Robotics and transanal total mesorectal excision

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Abstract: Management of rectal cancer has evolved over the last three decades, with a multidisciplinary strategy being the cornerstone of care. Magnetic resonance imaging (MRI), selective use of preoperative chemoradiation and detailed operative planning have facilitated appropriate radical resections. With the evolution of technology, minimally invasive options are readily available, making laparoscopic, robotic and transanal approaches valid alternatives to open total mesorectal excision (TME). The current debate is centered on which approach or combination would yield the best results to patients requiring radical resection for rectal cancer. Due to their potential benefits, a natural evolution of robotics and transanal minimally invasive surgery (TAMIS) techniques has been their combination. To date, there is scarce published data regarding the combined use of robotics and TAMIS: hybrid transabdominal robotic and transanal TME (R+taTME) or robotic-assisted transanal surgery-TME (RATS-TME). The objective of this article is to analyze the available literature, define the potential role for combined robotics and transanal TME (taTME) approaches and delineate future perspectives on this topic.

Keywords: Rectal cancer; total mesorectal excision (TME); robotic; transanal; transanal TME (taTME)

Background

The management of rectal cancer has evolved over the last three decades, with a multidisciplinary strategy being the cornerstone of care (1,2). Magnetic resonance imaging (MRI), selective use of preoperative chemoradiation and detailed operative planning have facilitated appropriate radical resections (3,4).

Surgery is still the most critical component of curative-intent treatment in rectal cancer (5). With the evolution of technology, minimally invasive options are readily available currently, making laparoscopic, robotic and transanal approaches valid alternatives to open total mesorectal excision (TME) (6).

Even under experienced hands, performing a TME is a difficult task. Poor maneuverability and visibility in the confined space of the pelvis potentially lead to suboptimal dissection with margin involvement or disruption of the mesorectal envelope, thus compromising oncologic outcomes (7,8). This is worsened in situations such as the male or narrow pelvis, obese patients, fibrosis due to radiation and low or bulky tumors.

Although recently, the ALaCaRT and ACOSOG Z6051 randomized controlled trials failed to demonstrate non-inferiority of a laparoscopic approach over an open approach for radical rectal cancer resection based on surrogate oncologic markers such as completeness of mesorectal resection, circumferential margin status and distal resection margin status (9,10), follow-up data from both, the ALaCaRT and ACOSOG Z6051 trial has demonstrated equivalent results in terms of 2-year disease-free-survival (DFS) and overall-survival (OS) between

laparoscopic and open surgery for rectal cancer (11,12). Furthermore, the CLASSIC II and COREAN trials also support the equivalency of oncologic outcomes between the laparoscopic and open approach (13,14).

This reflects the fact that even though there has been undeniable, steep progress and diffusion of minimally invasive surgery worldwide, conventional laparoscopic surgery alone may be insufficient to overcome the difficulties and technical pitfalls of a challenging pathology such as rectal cancer. Moreover, this explains why robotics and transanal minimally invasive surgery (TAMIS) as minimally invasive options for rectal cancer resection have become tremendously attractive alternatives amongst colorectal surgeons during the past decade.

Robotics provides benefits such as camera stability, 3D vision, improved access and visibility in narrow spaces, precise dissection, enhanced dexterity, tremor reduction and enhanced ergonomics, amongst others. To date, there is not enough data to support an oncologic superiority of robotic surgery over other approaches for rectal cancer resection. A recently published systematic review and metanalysis of controlled trials, including the ROLARR trial (15), suggest benefits of robotics over laparoscopic surgery in terms of conversion rates (16), thus supporting ease of dissection and navigation in the pelvis over conventional laparoscopy.

On the other hand, transanal TME (taTME) has developed from a fusion of concepts and technological developments; Heald's TME (17), Marks' transanal-transabdominal (TATA) dissection and 'bottom-to-up' approach (18), the development of minimally invasive surgery including laparoscopy and transanal access platforms such as Transanal Endoscopic Microsurgery ('TEM'—Richard Wolf, Knittlingen, Germany) (19) and more recently, TAMIS (20).

Benefits from a perineal approach for sphincter-preserving resections have been demonstrated by Denost *et al*. in a randomized controlled trial comparing perineal transanal approach in addition to laparoscopy versus a purely laparoscopic approach in 100 patients with low rectal cancer (21). The authors showed that the rate of positive circumferential resection margin (CRM) decreased significantly when a perineal approach was performed (4% versus 18%, P=0.025). In this scenario, a minimally invasive transanal approach would further improve visibility, maneuverability and dissection in the lower pelvis, thus, providing better quality specimens than a pure transabdominal approach with or without an open perineal approach. Recent systematic reviews and meta-analyses

mainly based on retrospective comparative data support this idea, with results showing better TME quality and fewer positive CRMs in taTME specimens when compared to purely laparoscopic TME specimens (22,23).

In the setting of a rapidly evolving field, the current debate is centered in which would be the best approach to treat patients that require resection for rectal cancer. Due to their potential benefits, the natural evolution of robotics and TAMIS has been their combination in the context of technological development and decreasing costs.

To date, there is scarce data on combined robotics and taTME: hybrid transabdominal robotic and taTME (R+taTME), and robotic-assisted transanal surgery-TME (RATS-TME).

The objective of this article is to analyze the available literature, define the potential role for combined robotic and taTME approaches, and delineate future perspectives on this topic.

Hybrid transabdominal robotic and taTME (R+taTME)

Robotic surgery helps overcome difficulties encountered in the middle and lower pelvis when dissecting along the extra-fascial TME plane. Despite enhanced maneuverability and visibility obtained with robotic technology, in the context of high-risk patients (obese patient, narrow pelvis and low or bulky tumors), it may still be insufficient to provide a perfect quality specimen.

TaTME improves control of the distal margin and dissection in the lower third of the pelvis (24). Better specimen quality due to less manipulation and traction injuries or mesorectal disruptions when dissecting in the lower pelvis could eventually translate into better oncologic outcomes in high-risk patients.

Data on R+taTME is scarce. The first report of such an approach was published by Mendes *et al*. (25) in 2015. The authors performed a combined procedure in a 55-year-old female with a cT3N+ rectal adenocarcinoma, 5 cm from the anal verge (FAV), previously treated with chemoradiation. Their setup involved an abdominal robotic component utilizing the da Vinci Si System (Intuitive Surgery, Sunnyvale, CA, USA) followed by taTME using the TEO platform ('Transanal Endoscopic Operations'—Karl Storz, Tuttlingen, Germany). The specimen was extracted transanally and a mechanical end-to-end anastomosis was fashioned with a circular stapler. A defunctioning colostomy was performed and no postoperative complications were

reported with a postoperative stay of 2 days. Operative time and blood loss were not reported. Even though a detailed pathological report is not provided, it is stated that the mesorectal resection was complete. The authors concluded that the combined approach is safe and may be useful in technically demanding situations such as the narrow pelvis, obesity and ultra-low rectal tumors.

During the same year, Gómez Ruiz *et al.* (26) published the results of 5 patients (4 men) where, both transabdominal and transanal dissections, were robotically-assisted and performed in a sequential fashion using the da Vinci Si System and PAT ('Puerto Acceso Transanal'—Developia-HUMV, Santander, Spain) combined with a GelPoint Path (Applied Medical, Rancho Santa Margarita, CA, USA). The mean age of patients was 57 [38–67] years and BMI was 25.8 [22–31] kg/m^2. Tumors were located at an average of 5 [4–6] cm FAV and were preoperatively staged as T2N0M0 (one patient) and T2N1M0 (four patients). The mean operative time was 398 [270–450] minutes with no intraoperative complications or conversion, and the mean length of hospital stay was 6 [5–7] days. There was one anastomotic leakage in the series. All specimens were complete mesorectal excisions with negative margins. The authors concluded that this approach is feasible and safe for early rectal cancer and may help overcome the limitations of traditional laparoscopic resection.

Another case was reported by Bravo *et al.* (27) in 2017 performing a simultaneous two-team approach ('Cecil' approach) with the da Vinci Xi System (Intuitive Surgical, Sunnyvale, CA, USA) and the GelPoint Path in a 50-year-old man with rectal cancer, 5 cm FAV. Preoperative clinical staging was T2N0M0. Total operative time was 160 min and the estimated blood loss less than 50 mL. The patient had no postoperative complications and was discharged on postoperative day 3. Pathology revealed an intact mesorectum and a pT2N0 tumor with negative margins. They concluded that hybrid surgery with pelvic robotic dissection and transanal TME was feasible, quick and safe.

To our knowledge, the largest series was recently published by our group (28). Eight patients (7 males) underwent R+taTME via a modified Cecil approach using the da Vinci Xi System and the GelPoint Path. The median age was 60 years [47–73] with a BMI of 29.5 [20–39.1] kg/m^2. Tumour height was at a median of 7.5 [4–13] cm FAV and six patients were clinical stage III cancers which received neoadjuvant chemoradiotherapy. The median length of stay was 9 [4–33] days. There were no intra-operative complications and no patients required conversion to an open approach. Complications included one anastomotic leak and one presacral collection. All patients had a complete mesorectum with negative margins.

Details of these publications are summarized in *Table 1*.

Abdominal setup

Before surgery, the patient receives mechanical bowel preparation and the operating team is organized for a two-team simultaneous procedure (*Figure 1*). The patient is anesthetized and prophylactic antibiotics administered at induction. An indwelling urinary catheter is inserted and the patient placed in the Lloyd-Davies position.

The transabdominal approach starts with an OptiPort entry through the right flank using a 0° 10 mm camera to establish pneumoperitoneum. Four 8-mm robotic ports are inserted under vision and robotic arms docked for a routine low anterior resection with the da Vinci Xi Surgical System, with the patient in a 15° head down and 12° left tilt position.

The inferior mesenteric vein is divided at the duodenojejunal flexure in between Hem-o-loks (Telefex Headquarters International, Ireland). The splenic flexure is then fully mobilized in a medial to lateral fashion while the patient is in a head-down position to enable synchronous operating with the perineal surgeon. The inferior mesenteric artery is then divided in between Hem-o-loks, and the descending and sigmoid colon are fully separated from the retroperitoneum, identifying and preserving the left ureter and gonadal vessels. The abdominal dissection must be efficient to be able to coordinate with the perineal surgeon. The transabdominal TME is then commenced in a standard robotic fashion. Dissection is carried out outside of the mesorectal envelope, in the extra-fascial TME plane. The abdominal dissection then meets the perineal surgeon's dissection and a Pfannenstiel incision is made to remove the rectum trans-abdominally given that a transanal extraction can be associated with traction damage to the marginal artery.

Perineal setup

The taTME approach is set up synchronously. The anus is everted with four 0 silk sutures placed in four quadrants to retract the anus. A Lonestar Retractor (Lonestar, Cooper Surgical, Trumbull, CT, USA) is used to retract the anoderm and the anal canal washed with cetrimide.

The GelPoint Path is then inserted using sponge forceps

Table 1 Summary of case reports and series reporting results of R+taTME

Variables	Mendes *et al.*	Gómez Ruiz *et al.*	Bravo *et al.*	Nikolic *et al.*
Study				
Year published	2015	2015	2017	2019
Kind of publication	Case report	Case series	Case report	Case series
Number of cases	1	5	1	8
Patient characteristics				
Male/female	0/1	4/1	1/0	7/1
Age (years)	55	57 [38–67][b]	50	60 [47–73][a]
BMI (kg/m^2)	n/a	25.8 [22–31][b]	28	29.5 [20–39.1][b]
Tumour DAV (cm)	5	5 [4–6][b]	5	7.5 [4–13][b]
Clinical stage (I/II/III/IV)	0/0/1/0	1/0/4/0	1/0/0/0	1/1/6/0
Neoadjuvant treatment	Yes	Yes (4/5)	No	Yes (6/8)
Procedure details				
Cecil approach	No	No	Yes	Yes
Robotic system[c]	da Vinci Si	da Vinci Si	da Vinci Xi	da Vinci Xi
Transanal platform	TEO[d]	PAT[e] + GelPoint Path[f]	GelPoint Path	GelPoint Path
Operative time (min)	n/a	398 [270–450][b]	160	240 [220–500][b]
Blood loss (mL)	n/a	90 [25–120][b]	50	n/a
Splenic flexure mobilisation	Yes	Yes	Yes	Yes
Defunctioning stoma	Yes	Yes	Yes	Yes
Anastomosis method (S/H/N)[g]	Stapled	3/2/0	Stapled	6/2/0
Conversion	No	No	No	No
Morbidity	No	1 anastomotic leak	No	1 anastomotic leak, 1 presacral collection
Length of stay (days)	2	6 [5–7][b]	3	9 [4–33][a]
Pathology				
Quality of TME	Complete	Complete	Complete	Complete
CRM involvement	n/a	No	No	No
Distal margin involvement	n/a	No	No	No

[a], median value [range]; [b], mean value [range]; [c], da Vinci Surgical System (Intuitive Surgery, Sunnyvale, CA); [d], TEO, Transanal Endoscopic Operation (Karl Storz, Tuttlingen, Germany); [e], PAT, Puerto Acceso Transanal (Developia-HUMV, Santander, Spain); [f], GelPoint Path (Applied Medical, Rancho Santa Margarita, CA); [g], S/H/N, stapled/handsewn/no anastomosis. n/a, not available; BMI, body mass index; DAV, distance from anal verge; TME, total mesorectal excision; CRM, circumferential resection margin.

and position confirmed using the dilator (*Figure 2*). A 1-0 prolene suture with a 26-mm rounded needle is used to create a purse-string to close the rectum distal to the lesion, ensuring that equal proportions of tissue are taken at equidistance from the port lip in a clockwise fashion.

Three ports are then inserted via the platform with the utilization of a 0° camera. A pneumorectum is established with an AirSeal® System (Conmed, Connecticut, USA) at a flow rate of five liters per minute and a pressure of 5 mmHg. A 5 mm SILS™ Hook diathermy (Covidien,

Figure 1 Theatre setup for R+taTME. Robot is docked from the left lateral side of the patient and display for taTME image is placed the patients' right side.

Dublin, Ireland) with articulation ability is used.

A planned circumferential mucosal mark was created with hook diathermy at the edge of the radial mucosal folds followed by a full-thickness circumferential rectotomy. The GelPoint Path is then removed and the purstring reinforced with 1-0 prolene, ideally inverting the mucosa. A cetrimide wash is again performed, the GelPoint Path repositioned, the camera is switched to a 30° laparoscope and pressure from the AirSeal is increased to 12 mmHg. 'Down-to-up' dissection is carried out through the TME plane circumferentially, avoiding damage to the mesorectal envelope and the nerves laterally, until dissection is completed in a combined transabdominal-transanal effort from both teams.

Anastomosis

A 33-mm haemorrhoidal stapler anvil (DST Series™ Technology—Covidien, Dublin, Ireland) is inserted into the distal end of the colon and secured with a purse-string suture. Transanally, a full-thickness purse-string suture is placed around the distal resection edge with a 0 prolene suture on a 26-mm round needle. Once the anvil has been
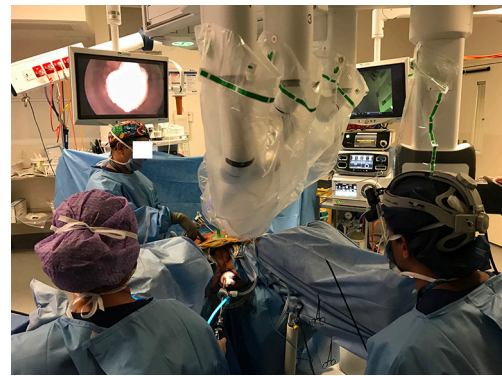

Figure 2 Perineal setup for transanal phase of R+taTME.

passed through the anus, the purse-string is tied and the stapler is introduced transanally to create the anastomosis. This may be a colonic-pouch-anal, side-to-end, or end-to-end anastomosis depending on the colonic length and patient anatomy. The anastomosis is then reviewed visually and tactically. A reverse leak test is performed. A 19-Fr Blake's drain tube is placed in the pelvis and a loop ileostomy is formed on the right side of the abdomen in a previously marked site.

Postoperatively, the ERAS (Enhanced Recovery After Surgery) protocol is followed.

Robotic-assisted taTME (RATS-TME)

An exciting new trend in colorectal surgery is the fusion of robotic technology and TAMIS. This has been coined as RATS by Atallah *et al*. and has been utilized for local excision of rectal neoplasms and TME with good initial results (29).

Theoretical advantages of RATS-TME over conventional taTME are related to improved visibility with high-definition 3D vision, camera stability, the use of wristed instruments that enhance dexterity and improve dissection, and ergonomics, amongst others. Also, the steep learning curve of a technically demanding approach, such as taTME, would be favored with the aid of robotic technology (30).

The first RATS-TME case was reported by Verheijen *et al*. (31) in 2014. A 48-year-old female with a cT3N+ rectal cancer, 8 cm FAV, underwent neoadjuvant chemoradiation and subsequently had a sequential laparoscopic and RATS-TME using the da Vinci Si System and the GelPoint Path. The specimen was extracted transanally and an end-to-end stapled anastomosis was performed using a circular stapler. A defunctioning loop ileostomy was fashioned. The total

operative time was 250 min, with an estimated blood loss of 50 mL. The postoperative stay was 3 days and the patient had no complications. The authors concluded that transanal TME using the robot is feasible and may help overcome technical difficulties associated with the use of conventional instruments in the setting of a single incision port.

Since then, six case series have been published and their results are summarized in *Table 2* (26,29,32-35).

Atallah *et al*. (29) reported 4 cases (3 males) where a hybrid abdominal laparoscopic and RATS-TME was performed sequentially. The mean age was 44 [29–59] years with an average BMI of 29 kg/m^2 and an average tumor height of 3.3 [1–5] cm FAV; three of them had neoadjuvant chemoradiation and subsequent resection and one had a pT1sm3 rectal cancer after local excision requiring completion TME. The mean operative time was 376 min with an estimated mean blood loss of 200 [50–300] mL. There was no intra-operative morbidity and the mean postoperative length of stay was 4.3 days. Mesorectal quality was reported as complete or near-complete in all cases. Resection margins were negative in all cases. Morbidity included one wound hematoma, one subsegmental pulmonary embolism (asymptomatic) and recurrent deep vein thrombosis, and a readmission for dehydration due to high ileostomy output. No local or distant recurrences were found in any of the patients after an average 8-month follow-up. The authors concluded that RATS-TME might facilitate dissection, especially of the distal two-thirds of the rectum.

Gómez Ruiz *et al*. (26) published results of 5 patients operated via a sequential robotic transabdominal and RATS-TME, as described in the previous section. Interestingly, they initially tested the procedure in pre-clinical cadaveric models using laparoscopic abdominal assistance before publishing their case series (36).

Huscher *et al*. (32) published an editorial communicating results of 7 patients (4 women) with rectal cancer who underwent a hybrid laparoscopic transabdominal and RATS- TME in a sequential fashion. The mean age was 63.2 [48–74] years and BMI was 29.9 [21.5–37.5] kg/m^2. All patients were clinical stage I or II and none of them received neoadjuvant therapy. The mean operative time was 165.7 [85–120] minutes. One patient had lower gastrointestinal bleeding, presumably from the anastomosis, requiring transfusion. None of the patients had an anastomotic leak. The mean hospital stay was 4.8 [4–6] days. The macroscopic assessment revealed a complete or near-complete mesorectum in all cases. The mean number of lymph nodes

resected was 14 [10–20] and an R0 resection was achieved in all cases. All patients had their defunctioning stoma closed during follow-up. They concluded that combining robotics and transanal access is feasible and could improve results in rectal cancer surgery.

Kuo *et al*. (33) reported a series of 15 patients (8 males) having a combined sequential single-port (plus an assistant port) robotic transabdominal approach followed by RATS-TME, performed by a single surgeon using the da Vinci Si System. The patients' median age was 60.3 [44–75] years, with a BMI of 21.97 kg/m^2. Indication for resection was rectal cancer in 13 patients and dysplastic polyps in the other two. Median operative time was 473 [335–569] min and the estimated blood loss was 33 [30–50] mL. Two patients required conversion to conventional laparoscopy, one due to a left ureteric transection and another due to bleeding during the transanal phase. Five patients had a diversion stoma. Reported morbidity included an intestinal obstruction requiring a return to theatre for adhesiolysis and another patient with a superficial wound infection. The mean length of hospital stay was 12.2 [10–14] days. All specimens were reported as complete mesorectum with clear circumferential and distal resection margins. The authors concluded that the application of robotic technology to a combined transanal and transabdominal approach for low rectal lesions is feasible and may offer benefits over conventional laparoscopy.

Monsellato *et al*. (35) published in 2019 a series of 3 patients (2 males) having a combined procedure. In two cases, the authors performed a sequential approach with a RATS-TME component first and a subsequent robotic transabdominal approach, and another where they performed simultaneous laparoscopic transabdominal and RATS-TME. The mean age was 61 [55–68] years and BMI was 26 [25–28] kg/m^2. Tumors were located at a mean distance of 4 [3–6] cm FAV, all clinical-stage III cancers treated with upfront chemoradiation. Mean operative time was 550 [440–600] minutes and length of stay was 10 [7–15] days. There were no surgical complications reported and all specimens were complete TMEs with negative margins. The conclusion was that RATS-TME is feasible and safe, with good initial postoperative results.

The largest series to date has been recently published by Hu *et al*. (34). Twenty patients (12 males) underwent simultaneous laparoscopic transabdominal and RATS-TME in a two-team approach. The abdominal component was performed via a single port (through the ileostomy site), whilst the perineal approach combined a da Vinci Xi System

Table 2 Summary of series reporting results of RATS-TME

Variables	Atallah *et al.*	Gómez Ruiz *et al.*	Huscher *et al.*	Kuo *et al.*	Monsellato *et al.*	Hu *et al.*
Study						
Year published	2015	2015	2015	2016	2019	2020
Number of cases	4	5	7	15	3	20
Patient characteristics						
Male/female	3/1	4/1	3/4	8/7	2/1	13/7
Age (years)	45 [26–59]	57 [38–67]	63.2 [48–74][a]	60.3 [44–75][a]	61 [55–68]	56.3 [31–79][a]
BMI (kg/m^2)	31 [21–38]	25.8 [22–31][a]	9	21.97 [range n/a][a]	26 [25–28]	23.9 [18.7–30.1][a]
Tumour DAV (cm)	3.3 [1–5][a]	5 [4–6]	2 [1–6.5]	3.3 [2–5][a]	4 [3–6]	5.8 [2–10][a]
Clinical stage (I/II/III/IV)	1/0/3/0	1/0/4/0	0/7/0/0	2/1/10/0, 2 benign polyps	0/0/3/0	4/4/10/2
Neoadjuvant treatment	Yes (3/4)	Yes (4/5)	No	Yes (11/13)	Yes (3/3)	Yes (12/20)
Procedure details						
Cecil or two team approach	No	No	No	No	Yes (1/3)	Yes (20/20)
Abdominal approach	Laparoscopic	Robotic	Laparoscopic	Single port robotic + assistant port	Robotic 2, laparoscopic 1	Laparoscopic
Robotic system[b]	da Vinci Si	da Vinci Si	da Vinci Si	da Vinci Si	da Vinci Si	da Vinci Xi
Transanal platform	GelPoint Path[c]	PAT[d] + GelPoint Path	GelPoint Path	GelPoint Path	GelPoint Path	GelPoint Path
Operative time (min)	376 [140–409]	398 [270–450]	165.7 [85–220][a]	473 [335–569]	550 [440–600]	172.3 [135–215][a]
Blood loss (mL)	200 [50–300]	90 [25–120]	n/a	33 [30–50][a]	n/a	82 [30–500]
Splenic flexure mobilisation	Yes	Yes	Yes	n/a	Yes	5/20
Defunctioning stoma	3/4[e]	Yes	Yes	5/15	Yes	14/18
Anastomosis method (S/H/N)	0/3/1	3/2/00	7/0/0	0/15/0	0/3/0	16/2/2
Conversion	No	No	No	2/15[f]	No	No
Morbidity	1 wound haematoma, 1 PE	1 anastomotic leak (CD II)	1 anastomotic bleeding (CD II)	1 mechanical bowel obstruction, 1 wound infection	1 ARF	7/20 (35%; including one pelvic abscess, no anastomotic leaks reported)
Length of stay (days)	4.3 [4–5]	6 [5–7]	4.8 [4–6]	12.2 [10–14]	10 [7–15]	8.8 [6–24]
Pathology						
Quality of TME (complete/ near complete/muscularis)	1/3/0	5/0/0	6/1/0	15/0/0	3/0/0	18/2/0
CRM involvement	No	No	No	No	No	3/20 (15%)
Distal margin involvement	No	No	No	No	No	No

Values expressed in median [range]. [a], indicates mean value [range]; [b], da Vinci Surgical System (Intuitive Surgery, Sunnyvale, CA); [c], GelPoint Path (Applied Medical, Rancho Santa Margarita, CA); [d], PAT, Puerto acceso transanal (Developia-HUMV, Santander, Spain); [e], one patient had an end ileostomy; [f], conversion to conventional laparoscopy. n/a, not available; BMI, body mass index; DAV, distance from anal verge; TME, total mesorectal excision; CRM, circumferential resection margin; S/H/N, stapled/handsewn/no anastomosis; ARF, acute renal failure; PE, pulmonary embolism; CD, Clavien-Dindo.
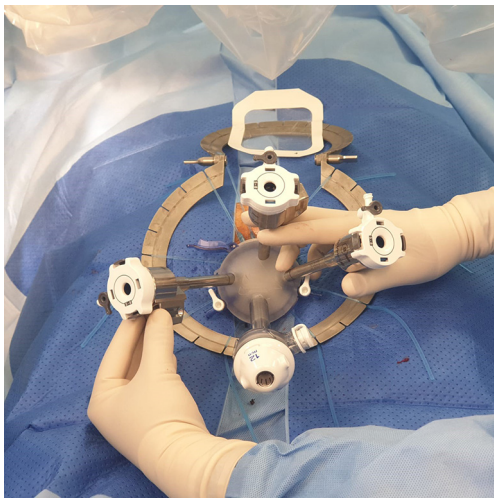
Figure 3 Robotic ports placement for RATS-TME.

Figure 4 Robot docked for RATS-TME.

with a GelPoint Path. The mean patient age was 56.7 [31–79], and the mean distance from tumor to anal verge was 6.0 [2–10]. Fifty percent of patients were stage III cancers and 60% had neoadjuvant treatment. Ninety percent of patients had a restorative resection. The mean intraoperative blood loss was 88 [30–500] mL and a circular stapling was utilized to restore bowel continuity in 80% of patients. The overall morbidity rate was 35%, including one pelvic abscess. One patient was reoperated due to perineal wound bleeding. They reported that all patients had complete or near-complete mesorectal resections and three patients had a positive CRM (15%). They conclude that RATS-TME assisted by laparoscopy is safe and feasible.

Setup

We have performed this approach in three low-risk cases in a totally-robotic sequential fashion, using the da Vinci Xi System and the GelPoint Path. In these cases, the operating theatre was setup for an initial transanal phase. The anus was everted, and a Lonestar retractor, GelPoint Path and purse-string suture are placed as described in the previous section.

Three robotic ports are then inserted via the platform; one of them an 8-mm bariatric port for the camera superiorly, two 8-mm normal length ports laterally, and an assistant port is placed inferiorly and is used for the AirSeal® (Conmed, Connecticut, USA) (*Figure 3*).

The da Vinci Xi System cart is placed laterally and the robot docked (*Figure 4*). We used three robotic arms with

the camera in the anterior aspect, a left-handed fenestrated bipolar and a right-handed monopolar spatula. Marking of the mucosa is made circumferentially and then a full-thickness rectotomy is performed. Further dissection is carried out through the TME plane; initially in the posterior aspect, then anteriorly in order to identify the prostate and avoid urethral injuries and then circumferentially until most of the pelvic dissection is performed transanally and the peritoneal reflection is breached anteriorly. Then the abdominal component was performed as described in the previous section. A Pfannenstiel incision in made to remove the specimen transabdominally and reconstruction is performed as previously described, ideally with a colonic-pouch-anal anastomosis.

Discussion

In the setting of a rapidly evolving field such as rectal cancer management, minimally invasive options are readily available to perform radical resections. Currently and mainly based on retrospective data, laparoscopic, robotic and transanal approaches seem to be valid alternatives to open TME (6).

Approaches to rectal cancer resection vary internationally. A recently published article by the ESCP collaborating group on a prospective audit of elective rectal cancer surgery showed that amongst 2,579 patients, 6.5% had a robotic approach and 19.9% had a minimally invasive approach (laparoscopic or robotic) with a taTME component, with results suggesting equivalent anastomotic leak rates and

positive resection margin in open, laparoscopic, robotic and transanal resections (37).

Robotic surgery provides several advantages over conventional laparoscopy, such as a high-definition image and 3D vision, camera stability, precise dissection, tremor reduction and enhanced ergonomics, amongst others. Even though robotics uptake for colorectal cancer surgery is still low, it is increasing worldwide, especially for rectal cancer surgery (37,38). Despite no proven oncological superiority of robotic resections over other approaches for rectal cancer surgery, randomized control data suggest benefits of robotic surgery over laparoscopic surgery in terms of conversion rates (16). Also, the learning curve of rectal resections is probably favored with robotic technology over conventional laparoscopy (39).

On the other hand, even though Buess (19) developed the TEM platform during the early 1980s and that the first taTME case published was performed using the TEM platform in 2010 (40), it was not until after the development of TAMIS in 2009 (20) that taTME was popularised worldwide.

Despite growing enthusiasm, there have been concerns around taTME and its profile of complications such as urethral and sidewall injuries and it´s oncologic safety based on recent Norwegian data (41).

The rate of urethral injuries in the first 720 cases published from the taTME international registry was 0.7% (42). Most of these complications have occurred early during the learning curve of different groups across the globe (43). Burden from urethral injuries is severe, resulting in a 22% conversion rate, an 8% rate of unplanned APR or Hartmann procedure and 26% of urethral repair complications, including a 9% need for permanent urinary diversion (43) Identifying key anatomical landmarks such as the neurovascular bundle of Walsh (44), the use of fluorescent urinary catheters (45) and identifying 'halo signs' or 'O's and 'triangles' during dissection (46), have all been proposed to prevent urinary tract and pelvic sidewall structure injuries to the sacral plexuses and major vessels when dissection is carried out too laterally. In order to prevent these injuries, especially during the learning curve, there has been a growing effort to develop training models and structured training programs across Europe, North America and Australasia, as highlighted by our group (47-49). Various consensus related to the current status of taTME, structured training curriculum and safe implementation has been published in the last few years (50-53).

A recent Norwegian publication has raised concerns in terms of anastomotic leak rates and recurrence rates and patterns amongst taTME patients (41). Even though randomized controlled data is awaited to solve this discrepancy, it is worth noting the low uptake of preoperative radiation in the taTME group compared with the national cohort (21% *vs*. 39%; P=0,001). It is also of interest, the high rate of pathologically positive or sub millimetric margin rate at 12.7% in the taTME group, which is not in keeping with most specialist centers and previously published data. As opposed to Norwegian data, recent systematic reviews and meta-analyses mainly based on comparative retrospective data have shown better TME quality and fewer rates of positive CRM in the taTME groups than the laparoscopic groups (22,23). It has also been shown in a publication based on follow-up data from 157 patients undergoing taTME for rectal cancer in two high volume centers in the Netherlands, that taTME is associated with favorable oncologic outcomes when performed in referral centers under experienced hands (54).

Also, others have shown that after adjusting for confounders, high anastomotic leak rates in taTME are mostly a result of an anastomosis in the lowest part of the rectum or the anus. Anastomotic leak rates in low rectal anastomoses remain high, regardless of the operative approach (37).

Despite these reasonable concerns, most of the literature would support taTME uptake and its utilization when performed under trained specialist surgeons in high volume centers.

In such an exciting and rapidly evolving field, still, most of the publications aim to compare outcomes of robotics and taTME and put them as competing approaches (55). The literature on combined robotics and taTME is in its infancy.

Colombo *et al*. evaluated the role of taTME in patients undergoing laparoscopic or robotic TME. In the context of similar conversion rates (4.8% *vs*. 3.2%; P=0.661), they found that the taTME use was significantly higher in the laparoscopic group than in the robotic group (16.7% *vs*. 1.7%; P=0.004). They conclude that the added benefit of taTME when robotic TME is performed is less significant than for laparoscopic TME, which was attributed to the enhanced ability of robotics to navigate through the pelvis during dissection (56).

Even though robotics help overcome some difficulties of conventional laparoscopy, in the context of high-risk patients, the role of taTME as a tool to control the distal

resection margin, perform rectal transection and distal mesorectal dissection, justifies its utilization (57). Moreover, a single stapled anastomosis would avoid multiple staple firing and crossed staple lines that could potentially have an impact on anastomotic leak rates (58). These reasons may explain why in a recent publication by the ESCP collaborating group on a multicentric, prospective audit on implementation of taTME internationally, a taTME component was used in 25% (31/126) of the cases where a robotic restorative resection for rectal cancer was performed. Besides, with this approach, there was a significantly lower conversion rate when compared to combined conventional laparoscopic and taTME (0% versus 16.2%) (37).

Published results on R+taTME (*Table 1*) show that this has mainly been implemented in male patients with a BMI over 25 kg/m^2 and in the context of low or locally advanced rectal cancers. Only our group presented a series of patients where a simultaneous two-team approach was systematically used. Interestingly, there are no conversions reported with this approach and publications communicate good results in terms of oncologic surrogate markers with complete TME and negative margins in all cases.

Our experience is that this approach allows improved visualization, articulation, and dissection abdominally via the application of robotic technology, facilitating the ability to perform meticulous rectal dissection along the TME plane. Distally, taTME has resulted in greater confidence to control the distal margin and to achieve an intact TME specimen, especially in high-risk patients. As a further matter, a transanal component yields control over choosing to take wider margins, such as the endopelvic fascia, when there have been concerns about CRM involvement in distal rectal cancers. We advocate on performing this kind of procedure in a two-team approach, with adequately trained surgeons, where continuous communication between teams enhances dissection, specimen quality and operative times.

More has been published on the combination of robotics and TAMIS for RATS-TME (*Table 2*). This approach has been mainly implemented in male patients with low, locally advanced rectal cancers, requiring neoadjuvant chemoradiation. Most of the series report a sequential procedure rather than a simultaneous two-team approach, and interestingly conversion rates are low. Only Kuo *et al*. (33), using a single-port robotic abdominal component and RATS-TME, reported two conversions in their series (13.3%) as previously described, where both cases were converted to conventional laparoscopy. Even though the robotic-assisted transanal component is a common factor in all reports, it is worth noting the heterogeneity of the transabdominal approach (conventional laparoscopy, robotic or single-port robotic) and the fact that this has been performed in a sequential or two-team fashion.

Based on these initial reports, RATS-TME appears to be safe and feasible when performed by experienced minimally invasive surgeons. The use of robotic technology in combination with transanal access platforms helps improve visualization with a stable high-definition 3D camera and dissection with the use of wristed instruments, potentially shortening learning curves, enhancing dissection and improving ergonomics. Despite its potential benefits, RATS-TME is still in its infancy and its disadvantages are mainly related to a complex theatre setup, docking, and probably longer operative time and costs.

In our experience, RATS-TME enhances dissection in the lower pelvis due to the added benefits of robotics, but its setup is more complex. In the scenario of being able to use a single robotic system, we would prefer the transabdominal use over the transanal, because of the ease of setup in the operating theatre and ability to perform a Cecil approach in a less complicated manner. We envisage that the increased utilization of a single-port robotic system (such as the da Vinci SP robot from below) and the possibility of dual robotics may alter this paradigm.

While technology is evolving, single-port robot prototypes are currently being tested in cadaveric models and initial human experiences (59-62) for natural orifice transluminal endoscopic surgery (NOTES). Navigation tools have also been developed and tested, eventually making it possible to apply augmented reality to pelvic dissection soon to patients with adverse pelvic anatomy or bad tumor features (63,64).

It is likely that the ongoing development of technology and technical aspects of rectal cancer surgery will make a two-field robot approach (65) or pure-robotic NOTES a reality in the near future.

Conclusions

A combination of robotic technology and taTME to perform hybrid procedures appears to be safe and feasible on the basis of initial published data.

Benefits from these approaches could be translated into a better resection quality, especially in high-risk patients, with potential improvement in oncologic and functional outcomes. These approaches need to be performed by

teams with sound concepts of oncological anatomy, appropriate surgical expertise and training, familiarity with minimally invasive techniques including robotic technology and taTME, and should be undertaken ideally in high volume referral centers.

Robotics and taTME should not be considered competing techniques. Due to their potential, the natural evolution of robotics and TAMIS has been their combination in a scenario of ongoing technological and technical development.

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Footnote

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