Systematic review analysis of robotic and transanal approaches in TME surgery- A systematic review of the current literature in regard to challenges in rectal cancer surgery

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A B S T R A C T

Several patients' and pathological characteristics in rectal surgery can significantly complicate surgical loco regional tumor clearance. The main factors are obesity, short tumor distance from anal verge, bulky tumors, and narrow pelvis, which have been shown to be associated to poor surgical results in open and laparoscopic approaches. Minimally invasive surgery has the potential to reduce perioperative morbidity with equivalent short- and long-term oncological outcomes compared to conventional open approach. Achilles' heel of laparoscopic approaches is conversion to open surgery. High risk for conversion is evident for patients with bulky and low tumors as well as male gender and narrow pelvis. Hence, patient's characteristics represent challenges in rectal cancer surgery especially in minimally invasive approaches. The available surgical techniques increased remarkably with recently developed and implemented improvements of minimally invasive rectal cancer surgery. The controversial discussions about sense and purpose of these novel approaches are still ongoing in the literature.

Herein, we evaluate, if latest technical advances like transanal approach or robotic assisted surgery have the potential to overcome known challenges and pitfalls in rectal cancer surgery in demanding surgical cases and highlight the role of current minimally invasive approaches in rectal cancer surgery.

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Introduction

Since surgical oncology of rectal malignancies was revolutionized in 1982 by introduction of the standardized total mesorectal excision (TME) [1], precise dissection along the mesorectal fascia asserted as a standard treatment for middle and lower rectal cancer. Combining the idea of tumor resection and maximized loco regional clearance, en-bloc resection of the primary tumor along with its blood supply and lymphatic drainage has been shown to increase disease free survival and overall survival significantly [2—6]. Thus, these quality features are surrogate parameters for short-term oncological outcome. Positive circumferential resection margin (CRM) is significantly associated with local tumor recurrence and is a strong predictor for oncological outcome [7,8]. Another strong prognosticator of tumor recurrence is the completeness of TME. Thus, TME quality is of crucial clinical significance especially in patients with negative CRM [9].

In regard to challenging anatomical situations like low tumors and locally advanced diseases, which are accompanied by higher rates of positive CRM, innovative surgical strategies may improve the outcome for high-risk patients [10,11].

Over the past 25 years, the laparoscopic approach has successfully been established in colorectal surgery. Laparoscopic TME (laTME) is a safe and valid approach compared to standard open anterior rectal resection with comparable oncological results, as measured by quality of TME, resection margins, number of harvested lymph nodes, local tumor recurrence and overall survival. Further, laTME showed comparable perioperative morbidity and mortality rates with superior results in terms of recovery and hospital stay [12—17]. However, high conversion rates up to 30% are still described for laTME [16,18—23], which are associated with higher rates of morbidity and poor oncological outcome [22,24].

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Increased conversion rates and low quality of oncological resections were found to be associated with narrow male pelvis, low and bulky tumors and obese patients, which are considered as major challenges for minimally invasive surgery [17,25,26].

Two recently established, innovative techniques have great potential to manage these pitfalls successfully resulting in safe procedures and avoidance of conversion even in demanding situations, when conventional laparoscopy hits its limits.

Robotic assisted TME (roTME), first reported in 2006, showed similar results in comparison to laTME in terms of perioperative and oncological outcome [27—34]. Stable camera platform, three-dimensional imaging, tremor elimination, motion scaling, ambidextrous capability, instruments with multiple degrees of freedom and a third arm for fixed retraction are the best-known advantages. Robotic technology enables precise dissection, especially in limited anatomical areas as narrow pelvis and obese patients [35].

First described in 2010, taTME offers comparable oncological and perioperative results to conventional laparoscopic TME [36—39]. Fourteen matched Case-Control-Studies [28,29,40—50] as well as three randomized trials [31,51,52] illuminate different aspects of perioperative and oncological outcome of transanal (taTME) and robotic total mesorectal excision (roTME), respectively, in comparison with conventional laparoscopic approach (laTME). Currently, Level 1 evidence is limited to the three randomized trials included in this review. Thus, we analyzed the recent advances and controversies and evaluated minimally invasive approaches with regards to known challenges for rectal cancer surgery.

Methods

According to the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) group, a comprehensive search of electronic databases has been conducted (Pubmed, Science Direct and Google scholar) using the key words 'rectal', 'TME',' total mesorectal excision' 'proctectomy' combined with the terms 'taTME', 'transanal', 'transanal minimally invasive surgery', 'transanal total mesorectal excision', 'single port', 'perineal' or 'robotic', 'robot', 'robotic assisted', 'robotic-assisted', 'robotic minimally invasive surgery', 'laparoscopic computer assisted'. The reference lists provided by the identified articles were additionally hand-searched for additional studies missed by the search strategy, and this method of cross-referencing was continued until no further relevant publications were identified. Evidence from these data was critically analyzed and summarized to produce this article.

Inclusion criteria comprise articles on robotic or transanal TME for rectal cancer. Eligible were either comparative case series compared to laTME or case series on one of roTME or taTME including more than 20 patients. Exclusion was considered as necessary, if outcomes of interest were not clearly reported and it was impossible to extrapolate or calculate the necessary data from the published results, the inclusion criteria were not fully met, articles were written in another language but English, only abstracts are available, no original data were obtained, comments or review articles. In a first screening, search results obtained via the online databases were excluded based on the title if they were ineligible or duplicate articles. Subsequently, remaining articles were reviewed by examining abstracts according to inclusion and exclusion criteria. Finally, the remaining articles were fully checked to ensure they met the inclusion criteria. Data extraction has been performed independently by two reviewers (MR and JKB) as follows: first author, year of publication, hospital, country, inclusion and exclusion criteria, study design, sample size, participant characteristics (sex, body mass index), tumor characteristics (distance from the anal verge), resection margin status, and short-term outcomes (operative time, hospital stay, readmission, major and minor

complication according to Clavien Dindo classification, conversion to open procedure) and surrogate parameter (Quality of mesorectal specimen, Circumferential resection margin, lymph nodes retrieved).

The studies were subject to significant bias, both in terms of the selection criteria for the study participants and also the reporting of data. To date, no level 1 evidence exists evaluating taTME or roTME versus laTME. The detailed search strategy is provided in Fig. 1.

Results

The systematic literature search identified 64 studies, which met the inclusion criteria. This leads to a total amount of 10288 patients: 570 cases of taTME, 4084 of laTME and 5758 of roTME (Fig. 1).

The majority of comparative case series (CSS) and matched case-control trial (MCC) included comparable patients cohort with no significant differences in surgical relevant issues as gender proportion, BMI or tumor localization (Table 1). Merely four roTME-studies revealed significantly different amounts of male and female patients, of whom three included proportionally more men in the roTME group [51,53,54], only one article had a gender misalignment for the benefit of laTME [55].

Operative time

Male gender, narrow pelvis diameter, obesity and tumor size were identified as independent prognostic factors for longer operative time reflecting the higher complexity of these cases [56].

Besides increased costs, robotic surgery is also accompanied by the disadvantage of a longer operative time resulting in longer anesthesia. This is endorsed by several studies, which observed a significant longer operative duration in roTME compared to laTME [29,30,45,48] (Table 2). Others revealed no significant difference in operative time [28,31,47,49]. In our experience, roTME is quite time consuming in the beginning of the learning curve, but comparable operation times to laTME are achieved after 20 to 30 cases [44].

On the other hand, taTME could be performed in equivalent [43,57] to significantly shorter operative time [42,44] compared to laTME. Though, taTME was performed by a more experienced team than laTME in one of the studies reporting a significant difference [44]. De'Angelis et al. state, that the reduction of operative time illustrates the simplifications of the surgical approach by a direct visualization and clear exposure of the lower rectum [42]. Further more, taTME can simultaneously be performed by two surgical teams and thereby lead to further reduction of the operative time [43].

Morbidity

Lower intraoperative complication rates, perioperative morbidity, shorter period of paralysis, less pain, shorter length of hospital stay (LOS), and faster recovery are the striking arguments for minimally invasive surgery in comparison to open approaches [12,16,22,58,59]. The question arises, if novel minimally invasive techniques can exceed this advanced level of perioperative convalescence.

Significantly shorter LOS are observed by Baik et al. in a randomized setting following roTME (roTME vs. laTME: 7 (5—10) d vs. 9 (6—12) d, p= <0.001) [31] (Table 3). The authors postulate, that this could be explained by less accidental tissue injury. Due to more careful tissue handling through retraction by robotic arm in contrast to assistant-guided retraction instruments, patients recover faster following roTME compared to laTME. Likewise, Kang et al. showed a shorter LOS following robotic surgery in a matched-case study (roTME vs. laTME: 10.8 ± 5.5 d vs. 13.5 ± 9.2 d, p=
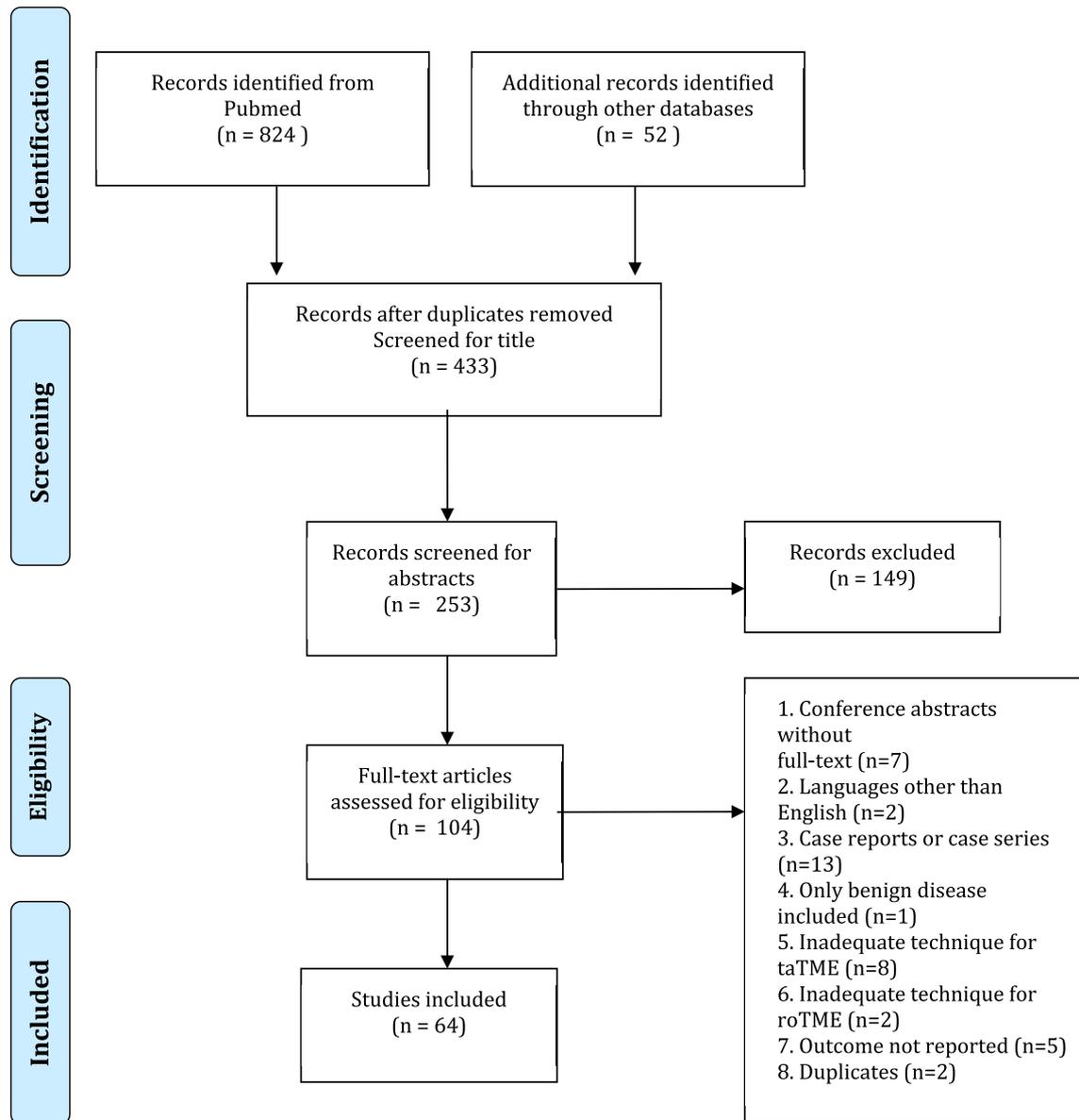
Fig. 1. Preferred reporting items for systematic reviews and meta-analyses diagram.

<0.001) [29]. For taTME, significantly shorter LOS [42,44] could be shown.

Overall complication rates tend to be comparable between laTME and roTME [60]. Furthermore, there is no difference in minor or major complications between taTME and roTME described in the literature [28,29,31,40–45,47–49,60]. However, to our knowledge, there is only one retrospective analysis available on direct comparison of taTME and roTME [61]. This data reveal equal postoperative complication rates (roTME 30.0% vs. taTME 50.9% p = 0.292) and comparable quality of TME specimen (Quirke's mesorectal grading: roTME Grad I 88.3% vs laTME 90.9%, Grad II roTME 11.7% vs. taTME 9.1%, p = 0.652).

In regard to the perioperative period, several authors described reduced analgesia usage [29] postoperative pain [29] and a shorter time to resume to liquid or soft diet, respectively [29,49] after roTME versus laTME, whereas others could not find difference in postoperative diet [28,47].

Overall, both novel techniques seem to improve postoperative recovery and are associated with shorter length of hospital stay with comparable readmission rates.

Conversion rate

Technical feasibility of minimally invasive rectal surgery is limited by known pitfalls resulting in conversion rates for laTME between 5 and 30% [62]. Locally advanced, bulky tumors, obesity, narrow pelvis and male gender are independent predictors for conversion and therefore can substantially hamper the surgical results [56,63].

Though, conversion is not only an indicator for the technical feasibility. Rather there is reliable evidence for an association with higher complication rates, in-hospital mortality, transfusion requirements, higher rate of metachronous metastasis and local recurrence as well as poor disease-specific survival [22,64–68].

Both, taTME and roTME, tend to be accompanied with lower conversion rates in comparison to laTME (Table 3). Whereas

Table 1
Demographics and clinical characteristics.

Author	Year	Country	Study design	Type	Patient number: overall	taTME	laTME	roTME	Gender M/F: taTME	laTME	roTME	p-value	BMI: taTME	laTME	roTME	p-value	Tumor location
					10962	1244	4084	5758									
Rouanet [76]	2013	France	CS	taTME	30	30			30/0				26.0 (21.0–32.4)				mid/low
Velthuis [40]	2014	Netherland	MCC	taTME	50	25	25		18/7	18/7		1.0	25 (20–36)	28 (21–34)		0.07	low/mid
Atallah [77]	2014	USA	CS	taTME	20	20			14/6				24 (18–41)				mid/low
De'Angelis [42]	2015	France	MCC	taTME	64	32	32		21/11	21/11		1.0	25.2 ± 3.5	24.5 ± 3.2		0.438	low/mid
Lacy [78]	2015	UK	CS	taTME	140	140			89/51				25.2 ± 3.9				up/mid/low
Tuech [79]	2015	France	CS	taTME	56	56			41/15				27 (20–42)				
Muratore [80]	2015	Italy	CS	taTME	26	26			16/10				26.2 (16.9–38.2)				
Chen [43]	2016	Taiwan	MCC	taTME	150	50	100		38/12	76/24		1.0	24.2 ± 3.7	24.6 ± 3.1		0.572	low/mid
Perdawood [44]	2016	Denmark	MCC	taTME	50	25	25		19/6	19/6		1.0	28 (18–46)	26 (19–38)		0.070	low/mid
Rasulov [57]	2016	Russia	CCS	taTME	45	22	23		11/11	14/9		0.463	26.0	26.0		0.47	mid/low
Veltcamp Helbach [81]	2016	Netherlands	CS	taTME	80	80			48/32				27.5 (19.5–40)				
Lelong [82]	2017	France	CCS	taTME	72	34	38		23/11	22/16		0.39	24 (18.6–45.0)	24.2 (17.7–32.7)		0.81	
Hellan [83]	2007	USA	CS	roTME	39			39			21/18				26 (16–44)		up/mid/low
Baik [31]	2008	Korea	RT	roTME	36		18	18		14/4	14/4	1.0		24.0 ± 2.5	22.8 ± 1.8	0.122	up/mid/low
Patriti [84]	2009	Italy	CCS	roTME	88		37	29		13/24	11/18	>0.05		25.4 ± 6.4	24.0 ± 6.2	>0.05	mid/low
Park [45]	2010	Korea	MCC	roTME	123		82	41		49/33	24/17	0.145		23.4 ± 3.3	23.4 ± 2.6	0.967	up/mid
Bianchi [27]	2010	Italy	CCS	roTME	50		25	25		17/8	18/7	0.8		26.5 (18.1–35)	24.6 (18.5–31.2)	0.06	up/mid/low
Baek [85]	2010	Korea	CS	roTME	64			64			40/24				26.8 (16.5–44)		up/mid/low
Pigazzi [86]	2010	USA	CS	roTME	143			143			87/56				26.5 (16.5–44)		up/mid/low
deSouza [87]	2010	USA	CS	roTME	44			44			28/16				28.2 (17.6–43)		up/mid/low
Baek [28]	2011	Korea	MCC	roTME	82		41	41		25/16	25/16	1.0		26.7 (16.8–40.3)	25.7 (17.1–34.0)	1.0	up/mid/low
Kwak [46]	2011	Korea	MCC	roTME	118		59	59		42/17	39/20	0.522		23.8 (21.9–26.3)	23.3 (21.8–25.2)	0.719	up/mid/low
Park [34]	2011	Korea	CCS	roTME	175		123	52		70/53	28/24	0.367		23.6 ± 3.3	23.7 ± 2.4	0.689	
Koh [88]	2011	Korea	CS	roTME	21			21			13/8				NR		
Kim [30]	2012	Korea	CCS	roTME	69		39	30		20/19	18/12	0.47		24.01 ± 2.19	24.36 ± 2.44	0.526	up/mid/low
Park [89]	2012	USA	CS	roTME	30			30			16/14				27.6 (25.0–32.0)		up/mid/low
Kang [29]	2013	Korea	MCC	roTME	330		165	165		97/68	104/61	0.333		23.2 ± 3.1	23.1 ± 2.9	0.721	
Park [90]	2013	Korea	CCS	roTME	80		40	40		25/15	28/12	0.478		24.3 ± 3.1	23.9 ± 2.4	0.444	
Luca [91]	2013	Italy	CS	roTME	74			74			38/36				24.8 (15.8–36)		up/mid/low
Baik [92]	2013	Korea	CS	roTME	370			370			232/138				23.3 ± 2.9		up/mid/low
Kenadawekar [93]	2013	India	CS	roTME	53			53			41/12				23.4 (18.4–27.4)		low/mid
D'Annibale [94]	2013	Italy	CCS	roTME	100		50	50		30/20	30/20	1.0		NR	NR		up/mid/low
Barnajian [47]	2014	USA	MCC	roTME	40		20	20		12/8	12/8	1.0		22 (18–31)	22 (18–31)	1.0	
Tam [95]	2014	USA	CCS	roTME	42		21	21		12/9	10/11	0.76		27 (20–38)	25 (20–37)	0.23	up/mid/low
Cho [48]	2015	Korea	MCC	roTME	556		278	278		184/94	182/96	0.929		23.7 ± 3.3	23.5 ± 2.9	0.522	up/mid/low
Melich [96]	2015	Canada	CCS	roTME	200		106	92		70/36	55/37			22.3 (22.9–23.5)	23.1 (22.5–23.7)		up/mid/low
Serin [97]	2015	Tukey	CCS	roTME	79		65	14		65/0	14/0			26.0 (21–32)	24.7 (23–27)	0.068	mid/low
Pai [98]	2015	USA	CS	roTME	101			101			63/38				28.0 ± 5.1		up/mid/low
Allemann [49]	2016	Switzerland	MCC	roTME	60		40	20		12/8	24/16	0.5		24.2 ± 7	25.9 ± 9	0.24	
Kim [60]	2016	Korea	MCC	roTME	99		66	33		46/20	23/10	1.0		23.3 ± 3.1	23.2 ± 2.3	0.86	
Kim [99]	2016	Korea	CCS	roTME	1019		486	553		302/184	333/200	0.74		23.8 ± 3	24.1 ± 3.1	0.203	up/mid/low
Feroci [55]	2016	Italy	CCS	roTME	111		58	53		42/16	27/26	**0.031**		24.6 (19–37)	24.6 (18–31)	0.512	mid/low
Ramji [100]	2016	Canada	CCS	roTME	53		27	26		19/8	19/7	0.52		27.6 ± 5.5	27.8 ± 5.5	0.96	
Shiomi [53]	2016	Japan	CCS	roTME	236		109	127		65/44	93/34	**0.04**		22.8 (12.8–34.9)	23.7 (17.5–39.0)	0.07	
Yamaguchi [101]	2016	Japan	CCS	roTME	442		239	203		154/85	140/64	0.315		23.1 ± 3.64	23.4 ± 3.16	0.251	up/mid/low
Sammour [102]	2016	USA	CS	roTME	276			276			168/108				27.0 (7.2)		up/mid/low
Gomez Ruiz [103]	2016	Spain	CS	roTME	198			198			132/56				26.9 (16.6–39)		up/mid/low
Colombo [104]	2016	France	CCS	roTME	120		60	60		42/18	40/20			23.8 (17.3–38.6)	25.8 (17.5–41.6)		up/mid/low
Bedirli [105]	2016	Tukey	CCS	roTME	63		28	35		19/9	24/11	>0.05		23.2 ± 3.2	24.7 ± 3.9	>0.05	mid/low
Buchs [106]	2016	UK	CS	taTME	40	40			32/8				27.4 ± 4.9				mid/low
Silva-Velazco [54]	2017	USA	CCS	roTME	184		118	66		66/52	50/16	**0.008**		27 (16–45)	29.5 (22–66)	**<0.001**	mid/low

conversion rates in roTME are given between 0% and 7.3% [28,29,47–49], conversion rates in ta TME range between 0% and 3.1% [43,44] in comparison to 0%–16% and 0%–22% in corresponding laTME procedures, respectively. By implication, taTME and roTME are promising techniques, which have the potential to make minimally invasive approaches amenable for a greater number of patients with rectal cancer. Particularly in complex anatomical situations, roTME and taTME can achieve excellent perioperative and oncological outcome.

Oncological outcome and efficiency

Based on the results of this systematic review analysis, roTME and taTME seem to be safe procedures with adequate oncological results. Analyses of the harvested lymph nodes revealed equivalent numbers in roTME [28,29,31,45,47–49,60] as well as in taTME [40–44] compared to laTME (Table 4).

Positive circumferential margins tend to be at least equivalent after roTME [28,29,31,45,47–49,60]. In contrast, Kim et al. observed a not significantly higher proportion of CRM involvement following roTME over laTME. However, in a preoperative CT scan, four of five roTME patients with positive CRM had a tumor infiltration of the mesorectal fascia [60]. Positive CRM has been shown to have a high predictive value for local tumor recurrence [7,8,69] and worse disease-specific survival [69] and occur significantly more frequently in low tumors [10,11].

Since the first description of taTME and roTME, only few results of systematic analyses of survival and local recurrence based on case-control studies or randomized trials have been published till now. Cho et al. observed in a matched-case study of 556 roTME and laTME patients, no difference in CRM or TME quality. Moreover no difference was revealed in regard to overall survival, disease specific survival or 5-year disease-free survival [48].

The first results of the ROLARR trial were published in the end of 2017 [52] and revealed comparable results for laTME and roTME in terms of surgical quality and safety. In sub group analysis, the conversion rate was observed to be lower in challenging cases such as obese male patients with large and low tumors, even though subgroups were to small to gain statistical significance.

Quality of mesorectal excision

The quality and completeness of TME is the main parameter of loco regional tumor clearance.

TaTME provides equivalent TME quality [42,44] in comparison to laTME (Table 4). Furthermore, Velthuis et al. could show superior taTME quality compared to laTME in a matched-case study (96.0% vs. 72.0%, p=<0.005) [40].

Quality of the specimen revealed comparable results for roTME and laTME [31,47,60], whereas Alleman et al. described a higher frequency of complete TME in robotic approaches (95% vs. 55%, p = 0.0003).

Nerve sparing procedure

Besides low postoperative morbidity and improved surgical quality, optimal long term functional outcome can be enhanced by the roTME as a result of nerve sparing surgical technique. Kim et al. showed in a prospective case series, that roTME is associated with faster recovery of bladder voiding and sexual function [30].

Cho et al. did not reveal any significant differences in terms of sexual dysfunction, but could find as well a significantly higher rate of voiding dysfunction after laTME compared to roTME (4.3% vs. 0.7%, p = 0.012) [48].

Currently, the only published study examining functional

Table 1 (continued)

Author	Year	Country	Study design		Patient number				Gender Male/Female			p-value	BMI Mean ± SD/median (range)			p-value	Tumor location
					overall	taTME	laTME	roTME	laTME	roTME	taTME		taTME	laTME	roTME		
					10962	1244	4084	5758									
Lim [107]	2017	Korea	CCS	roTME	138		64	74	46/18	50/24		0.439		22.7 ± 2.9	23.4 ± 2.9	0.728	mid/low
Kim [50]	2017	Korea	CCS	roTME	732		460	272	296/164	185/87		0.323		23.3 ± 3.2	23.5 ± 3.1	0.577	up/mid/low
			MCC		448		224	224	141/83	145/79		0.6941		23.4 ± 3.3	23.3 ± 3.0	0.84	
Law [108]	2017	China	CCS	roTME	391		171	220	97/74	148/72		**0.035**		24.6	24.9	0.988	mid/low
Kim [51]	2017	Korea	RCT	roTME	162		82	83	52/21	51/15		0.417		23.6 (3.0)	24.1 (3.3)	0.327	mid/low
Spanheimer [109]	2017	USA	CS	roTME	71			71		45/26					27.4 ± 6.4		up/mid/low
Tang [110]	2017	China	CS	roTME	392			392		241/151					23.3 ± 2.9		up/mid/low
Baukloh [35]	2017	EJSO	CS	roTME	348			348		229/119					26.2 ± 4.6		up/mid/low
Valverde [111]	2017	France	CCS	roTME	146		65	65	45/23	42/23		0.57		25 ± 4	25 ± 5	0.68	up/mid/low
Harslof [112]	2017	Denmark	CCS	roTME	208		141	208	90/51	137/71		0.7		26 (16–37)	25 (16–52)	0.64	
Jayne [52]	2017	International	RCT	roTME	471		234	237	159/75	161/76							up/mid/low
Penna [113]	2017	International	CS	taTME	634	634					NR		NR				
Koedam [70]	2017	Netherlands	CS	taTME	30	30					21/9			26.4 (3.8)			Up/mid/low

taTME – transanal total mesorectal excision, roTME -robotic total mesorectal excision, laTME – laparoscopic total mesorectal excision, CS – Case series, CCT – Comparative case series, MCC – matched case-control trial, RT – randomized trial, RCT - randomized, controlled trial BMI – Body Mass Index in kg/m², Tumor location: up: >12 cm from anal verge, mid: > 6–12 cm from anal verge, low: ≤6 cm from anal verge, SD – standard deviation, NR – not reported.

Table 2
Operative and perioperative Outcomes.

Author	Year	Operation time				Hospital stay				Readmission			
		taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value
Rouanet [76]	2013	304 (120−432)				14 (9−25)				NR			
Velthuis [40]	2014	NR	NR			NR	NR			NR	NR		
Atallah [77]	2014	243 (140−495)				4.5 (3−24)				NR			
De'Angelis [42]	2015	195 ± 43.6	225 ± 51.7		0.017	7.8 ± 2.1	9.8 ± 4.0		0.018	6.2%	9.4%		1.0
Lacy [78]	2015	166 ± 57				6 (5−9)				NR			
Tuech [79]	2015	270 (150−495)				10 (6−21)				NR			
Muratore [80]	2015	241 (150−360)				7 (3−25)				NR			
Chen [43]	2016	182.1 ± 55.4	178.7 ± 34.8		0.632	7.4 ± 2.5	7.1 ± 3.8		0.425	6.0%	110.0%		0.415
Perdawood [44]	2016	300 (235−420)	351 (220−480)		0.002	5 (2−43)	14 (4−50)		**0.020**	16.0%	16.0%		1.0
Rasulov [57]	2016	320 (265−495)	305 (210−455)		0.624	8.0 (6−18)	8.0 (4−17)		0.606	NR	NR		
Veltcamp Helbach [81]	2016	204 (91−447)				8 (3−41)				1.3%			
Lelong [82]	2017	NR				8 (5−22)	9 (6−24)		**0.04**	0.0%	15.7%		**0.03**
Hellan [83]	2007			285 (180−540)									
Baik [31]	2008		204.3 ± 51.9	217 ± 51.6	0.477		8.7 ± 1.3	6.9 ± 1.3	**<0.001**		NR	NR	
Patriti [84]	2009		208.0 ± 7.0	202.0 ± 12.0	>0.05		9.6 ± 6.9	11.9 ± 7.5	>0.05		NR	NR	
Park [45]	2010		168.6 ± 49.3	231.9 ± 61.4	<0.001		9.4 ± 2.9	9.9 ± 4.2	0.527		NR	NR	
Bianchi [27]	2010		237 (170−545)	240 (170−420)	0.2		6 (4−20)	6.5 (4−15)	0.4		NR	NR	
Baek [85]	2010			270 (150−540)				5 (2−33)				NR	
Pigazzi [86]	2010			297 (90−660)				8.3 (2−33)				NR	
deSouza [87]	2010			347 (155−510)				5 (3−36)				13.6%	
Baek [28]	2011		315 (174−585)	296 (150−520)	0.357		6.6 (3−20)	6.5 (2−33)	0.873		NR	NR	
Kwak [46]	2011		228 (177−254)	270 (241−325)	**<0.001**		NR	NR			NR	NR	
Koh [88]	2011			316 ± 57.4				6.4 ± 4.1				NR	
Kim [30]	2012		NR	NR			NR	NR			NR	NR	
Park [89]	2012			369 (306−410)				4 (3−6)				NR	
Kang [29]	2013		277 ± 81.9	309 ± 115.2	**<0.001**		13.5 ± 9.2	10.8 ± 5.5	**<0.001**		3.0%	3.0%	0.464
Park [90]	2013		185.4 ± 72.8	235.5 ± 57.5	**0.001**		11.3 ± 3.6	10.6 ± 4.2	0.113		NR	NR	
Luca [91]	2013			276 (155−448)				6.9 (4−44)				1.3%	
Baik [92]	2013			NR				5.3 ± 3.6				13 ± 3.5	
Kenadawekar [93]	2013			180 (150−230)				8 (7−15)				NR	
D'Annibale [94]	2014		280 (240−350)	270 (240−315)	**<0.001**		10 (8−14)	8 (7.11)	**0.034**		NR	NR	
Barnajian [47]	2014		180 (140−480)	240 (150−540)	0.066		7 (5−36)	6 (4−31)	0.978		0.0%	5.0%	
Tam [95]	2014		240 (171−360)	260 (189−449)	**0.04**		5 (3−14)	6 (4−23)	0.05		24.0%	5.0%	0.18
Cho [48]	2015		272.4 ± 83.8	361.6 ± 91.9	**<0.001**		10.7 ± 6.6	10.4 6.6	0.564		NR	NR	
Melich [96]	2015		262 (252−272)	285 8266-305)			9.9 (8.5−11.3)	9.6 (8.3−11.0)			NR	NR	
Serin [97]	2015		140 (90−300)	182 (140−220)			5 (4−10)	6 (2−32)	0.175		NR	NR	
Pai [98]	2015			345 ± 78				5 (2−15)				4.9%	
Allemann [49]	2016		313	291	0.24		NR	NR			12.0%	5.0%	0.28
Kim [60]	2016		277.0 ± 83.2	441.0 ± 90.2	**<0.001**		13.1 ± 12.8	10.9 ± 6.2	0.64		NR	NR	
Kim [99]	2016		205.0 ± 163.8	441.0 ± 180			10.9 ± 6.2	13.1 ± 12.8			NR	NR	
Feroci [55]	2016		192 (90−335)	342 (249−536)	**<0.001**		8 (5−53)	6 (3−17)	**<0.001**		NR	NR	
Ramji [100]	2016		240 ± 89	407 ± 97	**<0.001**		11.3 ± 13.7	7 ± 3.4	0.2		19.0%	24.0%	0.72
Shiomi [53]	2016		237 (125−421)	236.0 (123−484)	0.83		8.0 (6−44)	7.0 (6−29)	**<0.001**		NR	NR	
Yamaguchi [101]	2016		227 ± 62.6	232.9 ± 72.0	0.412		9.3 ± 6.7	7.3 ± 2.3	**<0.001**		NR	NR	
Sammour [102]	2016			NR				4 ± 3				NR	
Gomez Ruiz [103]	2016			292 (272−312)				8 (3−64)				NR	
Colombo [104]	2016		228 (127−431)	274 (125−437)	**0.005**		11 (6−60)	12 (6−27)	0.246		NR	NR	
Bedirli [105]	2016		208 ± 49	252 ± 62	**0.027**		5.1 ± 3.7	4.6 ± 2.8	>0.05		NR	NR	
Buchs [106]	2016	368.6 ± 101.7				7.5 (3−92)				16.0%			
Silva-Velazco [54]	2017		239 (96−505)	288 (141−544)	**<0.001**		6 (3−33)	5 (2−28)			12.7%	6.1%	
Lim [107]	2017		311.6 ± 79.8	365.2 ± 108.4	**0.033**		NR	NR			NR	NR	
Kim [50]	2017		233.8 ± 77.2	288.1 ± 77.0	**<0.001**		14.4 ± 19.2	13.2 ± 13.5	0.788		NR	NR	
			249.7 ± 80.9	285.8 ± 78.5	**<0.001**		13.8 ± 10.9	13.5 ± 14.1	0.2659		NR	NR	
Law [108]	2017		225 (101−520)	260 (137−671)	**<0.001**		6 (2−83)	6 (2−64)	0.290		NR	NR	

Table 2 (*continued*)

Author	Year	Operation time				Hospital stay				Readmission			
		taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value
Kim [51]	2017		227.8 (65.6)	339.2 (80.1)	**<0.001**		10.8 (7.4)	10.3 (3.4)	0.621		NR	NR	
Spanheimer [109]	2017			219 (184–275)				6 (4–8)				NR	
Tang [110]	2017			224 ± 60 (80–388)				12.1 ± 6.1				NR	
Baukloh [35]	2017			314.58 ± 97.14				11.01 ± 8.80				NR	
Valverde [111]	2017		226 ± 66	215 ± 53	0.32		12 ± 10	11 ± 8	0.46		NR	NR	
Harslof [112]	2017		NR	NR				7 (2–61)				NR	
Jayne [52]	2017		261 ± 83.2	298.5 ± 88.7			8.2 ± 6.0	8.0 ± 5.9			NR	NR	
Penna [113]	2017	NR				NR				NR			
Koedam [70]	2017	NR				7 (6–10)				NR			

taTME – transanal total mesorectal excision, roTME -robotic total mesorectal excision, laTME – laparoscopic total mesorectal excision, SD – standard deviation. NR – not reported.

outcome after taTME revealed comparable results to published data of laTME. Koedam et al. could solely show, that taTME induced less major lower anterior resection syndrome (LARS) compared to published scores after conventional open TME [70]. However, since this study suffers from several limitations as the authors stated theirselves, publication of COLOR III is awaited. This randomized controlled trial comparing taTME and laTME might be able to answer questions on functional outcomes reliably [71].

Discussion

LaTME has been shown to be safe and feasible by several studies, providing comparable oncological short- and long-term outcomes with reduction of perioperative morbidity in comparison with conventional open resection [12,58]. As revealed by the multicentric, randomized trials COLOR-II and COREAN [62,72] disease-free survival and local recurrence show no significant difference between laTME and conventional open resection. In contrast, in two recently published multicentric, randomized trials, ACOSOG-Z6051 and ALaCaRT, laTME failed to demonstrate non-inferiority of laTME compared to open surgery. Unfortunately, these studies did not include surgical data but only pathologic surrogate parameters for oncologic outcome [73].

COLOR-II revealed a significantly higher percentage of CRM positive resections in the subgroup of lower rectal cancer after open resection [12], but disease-free survival and local recurrence were equal in a 3-year follow up [62].

In the first RCT comparing laparoscopic versus open resection for colorectal cancer in 2005, the CLASSIC trial demonstrated comparable outcome of both techniques [22]. However, laTME cases that required conversion to open surgery were much more likely to have positive CRM and were therefore at higher risk of local tumor recurrence. We need to keep in mind that during the study period of the CLASSIC trial, surgeons were beginning to learn laTME. This fact might explain why conversion was not associated with higher rate of positive CRM in the later studies COLOR II and COREAN trial [74].

Nevertheless, laparoscopic surgery for rectal cancer remains technically challenging especially in complex anatomical situations. Several publications provide evidence for significant influence of patients' characteristic on perioperative morbidity. Known pitfalls include bulky and low tumors, narrow pelvis, male gender and obesity [17,25,26,35]. Due to technical limitations such as restricted view with an assistant-guided, unstable camera and limited dexterity of instruments as well as fixed angles in the deep pelvis, conventional laparoscopy struggles with these known pitfalls of minimally invasive rectal surgery. Innovative approaches as roTME

and taTME could assist to overcome these pitfalls successfully.

In the field of medical oncology, individualized therapies are becoming increasingly important [75]. Akiyoshi et al. already claimed for a stratification of rectal cancer patients to different surgical treatment options according to their individual patients' characteristics [26]. With recent advances in surgical techniques, the portfolio of treatment options is constantly growing and will allow more customized surgical strategies.

It has to be mentioned that this systematic review analysis has major limitations, which have to be kept in mind for interpretation of the presented results. Only roTME has been analyzed by level 1 evidence publications so far, therefor this review is only able to refer to retrospective analysis for taTME. Further more, included trials suffer from some heterogeneities as the taTME articles mainly report on middle and low tumors whereas the vast majority of roTME studies include tumors from the whole rectum. Overall, the results of these publications suggest safety and feasibility for both procedures, but high quality publications are lacking to verify this observation.

Persuading with a shorter hospital stay and the evidence of less pain and analgesic consumption, patients can gain from a faster convalescence after roTME and a lower readmission rate following taTME. On the other hand, potential downsides need to be elucidated: specific for taTME urethral injuries were observed, which are not known from any other TME-approach [76]. Since the most taTME publications include the learning curve of the respective surgeon, it needs to be seen, whether this is attributed to the beginnings of taTME comparable to common bile duct injuries in the early days of laparoscopic cholecystectomy or if remains a problem of this technique. Further, both approaches have several limitations and pitfalls, which cannot be easily evaluated by a systematic review analysis. Both procedures have an associated and long learning curve, which every rectal surgeon has to accomplish. Structured training programs are rare worldwide for both techniques.

Several publications aimed to show comparability and non-inferiority of different surgical approaches. The question arises, if the technique itself is the key of improvement of patients' outcome or if the skills of a specialized surgeon may have the main impact on perioperative outcome. An excellent laparoscopic surgeon might obtain a more favorable outcome compared to an average robotic or transanal procedure. Currently, the vast majority of publications included in this review comprise the cases of their learning curve, so that this question cannot finally be answered. Rectal resections remain complex procedures, especially for low and bulky tumors and male patients, which should be referred to specialized centers.

And of course, the aspect of cost intensity of the robot has to be

Table 3
Intra- and postoperative complications.

Author	Year	Major Complication Rate (%) CD III-V				Minor Complication Rate (%) CD I-II				Conversion Rate (%)			
		taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value
Rouanet [76]	2013	NR				NR				6.7%			
Velthuis [40]	2014	NR	NR			NR	NR			NR	NR		
Atallah [77]	2014	NR				NR				NR			
De'Angelis [42]	2015	6.2%	15.6%		0.663	18.8%	21.9%		0.663	3.1%	3.1%		1.0
Lacy [78]	2015	42836				23.6%				0.0%			
Tuech [79]	2015	NR				NR				4.3%			
Muratore [80]	2015	11.6%				15.4%				0.0%			
Chen [43]	2016	2.0%	4.0%		—	0.12%	0.13%		—	2.0%	5.0%		0.380
Perdawood [44]	2016	NR	NR			NR	NR			0.0%	16.0%		0.055
Rasulov [57]	2016	o.o	8.6%		0.661	27.0%	17.3%		0.661	4.5%	4.3%		0.368
Veltcamp Helbach [81]	2016	12.5%				26.3%				5.0%			
Lelong [82]	2017	5.9%	18.4%		01.6	NR	BR			2.9%	23.7%		**0.015**
Hellan [83]	2007												
Baik [31]	2008		0.0%	0.0%			5.5%	22.2%			11.1%	0,0%	0.486
Patriti [84]	2009		NR	NR			NR	NR			18.9%	0,0%	**<0.05**
Park [45]	2010		7.3%	9.8%	0.641		92.7%	90.2%	0.641		0.0%	0.0%	1.0
Bianchi [27]	2010		0.12	0.8%			NR	NR			4,0%	0,0%	
Baek [85]	2010			NR				NR				9.4%	
Pigazzi [86]	2010			NR				NR				4.9%	
deSouza [87]	2010			NR				NR				4.5%	
Baek [28]	2011		NR	NR			NR	NR			22.0%	7.3%	0.116
Kwak [46]	2011		NR	NR			NR	NR			3.4%	0.0%	0.496
Park [34]	2011		4.9%	7.7%	0.331		95.1%	92.3%	0.331		0-0%	0-0%	
Koh [88]	2011			NR				NR				0.0%	
Kim [30]	2012		NR	NR			NR	NR			NR	NR	
Park [89]	2012		NR				NR				0.0%		
Kang [29]	2013		NR	NR			NR	NR			1.8%	0.6%	0.623
Park [90]	2013		2.5%	5.0%	1.0		10.0%	10.0%	1.0		0.0%	0.0%	1.0
Luca [91]	2013		NR	NR			NR	NR				NR	
Baik [92]	2013		8.4%				14.9%				0.8%		
Kenadawekar [93]	2013		NR				NR				0.0%		
D'Annibale [94]	2014		NR	NR			NR	NR			12.0%	0.0%	**0.011**
Barnajian [47]	2014		NR	NR			NR	NR			10.0%	2.0%	0.261
Tam [95]	2014		NR	NR			NR	NR			0.0%	5.0%	1.0
Cho [48]	2015		12.2%	12.2%	1.0		11.5%	13.7%	0.523		0.7%	0.4%	1.0
Melich [96]	2015		4.7%	6.5%			12.3%	12.0%			3.8%	1.1%	
Serin [97]	2015		NR	NR			NR	NR			3.0%	0.0%	
Pai [98]	2015			15.8%				25.8%				4.0%	
Allemann [49]	2016		22.5%	20.0%	0.38		12.5%	20.0%	0.38		20.0%	5.0%	0.11
Kim [60]	2016		NR	NR			NR	NR			0.0%	6.1%	0.11
Kim [99]	2016		3.0%	3.0%			NR	NR			0,0%	6.1%	
Feroci [55]	2016		17.2%	7.5%	0.297		27.6%	24.5%	0.297		1.7%	3.8%	0.605
Ramji [100]	2016		0.0%	12.0%	0.11		25.0%	30.0%	0.11		37.0%	12.0%	0.05
Shiomi [53]	2016		6.4%	3.1%	0.19		17.4%	6.3%			0.9%	0.0%	0.46
Yamaguchi [101]	2016		NR	NR			NR	NR			3.3%	0.0%	**0.009**
Sammour [102]	2016			13.7%				21.0%				2.2%	
Gomez Ruiz [103]	2016			12.5%				18.8%				4.5%	
Colombo [104]	2016		20.0%	28.3%	0.246		NR	NR			4.8%	3.2%	0.661
Bedirli [105]	2016		NR	NR			NR	NR			NR	NR	
Buchs [106]	2016	12.5%				27.5%				7.5%			
Silva-Velazco [54]	2017		NR	NR			NR	NR			15.4%	9.1%	0.23
Lim [107]	2017		NR	NR			NR	NR			6.4%	1.4%	0.182
Kim [50]	2017		NR	NR			NR	NR			0.9%	0.0%	0.303
			NR	NR			NR	NR			0.9%	0.0%	
Law [108]	2017		NR	NR			NR	NR			3.5%	0.8%	0.308
Kim [51]	2017		5.4%	9.4%	0.227		17.8%	25.8%	0.227		0.0%	1.5%	0.475
Spanheimer [109]	2017			NR				NR				4.0%	
Tang [110]	2017			NR				NR				1.8%	
Baukloh [35]	2017			13.5%				18.7%				4.3%	
Valverde [111]	2017		15.0%	23.0%	0.26		34.0%	19.0%	0.37		17.0%	5.0%	**0.044**
Harslof [112]	2017			NR				NR			21.0%	31.0%	0.06
Jayne [52]	2017			NR	NR		NR	NR			12.2 [	8.1%	0.16
Penna [113]	2017	NR				NR				NR			
Koedam [70]	2017	17.0%				NR				0.0%			

taTME — transanal total mesorectal excision, roTME -robotic total mesorectal excision, laTME — laparoscopic total mesorectal excision, CD: Clavien Dindo classification: I - any deviation from normal postoperative course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions, Allowed therapeutic regimens are: drugs as antiemetics, antipyretics, analgetics, diuretics and electrolytes and physiotherapy. This grade also includes wound infections opened at the bedside II - Requiring pharmacological treatment with drugs other than such allowed for grade I complications. Blood transfusions and total parenteral nutrition are also included. III - Requiring surgical, endoscopic or radiological intervention, IV - Life-threatening complication (including CNS complications)* requiring IC/ICU-management, V - Death of a patient; SD — standard deviation, NR — not reported.

Table 4
Pathological outcome.

Author	Year	Completeness of TME (%)				Positive circumferential Margin (%)				Harvested Lymph Nodes	
		taTME	laTME	roTME	p-value	taTME	laTME	roTME	p-value	taTME/roTME: laTME	p-value
Rouanet [76]	2013	100.0%				6.7%				3 (8–32)	
Velthuis [40]	2014	96.0%	72.0%		**<0.05**	4,0%	8,0%		–	14 (7–24): 13 (1–36)	0.42
Atallah [77]	2014	55.0%				5.0%				22.5 (9–51)	
De'Angelis [42]	2015	84.4%	75.0%		0.611	3.1%	9.4%		0.342	17.06: 18.63	0.697
Lacy [78]	2015	97.1%				6.4%				14.7 ± 6.8	
Tuech [79]	2015	84.0%				5.7%				12 (7–29)	
Muratore [80]	2015	100.0%				0.0%				9	
Chen [43]	2016	NR	NR			NR	NR			16.7 ± 7.8: 17.4 ± 8.9	0.553
Perdawood [44]	2016	80.0%	68.0%		0.113	4.0%	16.0%		0.349	21 (9–42): 22 (7–45)	0.778
Rasulov [57]	2016	68.0%	74.0%		0.859	4.5%	0.0%		0.31	17 (0–54): 20 (8–56)	0.144
Veltcamp Helbach [81]	2016	88.8%				2.5%				14 (6–30)	
Lelong [82]	2017	55.9%	52.6%		0.66	5.9%	10.5%		0.29	14 (6–34): 12 (4–25)	0.29
Hellan [83]	2007									13 (7–28)	
Baik [31]	2008		72,2%	94,4%	0.41		NR	NR		18 (6–49): 22 (9–42)	0.437
Patriti [84]	2009		NR	NR			0.0%	0.0%		10.3 ± 4: 11.2 ± 5	>0.05
Park [45]	2010		94.4%	76.5%	0.323		NR	NR		20.0 ± 9.1: 17.4 ± 10.6	0.437
Bianchi [27]	2010		NR	NR			4.0%	0.0%	0.9	18: 17	0.7
Baek [85]	2010			NR				0.0%		14.5 (3–28)	
Pigazzi [86]	2010			NR				0.7%		14.1 (1–39)	
deSouza [87]	2010			NR				0.0%		14 (5–45)	
Baek [28]	2011		NR	NR			4.9%	2.4%	1.0	13.1 (3–33): 16.2 (5–39)	0.071
Kwak [46]	2011		NR	NR			0.0%	1.7%	1.0	20 (12–27): 21 (14–28)	0.702
Park [34]	2011		NR	NR			2.4%	1.9%	0.978	19.4 ± 10.2: 15.9 ± 10.1	0.06
Koh [88]	2011			NR				5.3%		17.8 ± 7.1	
Kim [30]	2012		94.9%	96.5%	0.717		2.5%	6.0%	0.407	NR	
Park [89]	2012			83.3%				0.0%		20 (14–25)	
Kang [29]	2013		NR	NR			6.7%	4.2%	0.097	15.0 ± 9.4: 15.6 ± 9.1	0.075
Park [90]	2013		NR	NR			5.0%	7.5%	1.0	12.9 ± 7.5: 13.3 ± 8.6	0.732
Luca [91]	2013			87.8%				NR		20.5 (15–44)	
Baik [92]	2013			NR				5.7%		15.6 ± 9.0	
Kenadawekar [93]	2013			84.9%				0.0%		13 (8–25)	
D'Annibale [94]	2014		NR	NR			12.0%	0.0%	**0.022**	16.5 ± 7.1: 13.8 ± 6.7	0.053
Barnajian [47]	2014		95.0%	80.0%	0.235		NR	NR		14 (3–22): 11 (4–18)	0.338
Tam [95]	2014		NR	NR			5.0%	0.0%	1.0	17 (8–40): 15 (8–21)	**0.03**
Cho [48]	2015		NR	NR			4.7%	5,0%	1.0	15.0 ± 8.1: 16.2 ± 8.1	0.069
Melich [96]	2015		NR	NR			2.8%	3.3%		17.2 (15.0–19.5): 16.3 (14.4–18.1)	
Serin [97]	2015		80.0%	100.0%	0.109		NR	NR		32 (17–56): 23 (4–67)	0.008
Pai [98]	2015			97.0%				5.0%		15 ± 7.4	
Allemann [49]	2016		55.0%	95.0%	**0.0003**		25.0%	10.0%	0.1	24 ± 14: 20 ± 7	0.1
Kim [60]	2016		91.0%	97.0%	0.235		6.7%	16.1%	0.42	22.3 ± 11.7: 21.6 ± 11.0	0.82
Kim [99]	2016		NR	NR			1.1%	1.5%	0.153	23.2 ± 10: 20.9 ± 8.5	**<0.001**
Feroci [55]	2016		NR	NR			1.7%	1.9%	0.729	18 (4–49): 11 (3–27)	**<0.001**
Ramji [100]	2016		44.0%	60.0%	0.36		0.0%	0,0%		16.7 ± 6.8: 16.8 ± 7.7	0.97
Shiomi [53]	2016		NR	NR			0.9%	0.0%	0.46	26.0 (11–60): 26.0(7–63)	0.49
Yamaguchi [101]	2016		NR	NR			NR	NR		30.0 ± 10.3: 29.3 ± 11.8	0.506
Sammour [102]	2016			75.8%				2.5%		22 (11)	
Gomez Ruiz [103]	2016			NR				5.6%		11.7 (0–31)	
Colombo [104]	2016		90.0%	93.3%	0.509		90.0%	93.3%	0.509	15 (6–71): 19 (6–68)	0.290
Bedirli [105]	2016		NR	NR			3.6%	2.9%	>0.05	27 ± 11: 23 ± 8	>0.05
Buchs [106]	2016	92.5%				5.0%				20 ± 9.7	
Silva-Velazco [54]	2017		90.4%	89.4%	0.81		3.4%	7.6%	0.42	22 (7–106): 24 (3–129)	0.93
Lim [107]	2017		98.4%	95.9%	0.384		1.6%	4.0%	0.384	11.6 ± 6.9: 14.7 ± 6.5	0.971
Kim [50]	2017		NR	NR			3.5%	5.5%	0.1861	19.7 ± 12.3: 21.7 ± 14.3	**0.049**
			NR	NR			4.9%	4.0%	0.8231	20.2 ± 12.1: 21.0 ± 14.4	0.44
Law [108]	2017		NR	NR			8.2%	4.1%	0.128	12: 14	**0.002**
Kim [51]	2017		78.1%	80.3%	0.599		5.5%	6.1%	0.999	18 (7–59): 15 (4–40)	
Spanheimer [109]	2017			NR				1.4%		15.7 ± 8.4	
Tang [110]	2017			NR				1.3%		14.6 ± 6	
Baukloh [35]	2017			95.8%				3.2%		14.62 ± 8.17	
Valverde [111]	2017		82.0%	88.0%	0.28		89.0%	6.0%	0.28	17 ± 9: 19 ± 10	
Harslof [112]	2017		NR	NR				7.0%		20 (6–47)	
Jayne [52]	2017		77.6%	76.4%	0.14		6.3%	5.1%	0.56	24.1 ± 12.9: 23.2 ± 12.0	
Penna [113]	2017	85.0%				2.4				16.5 ± 9.2	
Koedam [70]	2017	NR				0.0%				15 (9–18)	

taTME – transanal total mesorectal excision, roTME -robotic total mesorectal excision, laTME – laparoscopic total mesorectal excision, NR – not reported.

kept in mind when interpreting the published data. Thus, we tried to give an objective overview of the recent published studies dealing with roTME and taTME. We know that the level of evidence is still low but up to now, there are a variety of patients' cohort studies, which enable the first steps of evaluation.

Oncological outcome seems to be comparable following taTME and roTME. Results of disease-specific survival and local recurrence are currently not available for these latest techniques. But positivity of circumferential margin is described to be at least equivalent for roTME to laTME and has been found to be superior in taTME in

comparison to laTME. Further, a higher rate of TME completeness supports the hypothesis of higher oncological quality by roTME and taTME. The lower conversion rates reflect a greater feasibility of taTME and roTME, particularly in patient cohorts with mid and lower rectal cancer.

In conclusion, both approaches demonstrate favorable results facilitating minimally invasive surgery for a growing number of patients with the option of individualized surgical treatment.

Conflict of interest

No conflicts of interest.

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