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REVIEW ARTICLE

Techniques and technology evolution of rectal cancer surgery: a history of more than a hundred years

Marco Maria Lirici^a and Cristiano G. S. Hüscher^b

^aDepartment of Surgery, San Giovanni Hospital, Rome, Italy; ^bDepartment of Surgery, Rummo Hospital, Benevento, Italy

ABSTRACT

History of rectal cancer surgery has shown a continuous evolution of techniques and technologies over the years, with the aim of improving both oncological outcomes and patient's quality of life. Progress in rectal cancer surgery depended on a better comprehension of the disease and its behavior, and also, it was strictly linked to advances in technologies and amazing surgical intuitions by some surgeons who pioneered in rectal surgery, and this marked a breakthrough in the surgical treatment of rectal cancer. Rectal surgery with radical intent was first performed by Miles in 1907 and the procedure he developed, abdomino-perineal resection, became a gold standard for many years. In the following years and over the last century other procedures were introduced which became new gold standards: Hartmann's procedure, anterior rectal resection, total mesorectal excision (TME); the last one, developed by Heald in 1982, is the present gold standard treatment of rectal cancer. At the same time, new technologies were developed and introduced into the clinical practice, which enhanced results of surgery and even made possible performing new operations: leg-rests, stapling devices, instruments, appliances and platforms for laparoscopic surgery and transanal rectal surgery. In more recent years the transanal approach to TME has been introduced, which might improve oncologic results of surgery of the rectum. Ongoing randomized studies, future systematic reviews and meta-analyses will show whether the transanal approach to TME will become a new gold standard.

ARTICLE HISTORY

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Rectal cancer; rectal cancer surgery; Miles procedure; anterior rectal resection; surgical stapler; total mesorectal excision; transanal endoscopic microsurgery; laparoscopic rectal resection; transanal total mesorectal excision

The history of rectal cancer surgery has shown a continuous evolution of techniques and technologies over the years, with the aim of improving both oncological outcomes and quality of life of the patients.

Progress in rectal cancer surgery obviously depended on a better comprehension of the disease and its behavior, which led to real cultural changes in cancer management; also, it was strictly linked to advances in technologies and amazing surgical intuitions by some surgeons who pioneered in rectal surgery, and this marked a breakthrough in the surgical treatment of rectal cancer (Table 1).

Rectal cancer surgery at the beginning of the 20th century

It is conventionally believed that rectal surgery with radical intent was first performed by Sir William Ernest Miles (Figure 1) from 1907 on (1). Up to then, most surgery for cancer of the rectum was done with the mere intent of symptom palliation, even though the first rectal resections combining the abdominal

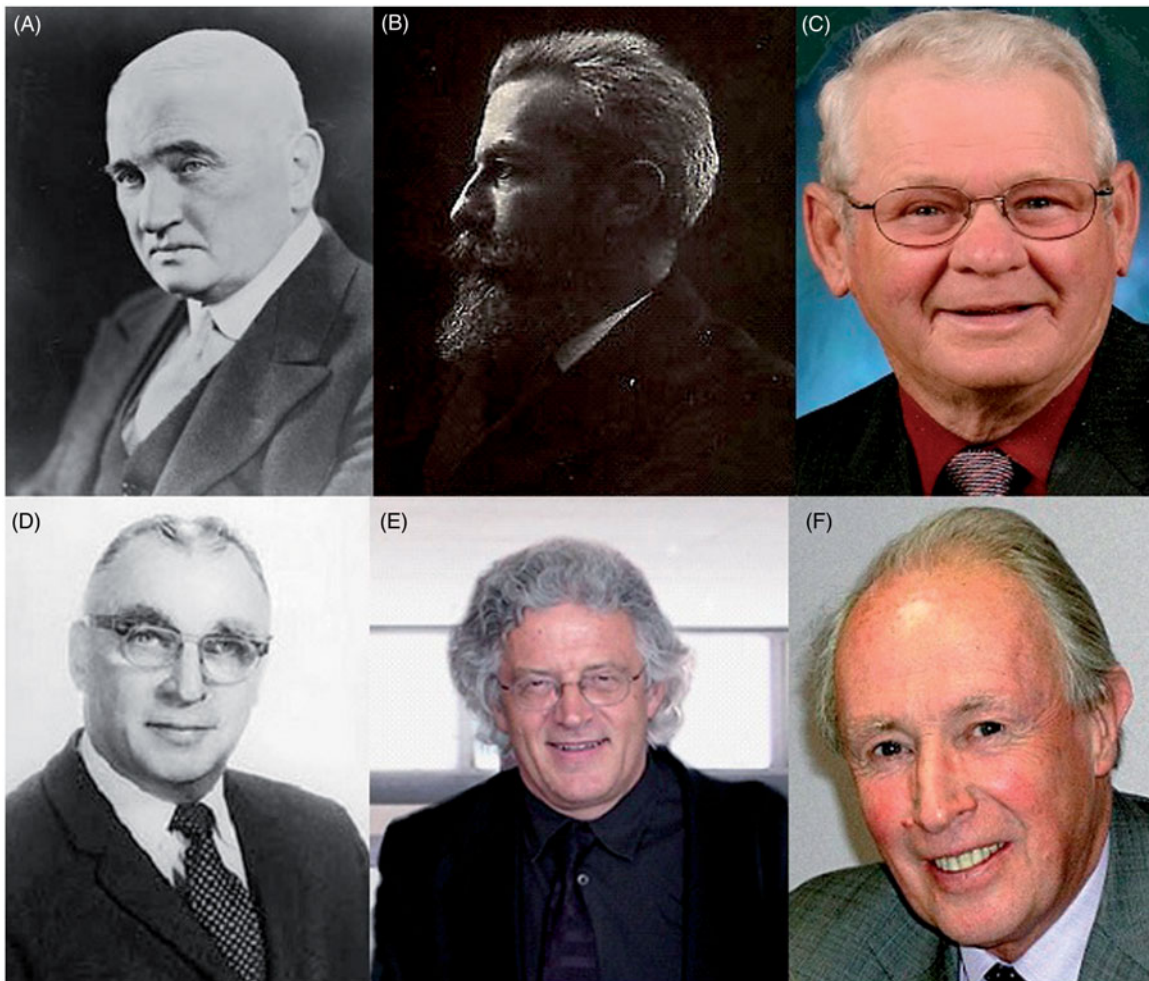
and perineal approaches had already been described in 1884 and 1904, respectively, by Czerny and Mayo.

Miles grounded his procedure on the presumption that rectal cancer was spreading both downwards and upwards in a cylindrical fashion. Thus, radical surgery made necessary an abdominal step of the operation with sigmoid division and rectal dissection from above before completing rectal resection and sphincter removal from the perineal approach. Notwithstanding a high morbidity and mortality rate, his first series showed a 58% one-year survival rate. Miles perfected the techniques he had first performed in 1907, and reported them over a number of years between 1908 (1) and 1923, eventually improving long-term remissions and gaining the acceptance of the surgical community of his time: Miles' operation became a gold standard in the treatment of rectal cancer.

In these very years surgeons started questioning what the best level of arterial ligation and division should be in a radical rectal resection. Whilst Miles proposed a low tie ligation of the inferior mesenteric artery, Sir Berkeley George Andrew Moynihan considered of utmost relevance the high tie ligation and

Table 1. Technical breakthroughs in rectal cancer surgery

Surgeon/S	Technique	Year/Years
Miles	ABDOMINO – PERINEAL RESECTION, LOW LIGATURE	1907–1923
Moynihan	ABDOMINO – PERINEAL RESECTION, HIGH LIGATURE	1908
Hartmann	NO PERINEAL RESECTION, COLOSTOMY	1921
Dixon	ANTERIOR RESECTION	1948
Goligher – Dukes – Nicholls	5 CM VS 2 CM SAFE MARGINS, LOW ANTERIOR RESECTION	1951–1983
Parks	LOW ANTERIOR RESECTION, COLO-ANAL ANASTOMOSIS	1976
Ravitch – Fain	STAPLED ANASTOMOSIS	1972–1977
Knight – Griffen	DOUBLE STAPLED ANASTOMOSIS	1980
Lazorthes – Parc	COLONIC J-POUCH	1986
Heald	TME	1982
Buess	TEM	1983
Hojo – Moriya	AUTONOMIC NERVES SPARING	1989
Several Authors/Clasicc, Color II, Acosog Studies	LAPAROSCOPY, ROBOTIC	1991–2010

**Figure 1.** Pioneers of rectal cancer surgery (A) Sir William Ernest Miles 1869–1947, (B) Henri Albert Hartmann 1860–1952, (C) Claude F. Dixon 1893–1968, (D) Mark Mitchell Ravitch 1910–1989, (E) Gerhard Friedrich Buess 1948–2010, (F) RJ (Bill) Heald.

division of this vessel to complete the lymphadenectomy. Moynihan believed that “the surgery of malignant disease is not the surgery of organs, it is the anatomy of the lymphatic system” (2). The answer to this question is still open, with pros and cons on both sides (3).

Surprisingly, until 1937, when leg rests were designed by Sir Huger Devine and their use was introduced in the operating theatres worldwide, abdominoperineal resections (APRs) were always performed with a change of the patient’s position from supine to prone or right semi-prone. Leg rests allowed to accomplish

ANTERIOR RESECTION FOR MALIGNANT LESIONS OF THE
UPPER PART OF THE RECTUM AND LOWER PART OF THE
SIGMOID*†

CLAUDE F. DIXON, M.D.
DIVISION OF SURGERY, MAYO CLINIC
ROCHESTER, MINNESOTA

THE OPERATION OF ANTERIOR RESECTION for lesions of the terminal part of the large intestine with re-establishment of intestinal continuity has been criticized by many authors as not being sufficiently radical. The present paper is an evaluation of the operation. The efficacy of any surgical procedure for cancer is judged by the number of persons undergoing the procedure who are alive five years or more and not on an anatomic basis—the extent of the excision.

This study is limited to the most controversial segment of the large intestine; namely, the distal 20 cm. It is for this region that new procedures are constantly being advocated and interest in old ones is being rekindled. A matter of 3 or 4 cm. from the dentate line makes the difference between an operation involving a permanent colonic stoma and one in which intestinal continuity can be re-established. While the majority of patients become adjusted to a permanent colonic stoma, there are some who have difficulty in its management. It should be remembered that those "cured" by anterior resection can live normally in every respect.

Because it is so important in determining the possibility of re-establishing intestinal continuity, I have considered the cases in this study in respect to the distance of the lower edge of the lesion from the dentate (pectinate) line as measured by the proctoscope. By studying the prognosis for each segment separately one could determine the lowest level at which it is sage to apply the procedure. I have avoided the use of the term "rectosigmoid" since it is merely a clinical designation for the rectosigmoidal juncture. Variation of the length of the rectum and of the level of the pelvic peritoneal fold, change of the length of the rectum after mobilization, shrinkage of the tissue by the time the pathologist measures it and differences in the interpretation of descriptive terms have led me to depend on the distance measured proctoscopically.

DEVELOPMENTAL BACKGROUND

The operation of anterior resection had been applied to lesions of the sigmoid before 1910, at which time primary anastomoses were performed, a large rectal tube being placed through the anastomosis for the purpose

*Read before the American Surgical Association, Quebec, Canada, May 27, 1948.
†I am indebted to Dr. A. L. Lichtman and Dr. G. Lowe for some of the material used in preparation of this paper.

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Figure 2. The first page of the original article published by Claude F. Dixon in the 1948 September issue of *Annals of Surgery*: The author reported a five-year survival rate of 64% after restorative anterior resection.

the abdominal and perineal steps of this operation simultaneously, with the patient lying on the table in the lithotomic position as it is still done today(4).

In 1921, the French surgeon Henri Albert Hartmann (Figure 1) introduced the anterior resection of the rectum with preservation of its distal third and sphincters and creation of a sigmoid colostomy on the left flank; proximal rectal tumors were the main indication for this procedure. Hartmann's aim was to reduce complications and mortality rates, which were significantly high after APR (5). Nowadays, the Hartmann procedure continues to be performed through either the open or the laparoscopic approach for complicated diverticulitis and large bowel obstruction caused by stenosing lesions of the recto-sigmoid.

Preserving the anal sphincters allowed to perform a less invasive procedure and to lower the mortality rate of APR, but still could not avoid a permanent

colostomy. On the other side, the early experiences with the pull-through technique for reestablishing bowel continuity after rectal resection were burdened by significantly high leakage and mortality rates. After the second world war, the time was ripe for re-thinking about anterior resection, turning it into a restorative procedure.

Introduction of restorative rectal resection and surgical staplers

In May 1948, Claude F. Dixon (Figure 1), head of the Section of General Surgery at the Mayo Clinic, presented the results of restorative anterior resection for tumors of the proximal rectum and the distal sigmoid colon at the meeting of the American Surgical Association held in Quebec, Canada. His data, published in the same year in *Annals of Surgery*, showed a five-year survival rate of 64% (6) (Figure 2). These results were stronger than the skepticism and criticism of most surgeons who considered anterior resection a non-radical procedure, and the technique developed by Dixon was more and more adopted for treating cancer of the upper third of the rectum.

In the following years two major facts boosted the diffusion of anterior rectal resection, making it a gold standard even when low visceral section and anastomosis were necessary: Data reported by Golligher, Dukes and Bussey about local tumor spread and recurrence, and the advent of surgical staplers.

In 1951, Golligher, Dukes and Bussey proved that local tumor spread in rectal cancer did not exceed 2 cm from tumor margins in most cases (cancer cells were found at a distance of >2 cm from the distal margin of tumor in only 2% of 1500 analyzed specimens); therefore the authors considered that a 5 cm margin of clearance would have ensured a reasonable radicality (7). These figures changed in the following years: First a safety margin of <5 cm and down to 2.5 cm was considered acceptable, then, in 1983, Nichols proved that a safety margin of 2 cm allows the same radicality of more extended resections with no change in overall survivals; finally, in most recent years, no differences in oncological outcomes were found with a safety margin of even <1 cm (4,8,9).

Surgical staplers were not only a technology breakthrough in colorectal surgery, they changed the way to fashion anastomoses, divide and close tissues, viscera and organs in almost all fields of surgery. The diffusion of stapler technology, and its application to surgery, started in 1972 thanks to Mark Mitchell Ravitch, a renowned pediatric surgeon with a Russian-born father (Figure 1) who introduced the technique of

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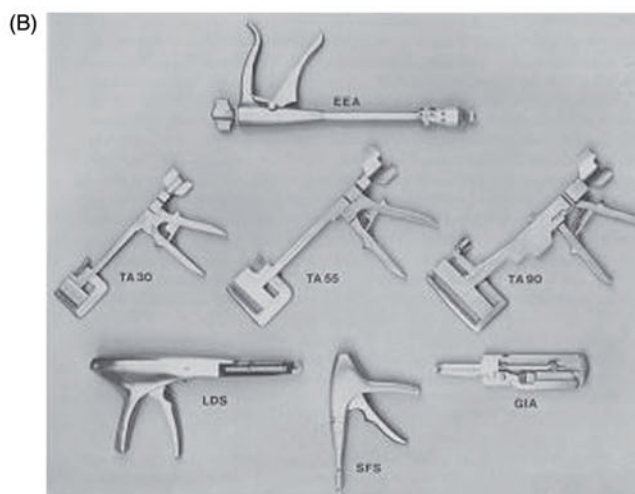


Figure 3. (A) The 2013 spring issue of PittMed where the amazing story of surgical staplers and their introduction into the clinical practice by Marc Ravitch was narrated, unveiling relevant anecdotes. (B) The United States Surgical Corporation assisted by Ravitch introduced the early version of reusable surgical stapler in 1972.

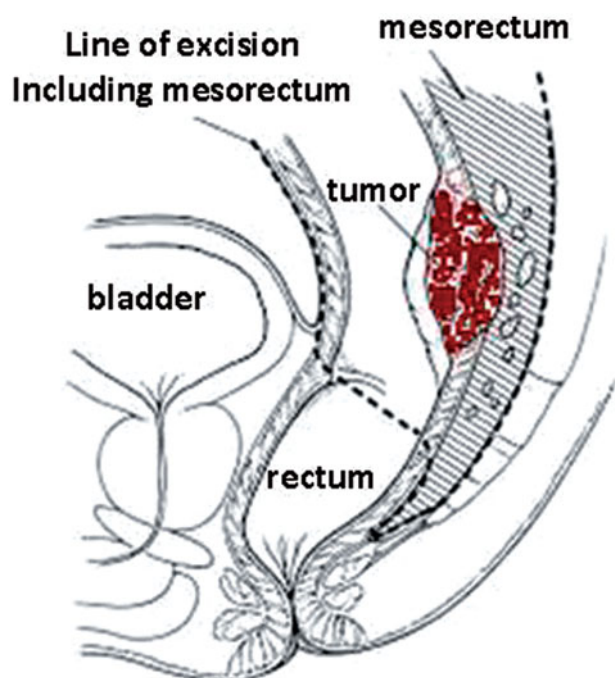


Figure 4. Sketch showing the principles and extent of Total Mesorectal Excision – TME

stapler suturing in the gastrointestinal tract (10,11). Actually, the development of surgical staplers began at the Moscow Scientific Research Institute for experimental Surgical Apparatus and Instruments in the ex-Soviet Union after the 2nd World War and Ravitch – as narrated by Elaine Vitone in 1993 (12) (Figure 3(A)) – could see the first hand-crafted staplers during his trip to Kiev in 1958, shown by the Thoracic Surgery Institute surgeon-in-chief Dr. Nikolai Amosov. He could buy one of these staplers, which he brought with him to the United States on his trip back. It took several years (from 1967 on) before a new-born company, the US Surgical Corporation, with Dr Ravitch as a pro-bono consultant on product design, started to industrialize surgical staplers (Figure 3(B)). The use of circular staplers made low colorectal anastomoses easier, with a leakage rate similar to that of hand-sewn anastomoses, as reported by Fain in 1975 (13).

In 1980, Knight and Griffen introduced the double stapling technique for low colorectal anastomoses. This procedure significantly accelerates the fashioning of colorectal anastomoses even in the narrow pelvis, avoids the disadvantage of joining segments of bowel different in size, and minimizes intraoperative contamination (14). From 1980 to 1986, coloanal anastomosis, intersphincteric rectal dissection and colonic-pouch anal anastomosis were introduced by Parks, Lazorthes and Parc, respectively, with the aim to preserve or improve sphincter function even in low rectal tumors (4,9).

Modern concepts and new developments in rectal cancer surgery

Certainly, the introduction of Total Mesorectal Excision – TME by RJ (Bill) Heald (Figure 1), whose work was first reported in 1982, constitutes the milestone of modern rectal cancer surgery (15). Until the late 1970s, anterior resection with blunt dissection of the mid and distal rectum (as described by Dixon) continued to have a disease-free five-year survival rate for all stages treated with curative intent not exceeding 50% with a local recurrence rate of up to 20%. This was mainly related to the breaches often created on the mesorectal fascia and the mesorectum itself during the blunt rectal dissection: Actually, positive radial margins are found in up to 85% of local recurrences (3). Heald's insight was that rectal cancer is “more apt to spread initially along the field of active lymphatic and venous flow”. The mesorectal fascia itself is “impenetrable only in the sense of being an avascular interface between viscus and soma” (16). This space is – indeed – the *holy plane*. Heald's principle was grounded on the knowledge that “the plane which surrounds the mesorectum is created by its separate embryological origin” whereas the whole rectum and mesorectum, which have the same embryological origin, “are one distinct lympho-vascular entity” (16). A surgical plane is a “potential space between contiguous organs which can be reproducibly created by dissection” (16). In rectal surgery the plane develops between the mesorectum and the surrounding somatic structures (Figure 4). Dissection along this plane should be sharp, under direct vision and gentle continuous traction (16).

Heald reported 80% five-year disease-free survivals with a local recurrence rate that dropped down to 4% after TME (17).

Besides the oncological outcomes, which have significantly improved after the introduction of TME, the quality of life outcomes after surgery also started to be of great value in the management of rectal cancer. Both the advent of laparoscopic surgery and the new awareness of the importance of autonomic nerve identification and preservation during rectal dissection had a positive impact on the patients' postoperative quality of life.

Hypogastric nerves and plexus saving techniques, identification of pelvic splanchnic nerves, identification and preservation of the neurovascular bundle of Walsh (the anatomy and anatomical relationships of the latter having been widely described by Heald who stressed the importance of preserving it and the autonomic genito-urinary nerve supply) significantly lowered the

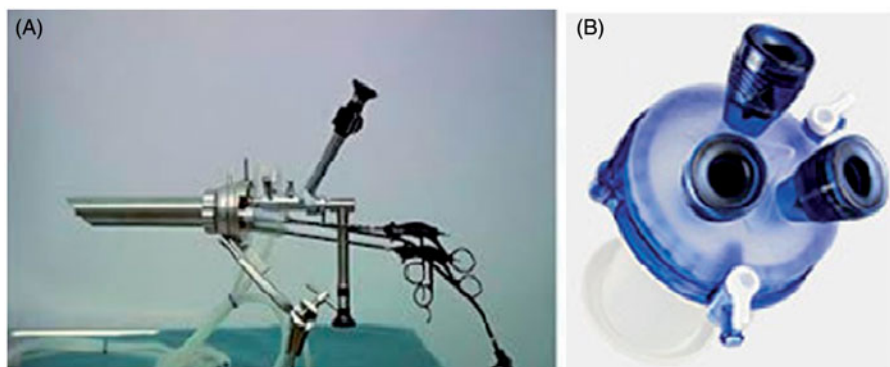


Figure 5. (A) Buess operation rectoscope and specially designed instrumentation (Richard Wolf gmbh, Knittlingen, Germany) for Transanal Endoscopic Microsurgery – TEM; (B) Gel-point path® transanal platform (Applied Medical, Rancho Santa Margarita CA, USA), a disposable device for TransAnal Minimal Invasive Surgery – TAMIS.

rate of bladder and sexual dysfunction, as reported by Hojo, Sawada and Moriya in 1989 (18).

Laparoscopic rectal resections and robotically assisted laparoscopic rectal resections according to the principles illustrated by Heald were increasingly performed in the last decade of 20th century and at the beginning of this century, the latter having been introduced in the most recent years. Optical magnification and carbon dioxide intraperitoneal pressure provide a potentially better view of the *holy plane* and an easier mesorectal dissection. Long-term results of the first randomized controlled trials (CLASICC RCT, COLOR II RCT, ACOSOG Z6051 Study), all accomplished between 2013 and 2015, are now available (19–21): The oncological results are somewhat controversial, whereas postoperative pain and quality of life resulted significantly better after laparoscopic rectal resections.

In 1983, just one year after the first report of TME, a young German surgeon, Gerhard Friedrich Buess (Figure 1), introduced a new procedure for the local treatment of rectal tumors: Transanal Endoscopic Microsurgery – TEM. Buess, who thought that the best surgery is a combination of good exposure and minimal invasiveness, developed the technique and also a number of dedicated technologies and instruments which allowed him to perform one of the first minimally invasive endoscopic surgical interventions ever (22,23). The main indications of TEM were benign tumors of any size, from the anal verge to the level of peritoneal reflection, and early-stage rectal cancers. In most recent years, right before his death, Buess proposed a transanal recto-sigmoid resection (24) as an evolution of the experimental procedure (the Tübingen procedure) he developed with Lirici in 1993 (25).

The new frontier: transanal mesorectal excision (TATME)

As mentioned above, TME requires a close and careful sharp dissection along the *holy plane*, under direct view. In many cases, even under the guidance of a laparoscope, the dissection of the distal mesorectum may be cumbersome and the integrity of the mesorectal fascia might not be preserved. TEM technology and TME technique merged with the intent of improving both the oncological and functional results and the quality of mesorectal dissection. The transanal endoscopic approach to radical excision of the perirectal fat and its overlying fascia, which is an evolution of the transanal-abdominal-transanal (TATA) procedure with bottom-up dissection of the distal rectum (26), was first introduced by Lacy, who reported the early results of a series of 20 patients in 2013, followed by several other authors (27,28). The transanal step of the operation may be performed through a rigid operation rectoscope or newly designed disposable platforms for transanal minimally invasive surgery – TAMIS (Figure 5).

Potential benefits of TATME are the following (29):

- Avoiding the most cumbersome phase of a laparoscopic approach to the distal mesorectum
- Obtaining significantly longer distal resection margin
- Improving the quality of mesorectal dissection especially when TATME and laparoscopic colon mobilization are combined
- Retrieving the specimen through the anal canal (NOSE), making minilaparotomy unnecessary
- Facilitating surgery in obese patients, in men, in patients with a narrow pelvis, in the presence of bulging tumors

Transanal TME, a procedure which represents the ultimate match point of several MIS approaches such as NOTES, NOSE, single access laparoscopy and endoluminal surgery, is still at an early stage, not yet well standardized and therefore validated. Several questions are still open, which may be summarized as listed below:

- Surgical approach: laparoscopic first vs. transanal first vs. combined procedure (Lacy's *Cecil* approach)
- surgical anatomy/landmarks
- indications
- morbidity rate
- learning curve
- long-term outcomes

Some more years are necessary before results from larger series of patients, including those from the ongoing COLOR III study, a multicentre RCT comparing transanal with traditional laparoscopic TME, meta-analyses and systematic reviews will be available; only then will we know whether TATME will be the next breakthrough in rectal cancer surgery.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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