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Cost comparisons of endoscopic and surgical resection of stage T1 rectal cancer

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ABSTRACT

Background and study aims Management of T1 rectal cancer is complex and includes several resection methods, making cost comparisons challenging. The aim of this study was to compare costs of endoscopic and surgical resection and to investigate hypothetical cost scenarios for the treatment of T1 rectal cancer.

Patients and methods Retrospective population-based cost minimization study on prospectively collected data on T1 rectal cancer patients treated using endoscopic submucosal dissection (ESD), transanal endoscopic microsurgery (TEM), open, laparoscopic, or robotic resection, in Skåne County, Sweden (2011–2017). The hypothetical cost scenarios were based on the distribution of high-risk features of lymph node metastases in a national cohort (2009–2017).

Results Eighty-five patients with T1 RC undergoing ESD (n = 16), TEM (n = 17), open (n = 35), laparoscopic (n = 9), and robotic (n = 8) resection were included. ESD had a total 1-year cost of 5165 € and was significantly ($P<0.05$) less expensive compared to TEM (14871€), open (21 453 €), laparoscopic (22 488 €) and robotic resection (26 562 €). Risk factors for lymph node metastases were seen in 68 % of 779 cases of T1 rectal cancers included in the national cohort. The hypothetical scenario of performing ESD on all T1 RC had the lowest total 1-year per patient cost compared to all other alternatives.

Conclusions This is the first study analyzing total 1-year costs of endoscopic and surgical methods to resect T1 rectal cancer, which showed that the cost of ESD was significantly lower compared to TEM and surgical resection. In fact, based on hypothetical cost scenarios, ESD is still justifiable from a cost perspective even when all high-risk cases are followed by surgery in accordance to guidelines.

Introduction

Colorectal cancer is the third most common cancer in the Western world and nearly 35 % of these tumors are located in the rectum [1]. Multiple therapeutic alternatives are available for treating early T1 rectal cancer, including local endoscopic resection methods such as endoscopic submucosal dissection (ESD) and transanal endoscopic microsurgery (TEM) as well as rectal surgery by open, laparoscopic or robotic resection [2–6]. Local resection of early rectal cancer is beneficial for patients in terms of preserved bowel function and decreased morbidity and mortality as compared to surgery [7–9]. However, the risk of lymph node metastasis (LNM) limits local resection as final treatment to cases with a low risk of LNM. Current guidelines recommend additional surgery after radical local excision of T1 rectal cancer if one or more of the following histopathological features are present; deep submucosal invasion (> Sm1), lymphovascular involvement (LVI), tumor budding and poor differentiation [6]. Surgery is in general first-line treatment when malignancy is confirmed, since pretherapeutic staging of LNM risks in rectal lesions is notoriously difficult. Thus, local resection is largely confined to unclear cases with cancer negative biopsies and patients with high age or aggravating comorbidities. With escalating health care costs due to demographic changes and new expensive and minimal invasive technologies there is an increased need for cost comparisons between alternative methods [10, 11]. Previous studies have shown that ESD is less expensive than TEM, due to avoidance of anesthesia and shorter hospital stay [12, 13]. In regards of treatment equality, the literature shows that ESD and TEM result in similar en bloc and R0 resection rates for malignant rectal lesions [13–15]. As for the surgical alternatives, a recent study showed that robotic rectal resection is more expensive than both open and laparoscopic resection without any additional benefit for patients [16]. Notably, previous studies have shown that both ESD and TEM are more cost-effective compared to surgical resection [17–19]. However, cost comparisons of endoscopic and surgical resection are challenging because the proportion of cases requiring subsequent surgery after local resection significantly influences the total cost of treating patients with early rectal cancer.

Based on the considerations above, the primary aim of this study was to compare the total 1-year costs of endoscopic and surgical methods to resect T1 RC, including costs of intensified follow-up and subsequent surgery in the local resection groups as well as costs for conversion of temporary ileostomies in the surgical resection groups. The secondary aim was to investigate hypothetical cost scenarios of performing local resection as initial treatment on all T1 RC, followed by surgery on all cases with high risk of LNM.

Patients and methods

All patients with T1 rectal cancer treated in Skåne County (approximately 1.4 million inhabitants) between 2011 and 2017 were identified in the Swedish Colorectal Cancer Registry, a national quality registry containing prospectively registered data. During the study period, the coverage compared to the compulsory Swedish Cancer Registry was 99 % for rectal cancer. Patients with T1 rectal cancer undergoing ESD, TEM, open, laparoscopic or robotic resection as primary treatment were included in this study. Patients with synchronous lesions, hereditary forms of rectal cancer as well as patients receiving neo-adjuvant treatment and patients treated in but residing outside Skåne County were excluded. Patients were assigned to one of five groups, according to the primary treatment method (ESD, TEM, open, laparoscopic or robotic resection). Hence, cases converted from laparoscopic or robotic resection to open resection as well as cases undergoing subsequent surgery after local resection were kept within their initial study group. Clinical record forms were created for the procedural period, including all events from admission to discharge and the follow-up period including all events from discharge up to 1 year after the procedure. In case of subsequent surgery after local resection due to severe pathology, an additional clinical record form was completed and the 1-year follow-up period was extended to include 1 year from the final procedure. An additional clinical record form was also completed in case of complications requiring surgery and for conversion of loop ileostomies. The Charlson comorbidity index was used to compare the disease burden between the groups [20]. The Clavien-Dindo classification of surgical complications was adopted to score adverse events [21].

Preoperative workup, procedures and postoperative care

All biopsy-confirmed or suspected cancers were discussed at a preoperative multidisciplinary team conference. Local resection was chosen in unclear cases with cancer negative biopsies as well as selected cases of confirmed rectal cancers in elderly and comorbid patients and open, laparoscopic or robotic resection were chosen in the remaining cases, at the discretion of the multidisciplinary team conference. All surgical resections were performed as total mesorectal excisions, either by anterior resections or abdominoperineal resections (open, laparoscopic or robotic). All TEM procedures were full-thickness resections and all ESD procedures were performed with submucosal dissection using fluid injections and a cautery knife as described previously [22]. Postoperative care of surgical patients was provided at dedicated colorectal surgery wards following standardized enhanced recovery pathways.

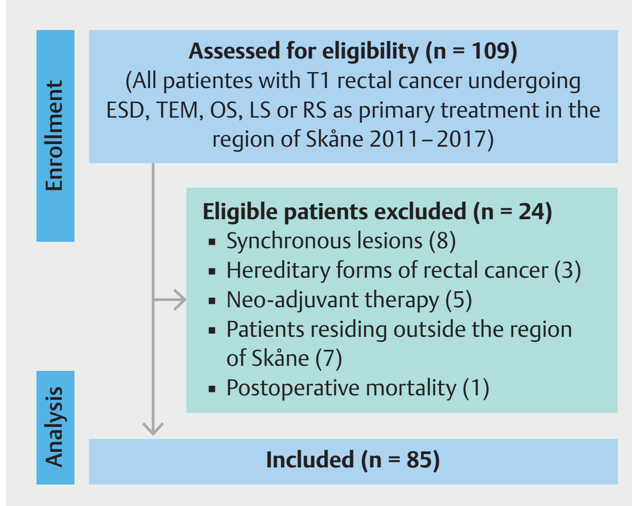
Cost analyses

Cost-effectiveness analyses are based on costs and treatment effectiveness, often expressed as quality-adjusted life-years, which was not attainable in this study. Consequently, this is not a cost-effectiveness analysis but rather a cost-minimization analysis, which implies comparisons of costs for treatment alternatives that achieve a common outcome to an equal degree. This study includes analysis and comparisons of direct costs, comprising all costs related to the treatment and patient care. Indirect costs, defined as costs related to losses in patient productivity due to disease-related morbidity and mortality were not included since the median age in this study was higher than the retirement age in Sweden. Direct costs were estimated for the procedural and follow-up periods respectively. The procedural period included all events from admission to discharge and comprised costs of: radiologic imaging, procedure-related (anesthesia, operating room time, consumable supplies, staff salary), daily hospitalization fee (medications, intravenous solutions, routine laboratory tests, and staff salary) as well as ancillary services as required.

Costs were derived from the Regional Price and Reimbursement List for the Southern Healthcare Region 2017 except for the procedural costs of open, laparoscopic and robotic resection, not included therein. Instead, a mean price for year 2017 was calculated for these procedures by the surgical department economist. Cases converted from laparoscopic or robotic resection to open resection were submitted an extra cost (25 % of the procedure cost of open resection) to account for extra equipment, consumables as well as prolonged operating room time. Costs applied to the follow-up period included costs of: appointments at the surgical policlinic (nurse or doctor visits), radiologic imaging, endoscopic examination, consumables related to stoma care (based on a report from the Dental and Pharmaceutical Benefits Agency [23]), emergency-room visits, as well as subsequent surgery following non-curative local resections and conversion of diverting ileostomies. All costs were converted from Swedish krona (SEK) to Euro (EUR) using Sweden's central bank mean conversion rate for 2017 (1 EUR = 9.63 SEK).

Hypothetical cost scenarios

We used hypothetical cost scenarios to estimate the cost of different primary treatment strategies: 1) local resection on all T1 rectal cancers followed by subsequent surgery in all non-curative cases; or 2) surgery on all T1 rectal cancers as first and final treatment. Thus, we used a national cohort (Swedish Colorectal Cancer Registry) comprising all patients with T1 rectal cancer in Sweden, treated with surgery or local resection from 2009 to 2017. A low-risk group in which local excision can be deemed as final and curative treatment was defined as absence of the following high-risk features: deep submucosal invasion (> Sm1), LVI and poor/low tumor differentiation. The high-risk group was hence defined as cases with any of the aforementioned risk factors. This definition is coherent to current guidelines [6] except for not including tumor budding as a high-risk feature, since this parameter was not registered in the Swedish Colorectal Cancer Registry during the entire study period. Patients receiving neo-adjuvant treatment and patients with synchronous colorectal cancers as well as cases with missing data on depth of submucosal invasion, LVI or histologic grade were excluded. All pedunculated lesions were excluded by means of including only cases with registered depth of submucosal invasion because this parameter is not applicable to pedunculated lesions. Scenario analyses were conducted for each treatment alternative by using the median costs derived from the selection of patients treated in Skåne County and extrapolating them to the national cohort. The following assumptions were made: 1) all cases with high-risk features of LNM would undergo subsequent surgical resection, regardless of age and comorbidities; 2) all TEM or ESD resections were en-bloc and R0 in all T1 sm1 cases; and 3) patient characteristics, treatment patterns, and costs in the Skåne County cohort were representative of the national cohort. Total 1-year per-patient costs for all T1 cases were calculated for the following scenarios: 1) ESD or 2) TEM followed by subsequent surgery (calculated as median of the two less costly surgical resection alternatives) in all high-risk cases; 3) open resection as primary treatment; 4) laparoscopic resection as primary treatment; and 5) robotic resection as primary treatment.



▶ **Fig. 1** Overview of study population in the Skåne municipal cohort.

Ethics

This study was carried out in accordance with the ethical principles of the Declaration of Helsinki. Approval by the Regional Ethical Review Board, Lund University (2017/546) was granted prior to study start. Data retrieved from the Swedish Colorectal Cancer Registry were coded and patient anonymity was guaranteed.

Statistics

To test for differences in operating room time and hospitalization rate between the groups, the Kruskal-Wallis test was used. The Wilcoxon rank-sum (Mann-Whitney U) test was used to test for differences in costs between two treatment groups. Analyses were performed using STATA statistical software (release 14.2, College Station, Texas, United States).

Results

A total of 109 patients with T1 rectal cancer fulfilled the inclusion criteria, of whom 24 met the exclusion criteria and one patient died 2 days after open resection due to myocardial infarction and was also excluded (▶ **Fig. 1**). The remaining 85 patients with T1 rectal cancers undergoing, ESD (n = 16), TEM (n = 17), open (n = 35), laparoscopic (n = 9), and robotic resection (n = 8) constituted the study population. Median age was 69 years (38–89) and 47 of the participants (55 %) were men (▶ **Table 1**). Median age and body mass index (BMI) were lowest in the ESD group (age 64, BMI 26) and highest in the laparoscopic resection group (age 72, BMI 27), whereas median Charlson comorbidity index was the same (5) in all groups (▶ **Table 1**). Operating room time was highest in the robotic (465 minutes), followed by the laparoscopic (359 minutes) and open (264 minutes) resection groups and lowest for TEM (65 minutes), followed by ESD (83 minutes). The differences in operating room time were statistically significant ($P < 0.05$), except for the difference between ESD and TEM (▶ **Table 1**). Hospitalization

▶ **Table 1** Baseline characteristics in the five treatment groups.

	ESD (n = 16)	TEM (n = 17)	Open resection (n = 35)	Laparoscopic resection (n = 9)	Robotic resection (n = 8)	Total (n = 85)
Age (years)	64 (44–89)	70 (62–79)	68 (38–86)	72 (59–80)	69 (60–76)	69 (38–89)
Male (%)	9 (56 %)	9 (53 %)	19 (54 %)	7 (78 %)	3 (38 %)	47 (55 %)
BMI	26 (17–34)	28 (22–33)	26 (16–36.5)	27 (23–31)	25 (22–30)	26 (16–36.5)
Charlson comorbidity index	5 (2–7)	5 (4–9)	5 (2–11)	5 (4–8)	5 (4–6)	5 (2–11)
Hospitalization (days)	0 (0–3)	2 (0–15)	10 (6–24)	7 (5–28)	9 (6–28)	7 (0–28)
Operating room time (min)	83 (18–594)	65 (25–234)	264 (152–398)	359 (245–554)	465 (341–692)	241 (18–692)

Presented as median and (range).
ESD, endoscopic submucosal dissection; TEM, transanal endoscopic microsurgery; BMI, body mass index.

▶ **Table 2** Complications in the five treatment groups.

	Clavien-Dindo	ESD (n = 16)	TEM (n = 17)	Open resection (n = 35)	Laparoscopic resection (n = 9)	Robotic resection (n = 8)	Total (n = 85)
Perioperative perforation[1]	I	1					1
Perioperative perforation[2]	II	1	1				2
Perioperative anastomotic leak	II			2			2
Postoperative infection[3]	II			5	2		7
Bowel paralysis	II		1	3	2	1	7
Acute renal failure	II			1			1
Atrial fibrillation	II				1		1
High stoma output	II					1	1
Postoperative anastomotic leak	IIIa				1		1
Pelvic Abscess	IIIa			1			1
Subcutaneous wound rupture	IIIb			1			1
Perforation of the small intestines	IVa				1		1
Acute renal failure (dialysis)	IVa			1			1
Clavien-Dindo	I	1	–	–	–	–	1
	II	1	2	11	5	2	22
	III	–	–	2	1	–	3
	IV	–	–	1	1	–	2

ESD, endoscopic submucosal dissection; TEM, transanal endoscopic microsurgery.
[1] Closed with clip, no other treatment.
[2] Closed with clip (ESD) or suturing (TEM), prolonged observation and antibiotics.
[3] Two cases of pneumonia, two cases of sepsis, one case of Clostridium difficile colitis.

rates also differed significantly between the groups ($P<0.001$) (▶ **Table 1**). Thirteen of the 16 ESD patients were treated as outpatients in contrast to the other groups in which all patients were hospitalized with the lowest and highest median hospitalization stay in the TEM (2 days) and open resection (10 days) groups, respectively (▶ **Table 1**). In total, 12 of 52 patients in the surgical resection groups received a permanent colostomy, 10 in the open resection group (10/35) and two in the robotic resection group (2/8). In addition, 33 of 52 patients received a diverting ileostomy, 20 in the open resection group (20/35), seven in the laparoscopic group (7/9), and six in the robotic resection group (6/8). All but one of the 33 diverging ileostomies were converted during the 1-year follow-up period.

Median tumor size was 4 cm (range 3–7 cm) in the ESD group, 5 cm (range 4–10 cm) in the TEM group and not stated for the surgical patients. High-risk features of LNM were observed in 11 of 16 ESD cases and in seven of 17 TEM cases, due to deep submucosal invasion (>Sm1) in nine ESD cases and six TEM cases and LVI in two ESD cases and one TEM case. Additional surgery, however, was only carried out in three of nine ESD patients with high-risk features (1 open, 2 robotic resections) and two of six high-risk TEM patients (2 robotic resections) because of patient reluctance to undergo surgery, aggravating comorbidity, or advanced age. All ESD and TEM cases were en-bloc and R0 in the lateral and vertical margins in all Sm1 cases. Three patients in the robotic resection group (3/8) and three patients in the laparoscopic resection group (3/9) were converted to open resection intra-operatively. Twenty-eight complications occurred in 21 of 85 patients, of which, the majority (23 of 28) were Clavien-Dindo I or II (▶ **Table 2**). Two patients required emergency surgery due to complications, one patient in the laparoscopic resection group, due to a perforation of the small intestine and one in the open resection group due to incisional dehiscence. In total, two patients were admitted to the intensive care unit: the patient in the laparoscopic resection group with perforation of the small intestine and one patient in the open resection group suffering from pneumonia, post-operative ileus and acute renal failure.

Cost analyses

The median direct costs for the respective procedures, comprising all costs from admission to discharge, follow-up costs (all costs from discharge to 1-year after the procedure) and total 1-year costs, are shown in ▶ **Table 3**. ESD was significantly less expensive, both in regard to procedural costs and total 1-year costs compared to the other groups (▶ **Table 4**). The procedural costs for TEM were significantly lower compared to open and robotic resection but not compared to laparoscopic resection (▶ **Table 4**). The total cost for TEM, however, was significantly lower compared to all three surgical alternatives (▶ **Table 4**). The procedural and total costs were significantly lower for open compared to robotic resection but not laparoscopic resection and there was no statistically significant difference between laparoscopic and robotic resection in regards of procedural or total costs (▶ **Table 4**).

Hypothetical cost scenarios

A total of 1514 surgically resected and 273 locally resected T1 rectal cancers were identified, of which 1008 were excluded due to neoadjuvant treatment (n = 208), synchronous cancers (n = 137), and missing data on depth of submucosal invasion, LVI and differentiation grade (n = 663). The remaining 779 patients with T1 rectal cancer constituted the national study cohort, consisting of 449 men (57 %) with a median age of 70 years (31–96). In total, 531 of 779 (68 %) included T1 rectal cancers had one or more risk factors for LNM (deep submucosal invasion (>Sm1), LVI and poor tumor differentiation) consisting of 35 patients in the local resection group (35/90, 39 %) and 496 patients in the surgical resection group (496/689, 72 %). The actual incidence of LNM in the surgical resection group was 84/689 (12 %). The estimated total 1-year costs for the different hypothetical scenarios are given in ▶ **Table 5**. ESD, followed by subsequent surgery for all non-curative resections (68 % of all cases) was the least expensive scenario with a 1-year cost of 18 168 € per patient (▶ **Table 5**). TEM, followed by subsequent surgery for all non-curative resections (68 % of cases) was the most expensive scenario with a 1-year cost of 28 319 € per patient.

▶ **Table 3** Costs in the five treatment groups.

	n	Median (€)	IQR (€)
ESD			
▪ Procedure	16	2650	2650–2650
▪ Follow-up		1979	899–2904
▪ Total cost		5165	3964–5781
TEM			
▪ Procedure	17	12 736	12 236–12 736
▪ Follow-up		1987	1342–3493
▪ Total cost		14 871	14 550–17 222
Open resection			
▪ Procedure	35	14 236	12 734–17 739
▪ Follow-up		5912	2479–8829
▪ Total cost		21 453	17 902–24 739
Laparoscopic resection			
▪ Procedure	9	13 831	11 137–22 063
▪ Follow-up		6351	5223–10 136
▪ Total cost		22 488	17 262–27 068
Robotic resection			
▪ Procedure	8	21 125	18 611–25 213
▪ Follow-up		6541	3886–9819
▪ Total cost		26 562	23 537–36 816
Total			
▪ Procedure	85	13 235	12 234–17 558
▪ Follow-up		3493	1896–7635
▪ Total cost		19 807	14723–24688

ESD, endoscopic submucosal dissection; TEM, transanal endoscopic microsurgery;
IQR, interquartile range (25 %-75 %)

Discussion

There are several different methods to treat patients with T1 rectal cancer. This cost-minimization study compared costs of treating early rectal cancer with local endoscopic and surgical

▶ **Table 4** Comparisons of procedural and total 1-year costs.

Procedural cost	vs	Procedural cost		Total cost	vs	Total cost	
ESD (2650 €)		TEM	*P* < 0.001	ESD (5165 €)		TEM	*P* = 0.001
		Open resection	*P* < 0.001			Open resection	*P* < 0.001
		Laparoscopic resection	*P* < 0.001			Laparoscopic resection	*P* = 0.003
		Robotic resection	*P* < 0.001			Robotic resection	*P* = 0.002
TEM (12 736 €)		Open resection	*P* = 0.008	TEM (14 871 €)		Open resection	*P* = 0.001
		Laparoscopic resection	*P* = 0.722			Laparoscopic resection	*P* = 0.033
		Robotic resection	*P* < 0.001			Robotic resection	*P* < 0.001
Open resection (14 236 €)		Laparoscopic resection	*P* = 0.630	Open resection (21 453 €)		Laparoscopic resection	*P* = 0.873
		Robotic resection	*P* < 0.001			Robotic resection	*P* = 0.010
Laparoscopic resection (13 831 €)		Robotic resection	*P* = 0.070	Laparoscopic resection (22 488 €)		Robotic resection	*P* = 0.070
Robotic resection (21 125 €)		–	–	Robotic resection (21 125 €)		–	--

Presented as median costs. *P* value was determined by use of Mann-Whitney U-test.
ESD; endoscopic submucosal dissection, TEM; transanal endoscopic microsurgery.

resection. Local resection of T1 rectal cancer is beneficial compared to surgery in terms of reduced morbidity and mortality [7–9]. These benefits, however, are only attainable for T1 cancers with low risk of concomitant LNM. The economic aspects of local and surgical methods to resect T1 rectal cancer are elusive since the true costs of local resection not only comprise that of curative resections but also all non-curative cases with high risk of LNM requiring subsequent surgery. This study shows that ESD not only had a significant lower total 1-year cost compared to the surgical alternatives but was also more than four times less costly than TEM in regards of procedural cost. In addition, we found that 68 % of all T1 rectal cancers exhibit high-risk features requiring surgical resection according to guidelines, although only 12 % of the surgically treated patients actually had LNM. However, the hypothetical scenario of performing ESD on all T1 rectal cancers initially, followed by subsequent surgery on all patients with high-risk features, had considerably lower total 1-year cost compared to all other hypothetical scenarios.

The primary aims in this study were procedural and total 1-year costs of five methods to resect T1 rectal cancer. We found that both the procedural and total 1-year costs related to ESD were significantly lower compared to the other alternatives. In fact, the procedural cost for TEM (12 736 €) was more than four times higher than that for ESD (2650 €). TEM has previously been reported to have a higher cost compared to ESD and the big gap in costs between the two oncological equivalent treatments is related to the expensive TEM equipment, need for an operating room and anesthesia as well as longer hospitalization stays [12, 15]. It should also be noted that although TEM comprises full-thickness resection and ESD implies submucosal resection, there are no oncological advantages or reduction in recurrence or LNM incidence associated with TEM. In fact, it has previously been reported that salvage surgery after TEM results in higher morbidity and higher rates of abdominoperineal resections and permanent stomas compared to performing surgery straightaway [24–27]. Thus, TEM-associated full-thickness resection can result in scarring and obliteration of the embryological planes, complicating surgical dissection [24–27]. Moreover, as expected, we found that the procedural and total costs of open resection were significantly lower than that for robotic resection, which is supported by numerous previous studies

▶ **Table 5** Hypothetical cost scenarios based on different index procedures on all T1 rectal cancers.

Index procedure	Per patient 1-year cost
ESD	18 168 €
TEM	28 319 €
Open resection	21 453 €
Laparoscopic resection	22 488 €
Robotic resection	26 562 €

Per patient 1-year costs were calculated for respective method as first-line treatment, based on 779 T1 rectal cancers identified in the Swedish Colorectal Cancer Registry 2009–2018, including costs of subsequent resection (mean cost of open and laparoscopic resection) in 530 (68 %) high-risk cases of lymph node metastases for ESD and TEM.
ESD, endoscopic submucosal dissection; TEM, transanal endoscopic microsurgery.

[16, 28, 29]. However, the difference in cost between laparoscopic and robotic resection in our study was not statistically significant. This finding is in contrast to previous studies showing that robotic resection is more costly than laparoscopic resection [16, 28, 30, 31]. This discrepancy could possibly be explained by the few cases in both the laparoscopic and robotic resection groups in our study, inducing a possible type-II error. Also, one of the patients in the laparoscopic group needed postoperative treatment in the Intensive Care Unit, following emergency surgery, which increased total cost in the laparoscopic group compared to the robotic group, in which no patient suffered serious complications. However, comparing costs of ESD and TEM with surgical resection in the present cost-minimization analysis is partially misleading, given that a majority of the high-risk TEM and ESD patients did not undergo subsequent surgery. We therefore performed hypothetical cost scenarios, to test the potential costs of ESD and/or TEM as initial treatment on all T1 rectal cancers, when all patients with high-risk features are followed by surgery, in accordance with guidelines [6].

We found that from 2009 to 2017 in Sweden, 68 % of all T1 rectal cancers were high-risk tumors in terms of LNM risk and would require surgical resection according to guidelines [6]. In this context, it is important to note that the actual incidence of LNM in our study was 12 % in the surgical resection group. Thus, adherence to guidelines results in unnecessary surgery in the majority of patients referred to surgery. The hypothetical scenario of performing ESD on all T1 rectal cancers followed by subsequent surgery on all non-curative resections (68 % of cases) was still associated with a lower cost compared to all other scenarios. The hypothetical scenario of performing TEM on all patients followed by subsequent surgery on all non-curative resections turned out to be the most expensive scenario of all and even more costly than performing robotic resection on all patients right away.

Our hypothetical cost scenarios are based on certain assumptions. First, that all local resections are en bloc and R0. As for both TEM and ESD, the procedures can be performed with an almost certainty of en bloc and R0 in the lateral margins and R0 in the vertical margins in cases of shallow submucosal invasion and without size limitations in expert centers, as demonstrated herein and in previous studies [5, 32–35]. We also assumed that our initial Skåne County cohort was representative in terms of patient characteristics, treatment patterns, and costs, and applicable on both a national level and at a larger scale. Although length of hospital stay, complication rates, and timing of stoma conversions might differ, the total annual costs is assumed to vary only marginally based on these variables because costs are primarily driven by operating room time and equipment for the different surgical procedures.

Our study was limited by small case numbers in each group and its retrospective design, although data were collected prospectively. The five groups were equal in terms of comorbidity but not age, BMI, and gender and the possible impact of these factors on costs is unknown, which also limits our study. Another limitation is that determination of costs and actual treatment costs can vary between countries. The study was further limited by not including tumor budding as a high-risk feature in the hypothetical cost scenarios.

Conclusions

In conclusion, to the best of our knowledge, this was the first study to analyze total 1-year costs of T1 rectal cancer treatment comparing methods for local and surgical resection. We found that the cost of ESD was significantly lower than that for all other alternatives. In fact, even when hypothetically all T1 rectal cancers were treated with ESD and followed by surgery in all high-risk patients, according to guidelines, ESD still had the lowest total cost for treating T1 rectal cancer.

Competing interests

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