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Robotic transanal total mesorectal excision: Is the future now?

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Abstract

Total mesorectal excision (TME) is the standard surgical treatment for the curative radical resection of rectal cancers. Minimally invasive TME has been gaining ground favored by the continuous technological advancements. New procedures, such as transanal TME (TaTME), have been introduced to overcome some technical limitations, especially in low rectal tumors, obese patients, and/or narrow pelvis. The earliest TaTME reports showed promising results when compared with the conventional laparoscopic TME. However, recent publications raised concerns regarding the high rates of anastomotic leaks or local recurrences observed in national series. Robotic TaTME (R-TaTME) has been proposed as a novel technique incorporating the potential benefits of a perineal dissection together with precise control of the distal margins, and also offers all those advantages provided by the robotic technology in terms of improved precision and dexterity. Encouraging short-term results have been reported for R-TaTME, but further studies are needed to assess the real role of the new technique in the

long-term oncological or functional outcomes. The present review aims to provide a general overview of R-TaTME by analyzing the body of the available literature, with a special focus on the potential benefits, harms, and future perspectives for this novel approach.

Key Words: Rectal cancer; Minimally-invasive surgery; Robotics; Total mesorectal excision; Transanal approach; Natural orifice surgery

Core Tip: Rectal cancer management has been an issue of concern and discussion during the last 40 years. Total mesorectal excision (TME) has been considered the paradigm for its surgical treatment, while new minimally invasive approaches to perform TME have been introduced and expanded worldwide. Transanal TME could provide better control of the distal margins in technically complex low rectal tumors, but its oncological safety remains controversial. In this review, we discuss the current status of robotic transanal TME, including technical aspects, short- and long-term outcomes, as well as the foreseeable future marked by the improvements on robotic platforms and real-time navigation.

INTRODUCTION

Colorectal cancer (CRC) is a global health problem. Its incidence in people younger than 50 years is increasing since the mid-1990s, especially driven by the growth in rectal tumors[1]. Rectal cancer (RC) itself is the eighth most common cancer worldwide and was responsible for more than 300000 deaths in 2018[2]. Surgical resection is the primary treatment to cure rectal cancers. The proctectomy is currently included within a multidisciplinary work plan that includes exhaustive preoperative evaluation and the use of neoadjuvant therapies for locally advanced disease. The concept of total mesorectal excision (TME) was proposed by Heald *et al*[3] in 1982 and is widely accepted as the gold standard for RC resection. The effectiveness of a conventional trans-abdominal TME, however, may be jeopardized in some particular cases (*e.g.,* low or extensive tumors, obese patients, *etc.*) increasing the odds for inadequate oncologic resections with involved distal or circumferential resection margin (CRM).

In 2010, Sylla *et al*[4] described a novel technique based on the natural orifice transluminal endoscopic surgery transanal endoscopic recto-sigmoid resection, by using transanal endoscopic microsurgery (TEM) with laparoscopic assistance[4]. The new approach was named transanal TME (TaTME) or "down-to-up" proctectomy. Conceptually, the TaTME seemed to facilitate the surgical treatment for mid and low RC, especially in obese or male patients with a narrow pelvis[5]. The transanal approach was supposed to provide a clearer identification of the distal tumor margin and better specimen quality than conventional up-to-down laparoscopic TME[6]. Although more than 10 years have passed since its introduction, to date no randomized controlled trial (RCT) focusing on the real effectiveness of TaTME has been published. Two ongoing RCT, the GRECCAR 11[7] and COLOR III[8] trials, are still recruiting. Therefore, the body of the current evidence is based on clinical series and retrospective comparative studies[9,10]. The difficulty to find a real standardized technique and accreditation system is also an important drawback associated with TaTME. Conventional laparoscopy is nowadays the most extensively used minimally-invasive approach for RC. Compared with open surgery, it presents benefits in terms of better intraoperative (*e.g.,* blood loss) and postoperative clinical outcomes (*e.g.,* earlier bowel recovery, hospital stay)[11-14], but concerns remain regarding its

oncological safety[15-17]. The body of available research agrees also to reflect the disadvantages of the conventional laparoscopic instruments in complex pelvic scenarios[18].

Robotics were applied to abdominal surgery to overcome the drawbacks of standard laparoscopic procedures. The first robotic (up-to-down) TME was performed in 2006 by Pigazzi *et al*[19]. During the past few years, and due to the continuous improvement in the platforms, robotics gained popularity with promising expectancies. The main benefit, when compared with the conventional laparoscopic approach, seems to be a reduction in the conversion rates to open surgery[20]. However, even though robotic assistance seems to facilitate the mesorectal dissection, no clear benefits have been shown to date in terms of oncologic and functional outcomes[21,22]. Robotic technology has been also applied to transanal procedures. First, robotic transanal minimally invasive surgery (R-TAMIS) has been used to resect small polyps or to perform rectal-preserving excisions of early neoplasms[23]. When compared with conventional TAMIS (C-TAMIS), R-TAMIS increases the chance of resecting difficult rectal lesions and facilitates the closure of the rectal defects, with similar postoperative and pathological outcomes but increased costs (3562 dollars for C-TAMIS *vs* 4441 dollars for R-TAMIS, *P* = 0.04)[24]. Robotic transanal mesorectal excision (R-TaTME) is a recent alternative for TME that allows to resect entirely the rectum from below, combining potential benefits and indications of robotics and TaTME. Few publications have appeared to date focusing on those new procedures, but some reporting has shown encouraging clinical and oncological results[25-38].

The present review aims to offer a detailed description of the current status of R-TaTME, with an emphasis on the perioperative outcomes and the near future perspectives.

TECHNOLOGICAL BACKGROUND

TEM was first reported by Buess *et al*[39,40] in the 1980s. TEM showed acceptable postoperative and oncological outcomes for polyps or early tumors located 5 to 20 cm from the anal verge[41]. However, the procedures were technically challenging and associated with a non-despicable learning curve, therefore the expansion of TEM was limited for many years. To overcome these difficulties, TAMIS was developed in 2009 by Atallah *et al*[42]. Although it was originally described using standard laparoscopic instruments, robotic-assistance for TAMIS was soon implemented in a cadaveric model[43]. In 2012, the first R-TAMIS for a local excision was performed[44]. Three years after the first TaTME[4], the first R-TaTME was successfully performed in humans[25]. The patient was obese with familial adenomatous polyposis diagnosed with synchronous hepatic flexure and RCs. The abdominal resection was done by a conventional laparoscopic approach. The TaTME was performed using a *Da Vinci Si®* robot transanally, with a GelPOINT® Platform as an interface. The specimen obtained presented a nearly-complete mesorectal quality and tumor-free margins[25].

The ever-expanding technological developments that continue to shape our world today have brought several possibilities to improve the limitations of the current diagnostic and therapeutic tools, especially minimally-invasive interventional procedures. R-TAMIS was first performed using the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA, United States)[44]. The novel application was supposed to overcome the main limitations of C-TAMIS and TEM, using endo-wristed instruments to enhance dexterity and precision. After the first published R-TaTME [25], many other studies have demonstrated the effectiveness of the following platform's evolution, the Vinci®Surgical System-Si[25,29-33,35,38]. The latest Vinci® robotic system was introduced in 2014. The da Vinci®Xi similarly has been found useful to perform R-TaTME[34,37]. The technical improvements introduced in the latest generation provided several advantages, especially regarding versatility in docking and thinner instruments.

Two main R-TaTME procedures can be distinguished: (1) Totally-robotic TaTME (TR-TaTME), in which the abdominal part is also performed by a robotic approach [27]; and (2) Robotic-assisted TaTME (RA-TaTME), in which the abdominal part is performed by conventional laparoscopy or open surgery (hybrid procedures)[25].

The GelPOINT® Platform (Applied Medical, Rancho Santa Margarita, CA, United States) is the most frequently used interface. This port was specifically designed for transanal surgery and offers sphincter protection by a rigid access channel. Gómez-Ruiz *et al*[29] developed a platform by using a PAT proctoscopy (PAT, Developia-HUMV), which was placed transanally after lumen occlusion, then fixed to the table. A

GelPOINT® Platform occluded the proctoscopy and allowed trocar placement[29]. This platform was a hybrid between TEM and TAMIS, with some reusable components. Complete technical details provided by the literature are displayed in Table 1.

Hybrid TaTME

Two teams reported hybrid procedures with robotic-assistance during the abdominal phase combined with a conventional TaTME[45,46]. Both reported similar outcomes to those obtained with R-TaTME. Bravo *et al*[45] performed the abdominal and the transanal resections simultaneously. Nikolic *et al*[46] published 8 cases, with one anastomotic leak and one presacral abscess managed conservatively. In all the patients, a complete TME with free CRM and distal margins was obtained. Samalavicius *et al*[47] reported a successful case of hybrid TaTME with robotic TME and pure transanal resection, using the Senhance® Transenterix robotic system. The postoperative course and the histologic report were both uneventful.

BENEFITS AND LIMITATIONS

Preoperative evaluation and adequate staging are essential for a proper selection of the surgical technique and the approach when we face RC. In this sense, imaging evaluation with magnetic resonance imaging of the pelvis, the possibility of neoadjuvant treatment with radiochemotherapy in locally advanced cases, and multidisciplinary team discussion about each patient are pivotal[38]. The major benefits of R-TaTME are expected in male, obese patients, with a narrow pelvis and/or a tumor distance to anal verge lower than 8 cm.

When performing R-TaTME, both the transanal and the abdominal phases can be theoretically benefited with the incorporation of robotic assistance. Robotic technology can provide a more precise dissection following the oncological planes, then avoiding damaging the adjacent structures. Three-dimensional high-definition imaging with a stable camera view, or enhanced movement's freedom with tremor control, would help to perform a purse-string suture or increase the chances of controlling unexpected bleeding[34]. Beyond these advantages, a subjective feeling of conducting a higher quality TME has been reported during the robotic dissection[32]. The transanal approach, *per se,* allows better control of the distal margin at the beginning of the procedure. Moreover, the robotics system confers additional advantages as improving ambidexterity at lateral dissection or providing surgical fields steadier compared with the traditional techniques[34]. The reduction of the angular restriction in the narrow pelvic space also facilitates the preservation of the pelvic nerves and their autonomic function[38]. For some authors, additionally, there was a subjective synergistic effect by incorporating robotics into both phases of the surgery[33].

Increased expenditures and limited access for most surgeons worldwide are the intrinsic limitations attributed to the use of robotics in surgery, becoming the greatest anchor for the widespread of technology. Cost-analysis studies determined that robotic surgery was more expensive than open and laparoscopic surgeries for CRC[48, 49]. In robotic rectal surgery, the ROLARR trial showed that the costs in the robotic-assisted laparoscopic group (11853 pounds or 13668 dollars) were higher than those in the conventional laparoscopic group (10874 pounds or 12556 dollars)[21]. Regarding robotic transanal surgery, Atallah *et al*[28] reported an increased cost of 1500 dollars per case, including the GelPOINT® Platform. The use of another laparoscopic system is supposed to increase the costs[38]. However, it can be expected that reducing procedural times with simultaneous two-field interventions or using new (hopefully cheaper) robotic platforms may mitigate the economic burden and make robotic surgery more accessible. Additionally, robotic digestive surgery is noteworthy, far from being yet fully developed.

Technical drawbacks are still important. The da Vinci® Si required a minimum inter-trocar distance higher than 8 cm[38]. When using the new da Vinci Xi together with the GelPOINT® Platform during the transanal phase, reaching the peritoneal reflection from below is hampered[34]. Finally, two-field simultaneous robotic interventions continue under development and are not still implemented in the normal clinical practice[50,51]. A learning curve is unavoidable for any new procedure. Robotic surgery requires special training and the development of new skills. Indeed, at least 20-23 cases are needed to achieve expertise in robotic TME[52]. On the other hand, TaTME is a complex and technically demanding technique. Its learning-curve has not been yet fully established but has been estimated in around 40 cases[53]. Therefore, all the published experience was performed by surgeons in the learning period of R-

Table 1 Technical details of the series reporting robotic transanal total mesorectal excision

Ref.	Period of study	*n*	Robotic platform	Transanal interface	Patients' position	Type of Robotic TaTME	Teams	Remarks
Atallah *et al*[25], 2013		1[1]	da Vinci Si	GelPOINT path	Dorsal lithotomy	Robotic-assisted	1	1st robotic TaTME
Verheijen *et al* [26], 2014		1	da Vinci	GelPOINT path	Lithotomy	Robotic-assisted	1	
Gómez Ruiz *et al* [29], 2015	August 2013 January 2014	5	da Vinci Si	Transanal Access Port + GelPOINT	Lithotomy	Totally robotic	1	1st totally robotic TaTME
Atallah *et al*[30], 2015	November 2011 August 2014	4	da Vinci Si	GelPOINT path	Dorsal lithotomy	Robotic-assisted	1	
Atallah *et al*[31], 2015		1	da Vinci Si	GelPOINT + Lonestar	Dorsal lithotomy	Robotic-assisted	2	1st robotic ISR + TaTME
Huscher *et al*[32], 2015	January 2014 April 2014	7	da Vinci Si	GelPOINT path		Robotic-assisted	1	
Kuo *et al*[33], 2017	July 2015 March 2016	15	da Vinci Si	GelPOINT path	Lithotomy 15º trendelenburg	Totally robotic	1	Robotic SSPO
Hu *et al*[34], 2020	January 2016 November 2016	20	daVinci Xi	GelPOINT path	Lithotomy	Robotic-assisted	2	
Monsellato *et al* [35], 2019	May 2017 October 2017	3	da Vinci Si	GelPOINT path	Dorsal lithotomy	Robotic-assisted	1 (2) 2 (1)	
Tan *et al*[36], 2020	September 2019	1				Robotic-assisted	2	Laparoscopic SSPO
Suhardja *et al*[37], 2020		1	da Vinci Xi	Lone Star + GelPOINT path	Lloyd-Davies	Totally robotic	1	
Ye *et al*[38], 2021	May 2017 January 2020	13	da Vinci Si	STARport path	Lithotomy trendelenburg	Totally robotic (9) Robotic-assisted (4)	1 (9) 2 (4)	

[1]Patient included in the study published by Atallah *et al*[30] in 2015.
Remarked as the first report on robotic Transanal total mesorectal excision. SSPO: Single-site plus one port; TaTME: Transanal total mesorectal excision.

TaTME, even if they were well-trained and skilled experts in robotic and laparoscopic surgery. In the future, structured training courses will be fundamental to shorten the learning curve. The industry should be also encouraged to continue innovating surgical technologies towards the same end.

SURGICAL OUTCOMES

In the present review, we identified 11 case reports or clinical series describing 71 R-TaTME procedures[26,29-38]. The earliest reports by Atallah *et al*[25,28] and Gómez Ruiz *et al*[27] were further included in larger series (Table 2)

Intraoperative outcomes

Robotic TME may decrease the conversion rates to open surgery when compared with conventional laparoscopic TME[20-22]. Although there were no conversions from R-TaTME to open surgery in the published cases or series, Kuo *et al*[33] reported two conversions towards a conventional five-port laparoscopy. Operative time ranged between 132 min and 530 min[35,36]. The largest series included 20 patients, and both interventions were performed simultaneously, with a mean operative time of 172.3 ± 24.2 min[34]. In three of the studies, the transanal phase was faster than the abdominal [32,37,38]. Operative time tended to be higher in the TR-TaTME series, maybe because both phases were not run simultaneously[29,33,38]. Blood loss was lower than 100 mL. in most of the cases[29,31,33,34,36,38]. Intraoperative complications were reported in 2

Table 2 Demographic and preoperative data, *n* (%)

Ref.	*n*	Male/female	Age (yr)	BMI (kg/m²)	Tumor DAV (cm)	Clinical stage (I/II/III/IV)	Neoadjuvant treatment	Type
Verheijen *et al*[26], 2014	1	0/1 (100)	48	23.6	8	0/0/1/0	1 (100)	CRT
Gómez Ruiz *et al*[29], 2015	5	4 (80)/1 (20)	57 ± 13.9[1]	25.8 ± 2.7[1]	5 (4-6)[2]	1/0/4/0	4 (80)	CRT
Atallah *et al*[30], 2015	4	3 (75)/1 (25)	44 (26-59)[2]	29 (21-38)[2]		1/0/3/0	3 (75)	CRT
Atallah *et al*[31], 2015	1	1 (100)/0	66	31.6	< 0.4[3]	1/0/0/0	0	
Huscher *et al*[32], 2015	7	3 (42.9)/4 (57.1)	63.2 ± 9.7[1]	29.9 ± 6.1[1]	2 (1–6.5)[4]	5/2/0/0	0	
Kuo *et al*[33], 2017	15	7 (46.7)/8 (53.3)	60.3 (44–75)[4]	21.97	3.3 (2.0–5.0)[4]		11 (73.3)	CRT
Hu *et al*[34], 2020	20	13 (65)/7 (35)	56.3 ± 14.4[1]	23.9 ± 3.4[1]	5.8 ± 2.6[1]	4/4/10/2	12 (60)	CRT 9 (45) RT 3 (15)
Monsellato *et al*[35], 2019	3	2 (66.6)/1 (33.3)	61 (55–68)[2]	26 (25–28)[2]	4.33 (3-6)[2]	0/0/3/0	3 (100)	CRT
Tan *et al*[36], 2020	1	1 (100)/0	71	24.08	3	0/0/1/0	1 (100)	CT
Suhardja *et al*[37], 2020	1	1 (100)/0	67		6	0/0/1/0	1 (100)	CRT
Ye *et al*[38], 2021	13	9 (69.2)/4 (30.8)	62 (42- 67)[5]	22.26 (20.90–24.08)[5]	4.5 (4- 6)[5]	1/2/10/0	11 (84.6)	CRT

[1]mean ± SD.

[2]Mean value (range).

[3]Distance from dentate line.

[4]Median (range).

[5]Median (interquartile range).

BMI: Body mass index; CRT: Chemoradiotherapy; CT: Chemotherapy; DAV: Distance form anal verge; RT: Radiotherapy.

cases: (1) Hu *et al*[34] reported one case of presacral surface bleeding solved without conversion to open surgery; and (2) A left-ureter section that was inadvertently encompassed within the linear stapler during vessel transection. This was related to inadequate anterior traction of the vascular bundle caused by limitations in movement of the Da Vinci®Si robotic arms. The incident was identified and repaired intraoperatively[33]. The majority of patients received a diverting stoma during the index surgery (Table 3).

Postoperative outcomes

Six series reported postoperative complications[29,30,32-34,38]. Two grade B anastomotic leaks were described, both successfully treated conservatively[29,38]. A third patient was diagnosed with a pelvic abscess treated with antibiotics[34]. Postoperative ileus (*n* = 2), duodenal bleeding (*n* = 2), and rectal bleeding (*n* = 1) were the other remarkable postoperative complications[32,34,38]. Two patients required surgical reoperation: (1) Laparoscopic adhesiolysis for postoperative intestinal obstruction; and (2) Wound bleeding requiring surgical hemostasis[33,41]. Postoperative complications were described on 17/71 (29.94%) patients (Table 4). Length of hospital stay ranged between 4.3 d and 14 d[30,35]. There was no postoperative mortality.

Pathologic outcomes

Maybe the most important single potential benefit of robotic assistance in colorectal surgery is to facilitate mesorectal dissection, particularly in complex mid and low rectal tumors. This may reduce the rates of positive CRM. A combination with the precise control of the distal margins provided by a transanal dissection is then extremely promising. There were no distal margin involvements in the literature, but Hu *et al*[34] reported 3 positive CRM. Two cases were thought to be due to initial T4 lesions that, despite size reduction after neoadjuvant treatment, still retained residual

Table 3 Intraoperative and postoperative outcomes, *n* (%)

Ref.	OT, min	TransanalOT, min	Abdominal OT, min	Blood loss, mL	Splenic flexure mobilization	Transanal specimen extraction	Defunction-ing stoma	Anastomosis method (H/S/E)[1]	Anastomosis height (*n*)	Intraoperative complications	Conversion	Postoperative complications	Length of stay, d	Mortality
Verheijen *et al*[26], 2014	205	65		50	Yes	1 (100)	1 (100)	100%/0%/0%	Colorectal	No	No	No	3	0%
Gómez Ruiz *et al*[29], 2015	398 ± 88[2]	123 ± 50[2]	112 ± 27[2]	90 ± 50[2]	Yes	5 (100)	5 (100)	40%/60%/0%	Coloanal (2); Colorectal (3)	No	No	1 (20)	6 ± 1[2]	0%
Atallah *et al* [30], 2015	376 (140-409)[3]			200 (50-300)[3]	Yes		3 (75)	75%/0%/25%	Coloanal (3)	No	No	3 (75)	4.3 (4-5)[3]	0%
Atallah *et al* [31], 2015	316			75			1 (100)	100%/0%/0%	Coloanal (1)	No	No	No		0%
Huscher *et al*[32], 2015	165.7 ± 54.4[2]	55.5 ± 12.4[2]			Yes	7 (100)	7 (100)	0%/100%/0%	Coloanal (7)	No	No	1 (14.29)	4.8 ± 0.6[2]	0%
Kuo *et al* [33], 20167	473 (335–569)[4]			33 (30–50)[4]		15 (100)	5 (33.3)	100%/0%/0%	Coloanal (15)	1 (6.7)	2 (13.3) to laparoscopic	2 (13.3)	12.2 ± 1.5[2]	0%
Hu *et al* [34], 2020	172.3 ± 24.2[2]			82.0 ± 107.1[2]	Yes (25)		L-colostomy 6 (30); L-ileostomy 8 (40)	10%/80%/10%	Coloanal (2); Colorectal (16)	1 (5)	No	7 (35)	8.8 ± 4.2[2]	0%
Monsellato *et al*[35], 2019	530 (440–600)[3]			Inconsistent	Yes	3 (100)	3 (100)	100%/0%/0%	Coloanal (3)	No	No	No	10.6 (7-15)[3]	0%
Tan *et al* [36], 2020	132			20						No	No	No	6	0%
Suhardja *et al*[37], 2020	210	50	160			No	1 (100)	0%/100%/0%	Colorectal (1)	No	No	No	5	0%
Ye *et al*[38], 2021	240 (195–270)[5]	95 (74–100)[5]		60 (50–100)[5]	Yes	13 (100)	12 (92.3)	61.5%/38.5%/0%	Coloanal (9); Colorectal (4)	No	No	3 (23.1)	7 (6–10)[5]	0%

[1]H/S/E: Hand-sewn/stapled/end-enterostomy.

[2]mean ± SD.

[3]Mean value (range).

[4]Median (range).

[5]Median (interquartile range).

OT: Operative time.

Table 4 Detail of postoperative complications

Ref.	
Gómez Ruiz *et al*[29], 2015	Grade B anastomotic leak diagnosed in the outpatient clinic on postoperative day 14
Atallah *et al*[30], 2015	Sub-segmental pulmonary embolism
	Dehydration related to high output from his diverting ileostomy that required readmission 3 wk postoperatively
	Wound hematoma requiring drainage 2 wk postoperatively
Huscher *et al*[32], 2015	Rectal bleeding requiring the transfusion of blood units without reoperation
Kuo *et al*[33], 2017	Laparoscopic adhesiolysis for postoperative intestinal obstruction
	Superficial wound infection
Hu *et al*[34], 2020	Postoperative Ileus with Conservative treatment
	Pelvic abscess treated with antibiotics
	Acute urinary retention that required reinsertion of Foley catheter
	Perineal wound bleeding that needed hemostasis
	Duodenal ulcer bleeding with conservative treatment
	Fever with unknown origin with conservative treatment
	Acute appendicitis managed with antibiotics
Ye *et al*[38], 2021	Anastomotic leakage grade B on postoperative day 3History of duodenal ulcer with duodenal hemorrhage on postoperative day 7 solved with conservative treatment
	Postoperative ileus treated with gastrointestinal decompression and parenteral nutrition

viable microscopic cancer cells. The third was thought to be secondary to a metastatic lymph node located less than 1 mm from the CRM. The authors discussed that all of them were related to the original disease and not directly to the surgical procedure. A complete TME has become a critical oncologic factor to predict tumor recurrence in the pelvis[54,55]. The quality of TME was reported as near-complete (n = 12) in four series [30,32,34,38]. This reflects a 17.1% rate for non-optimal TME quality, which may appear to be higher than initially expected. The number of lymph nodes harvested ranged between 12 and 33 (Table 5).

Long-term oncologic and Functional outcomes

None of the published studies adequately addressed the mid- or long-term oncological results. The longest median follow-up was only 15 (range 11-18) mo[38]. Hu *et al*[34] identified a local recurrence after 1.5 years. Distant metastatic disease was documented in a patient who developed liver metastases 7 mo postoperatively[34]. On the other hand, the functional outcomes and the quality of life remain essentially unexplored since only Suhardja *et al*[37] described no urinary or sexual dysfunction in a patient after 12 mo of follow-up.

FUTURE PERSPECTIVES

TaTME controversy

TaTME was introduced by Sylla *et al*[4] in 2010 to overcome the challenges of resecting a low RC. TaTME popularity rapidly grew. Great benefits were expected for the technique due to the enhanced ergonomics and exposition of the rectal anatomy and the adjacent structures. These improvements were supposed to have an impact demonstrated by lower rates of conversion or postoperative complications, or by greater chances to perform a successful oncologic resection. The results from the most important international TaTME registry, however, showed high rates of anastomotic failure. Urethral injuries and carbon dioxide embolisms were found also to be potentially severe complications during TaTME[56]. Moreover, in a recent meta-analysis, the TaTME also failed to show any significant improvement in the functional outcomes compared with the conventional laparoscopic TME[57]. To add insult to

Table 5 Pathologic, oncological, and functional outcomes

Ref.	Tumor size, cm	Quality TME (I/II/III), %	CRM +	Distal margin +	Harvested nodes	DAV, cm	CRM, cm	Follow-up, mo	Local recurrence	Distant progression, m	Functional (urinary/sexual)
Verheijen *et al*[26], 2014		100/0/0	No	No		2					
Gómez Ruiz *et al*[29], 2015		100/0/0	No	No	14 ± 9[1]	1.8 (1-2.5)[2]		3 (3)[2]	No		
Atallah *et al*[30], 2015	2.7 (1.5-3.5)[2]	25/75/0	No	No	27 (15-39)[3]	3.3 (1-5)[3]		8 (6-12)[3]	No	No	
Atallah *et al*[31], 2015	3	100/0/0	No	No	33	0.4					
Huscher *et al*[32], 2015		85.7/14.3/0	No	No	14 ± 3[1]	2.7 ± 2[1]	3.2 ± 1.8[1]	2.5 (2–3.5)[2]			
Kuo *et al*[33], 2017		100/0/0	No	No	12 (8-18)[3]	1.4 (0.4–3.5)[3]	0.7 (0.2-2.6)[3]				
Hu *et al*[34], 2020	3.3 ± 1.5[1]	90/10/0	3 (15)	No	18.7 ± 6.3[1]	2.9 ± 1.3[1]	0.88 ± 0.78[1]		1 (5) 18 m	1 (5) 7	
Monsellato *et al*[35], 2019		100/0/0	No	No				12 (12)	No	No	
Tan *et al*[36], 2020								7	No	No	
Suhardja *et al*[37], 2020		100/0/0	No	No	24			12	No	No	No
Ye *et al*[38], 2021	3 (2–4)[4]	61.5/38.5/0	No	No	15 (13-16)[4]	2 (1.5–2.5)[4]		15 (11–18)[4]	No	No	

[1]mean ± SD.

[2]Mean value (range).

[3]Median (range).

[4]Median (interquartile range).

CRM: Circumferential resection margin; DAV: Distance from anal verge; TME: Total mesorectal excision.

injury, the Norwegian TaTME Collaborative Group recently reported frightening data, warning the whole surgical community. They reported higher rates of anastomotic leak in TaTME patients compared with those included in NoRGast study (8.4 *vs* 4.5, *P* = 0.047) and higher local recurrence rates (7.6%), some of them with an atypical multifocal pattern of presentation. According to these findings, TaTME for RC was suspended in Norway. Future studies are expected to clarify the shadows around TaTME. GRECCAR 11[7] and COLOR III[8] RCTs results are expected soon. In this scenario, we agree with the recommendation to wait for the RCTs that will provide the required evidence either to support definitively or reject TaTME[58]. The RESET trial is also ongoing to evaluate all the surgical approaches currently used for low anterior resection plus TME in a specific subgroup of high-risk patients[59].

New robotic platforms

Technological progression is moving ahead at a staggering speed. The da Vinci® system was alone at the forefront of the sector, but for years now new platforms are being developed, some of them with a special focus on single-port and natural orifice surgery. First, it is worth noting the latest evolution of the da Vinci® robotic platform. The da Vinci® SP™ Surgical System promises some advantages such as the possibility of three working instruments with flexion. After an initial evaluation for RATS[60], Kneist *et al*[61] showed that single-port access for R-TaTME was technically feasible with the robot in both surgical fields, performing the intervention in a male human cadaver. It is expected to achieve soon the Food and Drug Administration approval for colorectal procedures. The Flex® Robotic System with CR (colorectal) Drive (MedRobotics, Corp. Raynham, MA, United States) was also successfully implemented in a cadaveric model[62]. However, the flexible effector arms were not robotic-assisted,

and the design of the platform does not allow a safe dissection in the distal rectum. The SPORT™ Surgical System (Titan Medical, Toronto, Canada) is under development with promising applications in general, colorectal, urologic, and gynecologic surgery. Although not used transanally, the Senhance® robotic system has been proposed as an alternative for the abdominal phase of a hybrid TaTME in humans[47].

Two-field surgery

The transanal dissection adds the possibility for two teams to work simultaneously. Although the combination of laparoscopic and robotic approaches has been described for RA-TaTME, robotic surgeons and industry engineers have not previously considered a two-field, dual-console robotic system as the ideal for TR-TaTME. Now, the da Vinci® Xi platform allows the use of a robotic camera in the transanal field together with a laparoscopic one, to be viewed by both console surgeons using software and hardware interfacing (TilePro®)[50]. The main limitation is the maximum of four arms in the Xi platform, which also needs a camera to be assigned to one, leaving then one surgeon to work with a single instrument. Recently, Versius Robotic Surgical System (CMR Surgical, Inc., Cambridge, United Kingdom) was proposed as an alternative to enable two-field robotic surgery in preclinical conditions[51]. The possibility to work simultaneously is thought to reduce the operative time and consequently the overall procedural costs. The Food and Drug Administration approval is expected.

Real-time navigation

Navigation may be useful for R-TaTME to enhance the precision of the movements and to fully understand the complex anatomies[63]. Blueprint for R-TaTME navigation was described by combining the da Vinci Xi® Surgical System and the Stryker Navigation System, with the GelPOINT® Platform[64]. More recently, real-time stereotactic navigation with the da Vinci® Xi platform *via* the TilePro® interface has been reported[65]. In this study, fluorescence-guided surgery was also used for structure localization by using indocyanine green in the ureters and at the tumor site. Although many limitations remain to be solved, real-time navigation and fluorescence-guided surgery appear to be the next steps in the evolution of robotics and digital surgery.

CONCLUSION

Robotic TaTME has been introduced as a novel technique, with the potential benefits of both TaTME and robotic technology. This combination may overcome the limitations of the conventional laparoscopic TME and also mitigate some of the concerns attributed to the conventional TaTME. However, the available experience for R-TaTME is still limited. To date, this operation has been performed only in small groups of selected patients. Moreover, no team has reported data regarding the long-term follow-up. Preliminary results should be interpreted with caution and well-designed comparative studies are needed to give the green light to this promising approach. Critical aspects, as the real value of the procedure and its impact on the learning curve, have not been addressed yet. The evolution of the new robotic platforms and the chances provided by two-field surgery and real-time intraoperative navigation are the cornerstones for the success and future expansion of R-TaTME.

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