Transanal Endoscopic Microsurgery (TEM)

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11.1 Introduction

Surgery of the rectum is difficult, as it is located within the confines of the narrow bony pelvis. This precludes good lighting and good exposure. With the proximity of nerve plexuses and venous plexuses to the pelvic organs, it is very demanding to attain good oncological surgery with optimal functional outcomes. Transanal endoscopic microsurgery (TEM) is a form of minimally invasive surgery developed by Buess et al. in 1984 as a means of local resection of early rectal tumor (T0, Tis, and low risk T1). It is a technically demanding local resection, operating through the anus, and avoiding any skin incision. It may not be an overstatement to say that TEM is actually the "Minimally Invasive Surgery of Minimally Invasive Surgery" in rectal operation.

Total mesorectal excision (TME) [1] is the current gold standard of rectal resection. Even with the development of minimally invasive surgery (MIS) approach, laparoscopic TME [2] is still an ultra-major surgery with the requirement of temporary covering ileostomy. With the understanding of the adenoma–carcinoma sequence [3], we can appreciate that rectal tumor is actually a spectrum of disease. Hence, it is quite logical that total mesorectal excision (TME) may not be the best answer to all rectal tumors. We should have different MIS for different stages.

TEM is also a platform for exciting developments for various advanced MIS surgery. Local excision with TEM with neoadjuvant therapy of chemoradiation may be the way forward for rectal conservative therapy (RCT). TEM itself is single-port access (SPA) surgery and the rectoscope of TEM can serve as a port to retrieve the specimen, i.e. natural orifice specimen retrieval (NOSE) as well. Transanal total mesorectal excision (TaTME) is another hot topic whereby synchronous laparoscopic and transanal TME serves to complement each other to fulfill the stringent requirement proper TME. With further development in robotic surgery, this may be another pathway for natural orifice transluminal endoscopic surgery (NOTES) in the future.

With advancement in technology and concepts, it will be ideal if we can apply the same techniques and technology on rectal tumor, which is actually a spectrum of disease ranging from early to late stage. Hence, following our oncological principles stringently, we should modify our treatment accordingly so that patients can enjoy the benefits of minimally invasive surgery (MIS).

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11.1.1 Adenoma-Carcinoma Sequence

Colorectal cancer is believed to occur through two main pathways [4], and the first and the most common is the adenoma-carcinoma sequence. The transformation from polyp to cancer is originated due to the accumulation of numerous genetic abnormalities (Fig. 11.1), e.g., p53, K-ras, and deleted in colorectal carcinoma (DCC) and chromosomal instability, e.g., loss of heterozygosity (LOH) [5]. Two-thirds of colorectal cancers are believed to evolve as a consequence of this pathway.

The second pathway involves mutation in mismatch repair (MMR) genes seen in hereditary non-polyposis colorectal cancer (HNPCC) [6]. It involves the silencing of mismatch repair genes through a process of methylation without mutation. Loss of mismatch repair as a consequence of mutation accounts for up to 5% of hereditary cancers and methylation of mismatch repair genes account for 10–15% of sporadic cancers [7]. This pathway has been termed the microsatellite instability (MSI) pathway.

From the study of age distribution curves, it is shown that polyps are recognized about 4 years before cancer [8]. This may be an underestimate because the diagnosis of benign tumor at early stage is more inaccurate than for cancer. Furthermore, the malignant potential of adenomas of the colon and rectum varies with size, histological type, and grade of epithelial atypia. It was known that most colorectal cancer progressed through the adenoma-carcinoma sequence, although the majority of adenomas do not become cancerous during a normal adult life span. Unfortunately, there are no reliable criteria to predict the progression or recurrence. Nevertheless, it is known that after removal of the precursor polyps, one-third of the patients will have further adenoma [9]. Hence, we have the policy of endoscopic surveillance after all polypectomies [10].

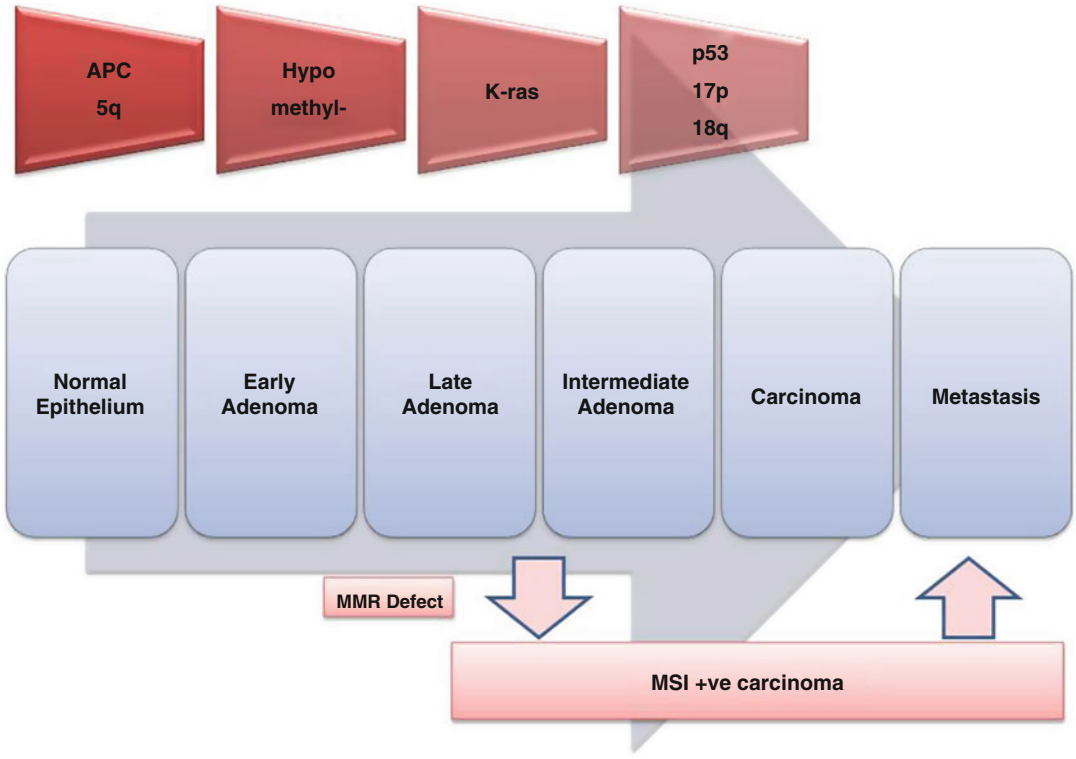

Fig. 11.1 Adenoma-carcinoma sequence and microsatellite instability (*MSI* microsatellite instability, *MMR* mutation mismatch repair)

11.1.2 TNM Staging

The TNM staging system [11] was developed and is maintained by the American Joint Committee on Cancer (AJCC) and the Union for International Cancer Control (UICC). The TNM staging system is based on the extent of the tumor (T), the extent of spread to the lymph nodes (N), and the presence of metastasis (M). For T staging of rectal tumors, it ranges from rectal tubular or villous adenoma (T0), carcinoma in situ (Tis), early rectal tumor that is limited to submucosa (T1), to late-stage carcinoma (T2–T4).

cTNM is the clinical classification and pTNM is the pathologic classification. The y prefix is used for those cancers that are classified after neoadjuvant pretreatment (e.g., ypTNM). The r prefix is to be used for those cancers that have recurred after a disease-free interval (rTNM). Furthermore, according to the investigations, we have the u prefix for transrectal ultrasonography, ct prefix for CT scan, and mr prefix for MRI staging.

11.1.3 Staging of Malignant Colorectal Polyp

For early tumor and malignant polyps, we will use the Kikuchi classification [12], which aimed at describing the depth of invasion into the submucosa. It divides the submucosa (Sm) into thirds and then the horizontal spread of tumor has also been described separately within the upper most third layer (Sm1: invasion to a depth of 200–300 μm). Sm1a is less than a quarter of the width of the tumor invading the submucosa; Sm1b is a quarter to half the width of the tumor invading the submucosa; Sm1c is more than half the width of the tumor invading the submucosa; Sm2 is intermediate between Sm1 and Sm3; and Sm3 is carcinoma invasion near to the muscularis propria.

11.2 Method and Indications

Transanal endoscopic microsurgery (TEM) was first developed by Professor Gerhard Buess for the local resection of rectal tumor [13]. It was popularized and the technique was promulgated around the world and TEM was first introduced into Hong Kong in 1995 [14].

We were very stringent in our case selection. Indications for curative resection are rectal villous adenoma (T0) or early rectal tumor including Tis and low-risk T1 (i.e., well-differentiated carcinoma with no lymphovascular permeation). Palliative resection is only offered to elderly patient with multiple comorbidities with mobile tumor on digital examination.

For rectal villous adenoma with transrectal ultrasonography showing no sign of invasion (uT0), we will proceed with submucosal dissection. We aim at 1 cm circumferential margin at the least. For early tumor with biopsy showing malignancy, we will aim for full-thickness excision with at least 1 cm resection margin. The specimen is then pinned on corkboard for detailed pathological examination.

11.2.1 Preoperative Management

Complete history with emphasis on fecal and urinary continence should be recorded and thorough physical examination should be done. Fecal continence to solid, liquid, and flatus should be assessed and in case of incontinence, whether it is occasional or frequent episodes, should be asked (Williams' Score). For urinary continence, we should screen for stress incontinence, urge incontinence or a mixed type.

Digital rectal examination and rigid sigmoidoscopy are mandatory as the position, site, and size of the tumor would determine the patient position on the operation table. With the tumor situated at 6 o'clock, 12 o'clock, 3 o'clock, and 9 o'clock, the patient operative position should be lithotomy, prone, left lateral, and right lateral accordingly.

We advocate the detailed documentation of the tumor: (1) distance from the dentate line (e.g., 6–8 cm); (2) position (e.g., from 6 to 10 o'clock position); and (3) percentage of the circumference involved (e.g., 30% of circumference). The relative position to the middle Valve of Houston should be noted as this may signify

the approximate position of peritoneal reflection. All these are of significance in planning and position of the operation.

Apart from transrectal ultrasonography, chromoendoscopy, magnifying colonoscopy, and narrow band imaging (NBI) in colonoscopy will be helpful in determining the local staging. Many a times, eye-balling the morphology of the polyp may be a more practical approach if sophisticated investigations are not available. However, in case of malignancy, magnetic resonance imaging (MRI) of the rectum as a base line is indicated. Preoperative colonoscopy is also essential to screen and to deal with synchronous polyps or tumors.

Full bowel preparation with polyethylene glycol was preferred and prophylactic antibiotics (Cefuroxime 1.5 gm IV and Metronidazole 500 mg IV) should be given. TEM would be performed under general anesthesia.

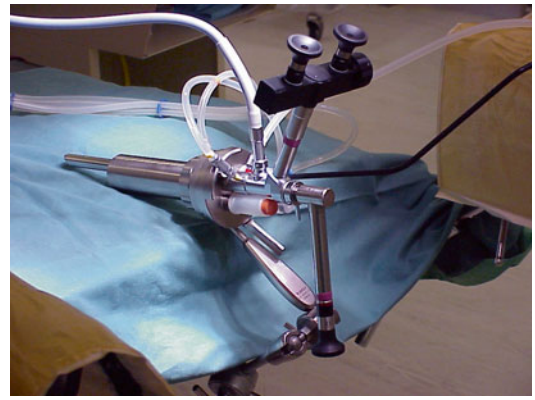

Fig. 11.2 TEM

11.2.2 Operation Setup and Instruments

Due to the sole access through the anus and the limited space for surgical manipulations, specific instruments are being designed (Fig. 11.2). TEM machine was manufactured by Richard Wolf (Knittlingen, Germany). It consists of a rectoscope of 4 cm in diameter (12 cm or 20 cm in length) with the edge being either oblique or flat. Rectoscope of different length can be applied for tumors at different distance away from the anal verge. The optimal location of the tumor is from 5 cm to about 20 cm from the anal verge.

There are three working channels sealed with special rubber sleeves with caps. The working channels can accommodate custom-made angulated instruments including a diathermy needle, dissecting forceps, needle holder, and suction cannula.

In addition, there is another optical channel for stereoscope, which enables three-dimensional stereoscopic imaging for direct visualization with 13.8 mm OD, 50° angle of view, 75° field of view. This is installed with adjustable stereo eyepiece and anti-droplet rinsing feature. The image is also shared to an integrated documentation optics for monitor viewing or recording. In the second generation of TEM, this documentation optics has changed to pointing upward. This allows for less obstruction for the manipulation of instruments. Furthermore, high-density (HD) monitors and signals are used.

The selected rectoscope is mounted to the operating table via the U-shaped support arm consisting of three joints and a single screw, which is called the Martin arm. The position of the rectoscope is secured by turning a single screw knob and it relies on mechanical fixation. Recently, a new locking mechanism is introduced and the whole system can be locked securely by the press of a button rather than the slow turning of the screw.

The combined endosurgical unit of TEM provides the automated carbon dioxide insufflation with real-time barometric feedback. This is particularly important in difficult cases when optimal view and exposure depends crucially on insufflation of the rectal lumen. The surgical instruments (Fig. 11.3) include the specially designed diathermy needle, and needle for injection. Custom-made angulated forceps, needle holders, and suction probes are designed such that they can reach out to the different region as shown in the field of view of the rectoscope. There are clip applicators for the silver clips, which anchors onto the suture and also the scissors for cutting sutures.

Simplified version of the equipment namely Transanal Endoscopic Operation (TEO) device (Karl Storz, Tuttlingen, Germany) are also available, and recently, several disposable transanal ports have been introduced in the market.

Fig 11.3 Specially designed surgical instruments for TEM

11.2.3 Operative Procedure

11.2.3.1 Patient Positioning

The position of the patient on the operating table is such that the rectal lesion is at the lower half of the operating field of view (Fig. 11.4). An anterior lesion requires prone position; left rectal wall lesion requires the left lateral position and vice versa; and a posterior lesion requires lithotomy position.

11.2.3.2 Technique of TEM

First, we will mark the resection margin with the diathermy needle before the dissection. We can operate in usual laparoscopic positions but when we want precise and fine dissection, we will use the stereoscope, which provides excellent 3D images (Fig. 11.6). Manipulation of the instruments is different from the usual skill sets of laparoscopic surgery with particular emphasis on elbow movement. Hence, surgeons should have specific training.

Fig 11.4 TEM operative setup

11.2.3.3 Submucosal Excision

For rectal villous adenoma, we will perform submucosal dissection using the diathermy needle. The mucosa is elevated by injecting modified gelatin (colloid) mixed with methylene blue into the submucosal plane. We tried adding adrenaline in but apart from vasoconstriction, the hemostatic effect was not significantly impressive. We have also tried saline but the absorption was too quick and repeated injections were needed. Mixing with methylene blue will highlight the submucosal plane and the inner muscular layer to facilitate sharp dissection with diathermy needle.

In situations whereby the mucosa cannot be elevated despite correct injection to the submucosal plane, we have to be aware such a "non-lifting" sign may indicate malignant infiltration and we should convert to full-thickness excision.

11.2.3.4 Full-Thickness Excision

For lesions with possibility of carcinoma or biopsy revealing malignancy, we should go for full-thickness excision with ultrasonic dissector. Reusable ones are more cost-effective. We have tried using electrocautery but the smoke generated within the confined rectal lumen would obscure the view and would not settle quickly. Technically, we found that there is less smoke in using the 5-mm curved-tip Harmonic Ace (Ethicon Endo-surgery, Johnson & Johnson) [15] as compared to the high-frequency needle knife. Furthermore, the hemostasis of ultrasonic dissector is perfect, in contrast to the use of electrocautery where time and again, we have occasional spurting of blood onto the optics.

11.2.3.5 Intracorporeal Suturing

After both types of dissection, the specimen will be retrieved via the rectoscope and we will always irrigate with cytocidal solutions to prevent tumor cell implantation. The defect can then be closed with a single-layer continuous monofilament suture with silver clips anchoring at either ends. This avoids the difficult intracorporeal and intraluminal knot tying; we do it in a transverse manner to avoid stricture. Some will skip this step of suturing the defect, in particular for submucosal dissection. However, in case of full-thickness excision, we recommend to suture to prevent rectal stenosis.

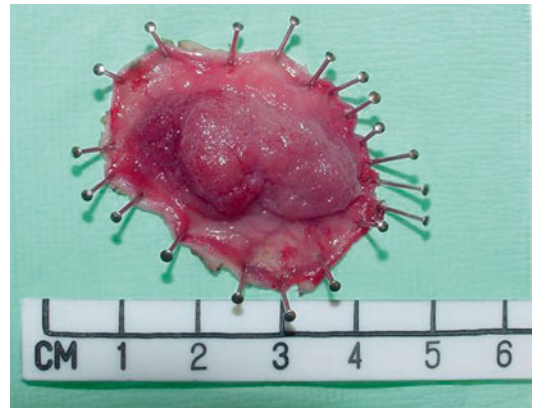

Fig 11.5 Mounted specimen of TEM

11.2.3.6 Mounting of Specimen

The specimen is orientated during the retrieval. It should then be mounted on a Foam board (Fig. 11.5) and sent to the pathologist. By and large, this is a technically demanding local excision inside the rectum. It avoids skin incision and does not have a stoma. Furthermore, it provides a nice specimen en bloc, enabling precise staging by pathologist.

11.2.3.7 Postoperative Management and Complications

After full-thickness excision, the patients may have a typical two-day fever, which will subside spontaneously. We suspected that this was a reflection of the inflammatory response in healing. Nevertheless, we will always cover with perioperative antibiotics. Severe necrotizing fasciitis has been reported in the literature [16].

For complications, there were also reports of postoperative bleeding. Since the application of ultrasonic energy, hemostasis is usually not a problem. Two patients in our local series complained of temporary flatus incontinence. Subsequent endoanal ultrasonography revealed no structural sphincter damage. Both of the patients were fully continent within a week. Anorectal physiology studies showed reduced volume but no significant changes in pressure [17].

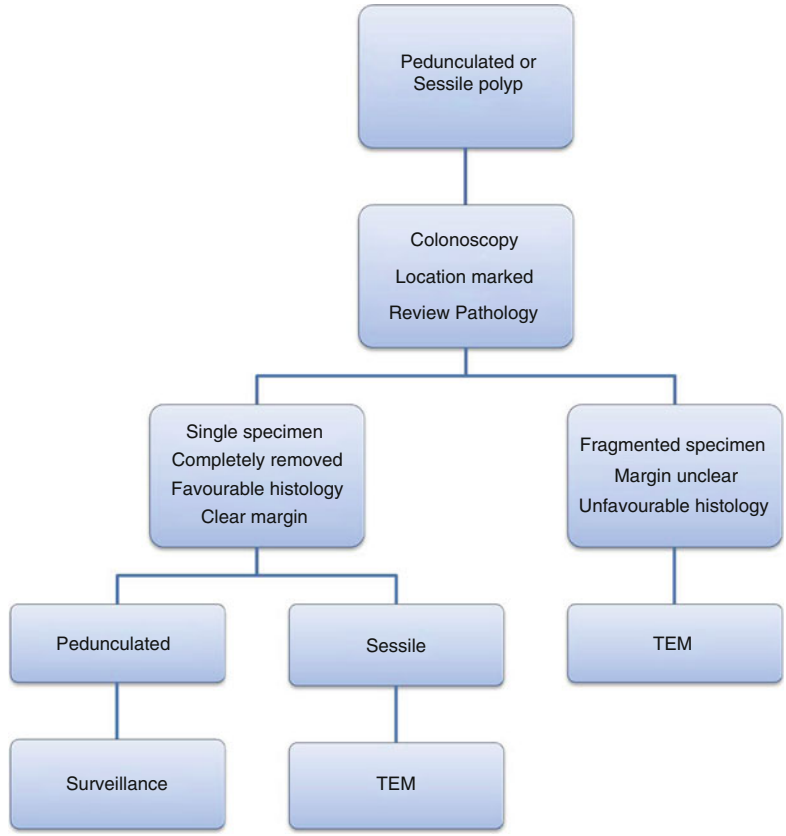

Fig 11.6 Management flowchart of early rectal polyp

11.2.4 Practical Algorithms

11.2.4.1 Case Selection

TEM provided a means of complete excision of early rectal tumor. This is a method of low morbidity and mortality and avoids the creation of stoma [18]. The National Comprehensive Cancer Network (NCCN) [19] provides guidelines for management of the rectal polyps and cancer.

According to the surgical principles of the NCCN guidelines, transanal excision is recommended in the condition as indicated (Fig. 11.6). When the lesion is adequately identified in the rectum, TEM may be used.

11.2.4.2 Giant Rectal Villous Adenoma Extending to Dentate Line

For villous adenoma located within 4–5 cm from the anal verge, we would agree that Park's peranal excision is a recognized approach (Fig. 11.7). However, when we are faced with carpet-like rectal villous adenoma with extensive involvement or tumor high up in the mid or upper rectum, we may have difficulty. Lack of good exposure may lead to lack of precision of resection, piecemeal removal, and hence high recurrence rate.

In these cases, we propose a hybrid approach where we will start off with the distal resection via Park's peranal approach and submucosal dissection with mucosal elevation by submucosal injection. Headlight seems to be helpful in this part of the operation (Fig. 11.8). We shall proceed cranially as far as possible, usually 2–3 cm above the dentate line.

Then we will start off with the proximal submucosal dissection by TEM. Methylene blue was mixed with modified gelatin (colloid) for elevation of the mucosa. We can then link up the dissection and attain a complete specimen en bloc.

11.2.4.3 Pathological Surprise of uT1 pT2

Lymph node involvement was quoted as 5% in pT1, over 10% in pT2, and up to 20% in pT3 tumor [20]. In our series, we had two pT2 and

one pT3 patient and all three patients were understaged by preoperative transrectal ultrasonography. They were all cases early in our series and we attribute to the learning curve of ultrasonography. We offered laparoscopic TME with covering ileostomy for all three patients within one week of TEM as salvage surgery. All three final reports came back as negative for over 12 harvested lymph nodes (pN0) (Fig. 11.9).

11.2.4.4 Down-Staging After Neoadjuvant Therapy: ypT1

As a routine, for preoperative mrT3 tumor, we will offer neoadjuvant therapy after assessment by oncologist. Time and again, repeat MRI revealed down-staged lesions and we are possible to proceed with sphincter-sparing surgery. According to our present protocol of treatment of rectal cancer, we still offer laparoscopic TME. Time and again, final pathology came back as ypT1. On reflection, should we have performed TEM or other minimally invasive radical surgery in these cases [21]? Are we "overkilling"? These are questions to be answered by on-going trials in Netherlands and France.

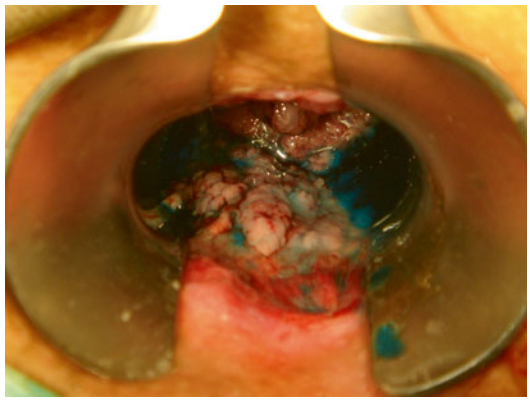

Fig 11.7 Giant villous adenoma extending to dentate line

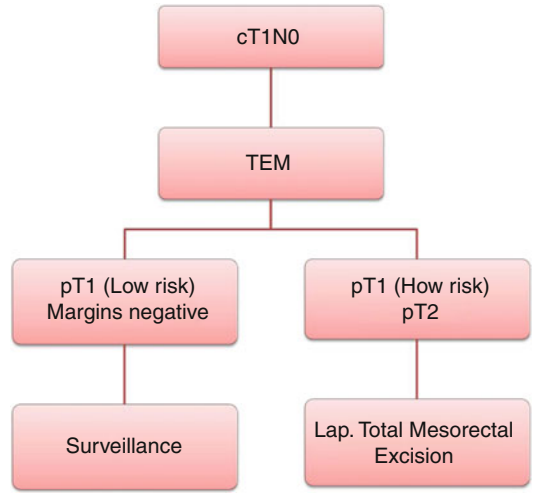

Fig 11.9 Algorithm for uT1pT2

Fig 11.8 Park's peranal approach

11.2.4.5 Perforation into Peritoneum

For starters of TEM, it is always a nightmare to enter into the peritoneum. We have two such cases early in our series. They are all villous adenoma by final pathology.

To tackle with such situation, firstly, we will insert the TEM suction device into the peritoneum to reduce the pneumoperitoneum. Then we will close off the peritoneum by continuous suture. Despite these tense situations, we must stay calm and perform the suture step by step. In fact, by going slowly, the carbon dioxide pumped into the peritoneum will be absorbed. The pneumo-rectum will be reestablished slowly and the defect can be closed by routine TEM suturing.

Nevertheless, prevention is better than cure and it would be nice to plan ahead. If the tumor is located at more proximal position, and pathology reviewed sessile polyp only, we may proceed with submucosal excision. In case of tissue biopsy confirming malignancy, we may elect transabdominal approach of laparoscopic anterior resection.

11.3 Future Direction of Development

11.3.1 Single-Port Access (SPA) Surgery with TEM

As a start, disposable ports were used for single-port access (SPA) surgery and traditional laparoscopic instruments were utilized with great difficulty. Nevertheless, appendectomy, cholecystectomy, and colectomy were attempted. Operation time was long and the technique was demanding. TEM with articulated instruments with its specific dissection technique was actually ideal for single-port access. The articulated tip of the instrument provided triangulation, which facilitated the vision of the dissection field.

A feasibility study on cholecystectomy was firstly assessed in porcine model. It was followed by successful application in human. Problem to overcome was the extra length from the umbilicus to the gallbladder fossa. This resulted in the imbalance of the pivot point and hence the overshooting of dissecting movements.

It was concluded that, single-port access (SPA) cholecystectomy is feasible with transanal endoscopic microsurgery (TEM) instruments [22]. The special TEM technique of manipulation within a confined space is beneficial for single-port surgery. The TEM port is more cost-effective as it is reusable. Furthermore, the extended indication in cholecystectomy would improve the value for money of the TEM instruments, which was limited to early rectal tumors beforehand.

11.3.2 Rectal Conservative Therapy (RCT)

TEM allows surgeons to excise more proximally located rectal lesions that cannot be excised by traditional peranal methods of excision. Lezoche reported on preoperative chemoradiotherapy and TEM for selected patients who have T2N0 rectal cancer [23]. It is possible to achieve the same long-term oncologic results observed after laparoscopic resection with total mesorectal excision, which is our current gold standard, in terms of local recurrence and survival. Furthermore, for mobile T2 or T3 carcinoma, TEM would be a good palliation.

Bökkerink reported on a multicenter trial [24] investigating the role of a rectum saving treatment modality using chemoradiation therapy and local excision by TEM for rectal cancer. We regard this as analogous to breast conservative therapy (BCT) of carcinoma of breast and hence coined rectal conservative therapy (RCT).

According to the study, patients over 18 years of age and with cT1-T3 tumor on imaging are recruited. All patients will receive neoadjuvant chemoradiation (CRT), consisting of radiotherapy with a total dose of 50 Gy, which is given in 25 fractions during 5 weeks. Patients will receive 825 mg/m^2 capecitabine b.i.d. 7 days per week during the whole treatment period. At 8–10 weeks after the end of the neoadjuvant treatment, patients with a ycT0-2 tumor after CRT will undergo TEM. The other patients will undergo total mesorectal excision (TME) surgery. After histological examination of the resected specimen, all patients with an ypT2-3

tumor, positive resection margins, or lymphangio-invasive growth, will undergo radical surgery within 4–6 weeks after the TEM procedure. This is the so-called The CARTS study: Chemoradiation therapy for rectal cancer in the distal rectum followed by organ-sparing transanal endoscopic microsurgery. We are looking forward to the long-term results.

11.3.3 Transanal Total Mesorectal Excision (taTME) with TEM

Low anterior resection (Lap LAR) and total mesorectal excision (TME) [25] is the gold standard of minimally invasive surgery (MIS) for mid and low rectal tumors. However, the pelvic resection in particular for bulky tumor in the narrow male pelvis has always been a challenge for surgeons.

Due to the curvature of the pelvis, in particular at the prostate level or at the Pouch of Douglas, we are working at a difficult angle-up position. Transanal TME [26], as a bottom-up approach, provided a straight end-on view for the distal part of TME, which made the pelvic dissection much easier.

Synchronous laparoscopic LAR and transanal total mesorectal excision (taTME) by and TEM [27] is a newly developed method. The abdominal as well as the perineal surgeon could often guide each other in the dissection at the "Holy plane" in a "rendezvous" manner, i.e. to meet each other in the middle. It saved quite significant operation time and ensured dissection along correct planes.

This coloanal anastomosis (CAA) was made feasible by KOL (Touchstone, Suzhou, Jiangsu, China) stapling gun. The mechanism was like that in stapled hemorrhoidopexy whereby the purse-string and additional anchorage suture can be pulled from within the ring of staples.

In conclusion, transanal total mesorectal excision (taTME) by synchronous laparoscopic LAR and TEM is feasible. We are combining operative techniques that are well-established, currently available and cost-effective. Most important of all, it complied with the oncological principles and made the most difficult part of TME much easier.

11.3.4 Natural Orifice Specimen Extraction (NOSE) Using TEM

Amongst all the natural orifices, e.g. oral, vaginal, urethral, the anal opening is the least controversial option. Retrieval of specimen through the vagina [28] was also reported but there is the problem of postoperative pain and dysparuenia.

With the protection of the TEM rectoscope of the rectal stump, direct contact of the tumor to the rest of the bowel is avoided. Natural orifice specimen extraction (NOSE) preferably done via the rectal stump [29] is more acceptable by colorectal surgeons. This will help in decreasing the number and size of the ports of laparoscopic proctectomy.

11.3.5 Natural Orifice Transluminal Endoscopic Surgery (NOTES)

Last but not the least, the dimensions of the TEM can potentially be extended from bottom up to encompass all facets of surgical treatment of rectal cancer. In the future, with the development of single-port robotic surgery, TEM may possibly be the platform to enable natural orifice transluminal endoscopic surgery (NOTES).

Conclusions

Transanal endoscopic microsurgery is the "Minimally Invasive Surgery of Minimally Invasive Surgery in rectal operation". Developed by Professor Gerhard Buess, it is a means of local resection of early rectal tumor. As a technically demanding operation through the natural orifice, it has its own skill sets different from that of laparoscopic surgery. It is also the platform of development for single-port access surgery, natural orifice specimen retrieval and natural orifice translumenal endoscopic surgery and has recently applied as an adjunct for total mesorectal excision. Future developments of organ-sparing surgery and robotic surgery on this basis are well under way. In this chapter, we have concluded our experience on the indications of various applications and tips and tricks to share with fellow surgeons.

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