dear Friends , and for everyone that I cannot mention separately here. Thank you for your all the good advice, and friendship over the years.

Lieve ouders, papa en moeke, het is dankzij jullie dat ik hier nu sta vandaag. Ik ben apetrots dat ik dit boekje aan jullie mag overhandigen. In de voorbije jaren heb ik op veel podia gestaan, maar geen podium zo belangrijk als vandaag, om dit te kunnen vieren met jullie. Ik was zeker niet de slimste (en zeker niet de meest geïnteresseerde) op school en enkel doordat jullie me met regelmaat achter de veren zaten heb ik mijn middelbare studie gehaald. De keuze voor geneeskunde was zeker niet in overeenstemming met mijn studieadvies, maar jullie hebben mijn keuze altijd ten volle gesteund! Bedankt voor alle mogelijkheden die jullie mij hebben gegeven en de opvoeding die mij hebben gemaakt tot de persoon die ik nu ben.

Liefste Broer en Zus, heel fier dat jullie er bij zijn vandaag. We wonen nu wel een eindje rijden uit elkaar, maar als we elkaar zien is het altijd gezellig. Bedankt voor jullie onvoorwaardelijke steun.

Ik hou van jullie familie Hompes !

Lieve Cato, Giel en Teun. Wat ongelooflijk fijn dat jullie vandaag hier op de eerste rij zitten. Zenuwachtig is pappa alleen, omdat de presentatie speciaal voor jullie is, en een heel klein beetje ook voor de andere mensen in de zaal. Jullie vonden het wel heel stoer dat pappa een boek aan het schrijven was en dit is het resultaat! En papa moest wel heel erg lachten toen Teun vroeg in welke boekhandels het te krijgen zou zijn en hoeveel ik eraan zou verdienen. Liefste schatten, ik besef dat je mij vaak moeten missen, maar ik denk altijd aan jullie, ben ontzettend trots op de knappe persoontjes die jullie zijn geworden en hou ontzettend veel van jullie. Dikke knuffel en zoen.

Liefste Jasmijn, dankzij jou onvoorwaardelijke liefde en overgave voor ons gezin kon ik mijn carriere uitbouwen en (te veel !) reizen. En ook al zijn we nu niet meer samen, ik hou nog steeds van jou en ik zal er altijd voor je zijn. Want samen hebben wij het mooiste en belangrijkste in het leven; 3 mooie, gezonde, knappe kinderen.