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Perioperative and Long-Term Oncological Outcomes of Robotic versus Laparoscopic Total Mesorectal Excision: A Retrospective study of 672 Patients

Niyaz Shadmanov
Bogazici Academy for Clinical Sciences
Vusal Aliyev
Bogazici Academy for Clinical Sciences
Guglielmo Niccolò Piozzi
Portsmouth Hospitals University NHS Trust
Barıs Bakır
Istanbul University
Suha Goksel
Maslak Acibadem Hospital
Oktar Asoglu
oktarasoglu@yahoo.com

Bogazici Academy for Clinical Sciences

Research Article

Keywords: Total mesorectal excision, Robotic approach, Laparoscopic approach, Rectal cancer, Oncological outcomes

Posted Date: March 12th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4020628/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Journal of Robotic Surgery on March 30th, 2024. See the published version at https://doi.org/10.1007/s11701-024-01922-w.

Abstract

Backround

Although there's growing information about the long-term oncological effects of robotic surgery for rectal cancer, the procedure is still relatively new. This study aimed to assess the long-term oncological results of total mesorectal excision (TME) performed laparoscopically versus robotically in the setting of rectal cancer.

Methods

Restrospective analysis of a prospectively maintained database. A total of 489 laparoscopic (L-TME) and 183 robotic total mesorectal excisions (R-TME) were carried out by a single surgeon between 2013 and 2023. The groups were compared in terms of perioperative and long-term oncological outcomes.

Results

In the R-TME and L-TME groups, male sex predominated (75.4% and 57.3%, respectively), although the robotic group was significantly greater ($p = 0.008$). There was no conversion in R-TME group, whereas three (0.6%) converted to open surgery in L-TME group. The R-TME group had a statistically significant higher number of distal rectal tumors (85%) compared to the L-TME group (54.6%). Only three (1.7%) patients in the R-TME group received abdomineperineal resection (APR); in contrast, 25 (5%) patients in the L-TME group received APR ($p < 0.001$). For R-TME, the mean follow-up was 70.7 months (range 18–138) and for L-TME, it was 60 months (range 14–140). Frequency of completed mesorectum was significantly greater in R-TME group (98.9% vs 94.2%, $p < 0.001$). The 5-year overall survival rates for R-TME and L-TME groups were 89.6% and 88.7%, respectively. The 5-year disease-free survival for R-TME and L-TME groups were 84.1% and 81.1%, respectively. The local recurrences rates were 7.6% and 6.3%, respectively in R-TME and L-TME groups ($p = 0.274$).

Conclusion

R-TME is characterized by no conversion and improved mesorectal integrity. R-TME had longer operation time. The long-term oncological outcomes were comparable between groups.

Introduction

Since its introduction in the 1980s, Total Mesorectal Excision (TME) has become a widely adopted technique, significantly enhancing local control post-surgery and remaining a pivotal aspect of rectal cancer surgery [1]. The standard of surgical therapy now includes laparoscopic TME (L-TME), which is universally approved and carried out. L-TME has been shown in many randomized trials to have superior

short-term oncological safety, less postoperative pain, improved cosmetic outcomes, faster recovery, and shorter hospital stay than open surgery. Nevertheless, laparoscopic surgery has numerous potential drawbacks, despite its clinical efficacy as a surgical approach for rectal cancer [2–3]. These include the high conversion rate to open surgery and the limited visibility due to unstable cameras [4–5]. Notably, due to the limitations of the limited pelvic anatomy, the laparoscopic approch poses technical obstacles in the successful treatment of low rectal cancer, particularly in cases with bulky tumors and in male or overweight patients undergoing neoadjuvant chemoradiotherapy (NCRT).

Theoretically, in an attempt to overcome the drawbacks of laparoscopy, robotic surgery was developed and could provide benefits in limited spaces as for pelvic surgery. Robotic approach has been proving to be safe and to provide good short- and mid-term oncological outcomes for rectal cancer surgery [6]. Besides improved dexterity, the robotic platform provides robust, readily adjustable three-dimensional imaging and a stable platform for surgeons, minimizing fatigue and improving comfort during rectal dissection [7].

This study aims to compare the perioperative and long-term oncological outcomes of L-TME and robotic TME (R-TME).

Methods

Study population

This retrospective study evaluated a consecutive series of patients with rectal cancer undergoing either L-TME or R-TME surgery between January 2013 and June 2023. Data were extracted from a prospectively maintained surgical database. This study was conducted in compliance with the Principles of the Declaration of Helsinki. Informed consent was obtained from each patient.

Primary aim was to report perioperative and long-term oncological outcomes.

Inclusion criteria were: 1) rectal adenocarcinoma; 2) tumor location (15 cm from the anal verge, AV); 3) clinical TNM stage I–III; 4) absence of distant metastases and synchronous tumors; 5) sphincter-saving TME or abdominoperineal resection (APR); 6) elective surgery; 7) curative intent surgery.

Exclusion criteria were: 1) sigmoid resections; 2) Hartmann’s resection; 3) local excision; 4) sistemic metastases; 5) palliative surgery.

The boundary between the anal mucosa and the perineal skin was defined as AV. The distance between the tumor's caudal border and the anal margin was measured through rectal magnetic resonance imaging (MRI), flexible sigmoidoscopy, and digital rectal examination.

Preoperative protocol

Preoperative staging included chest X-ray, carcinoembryonic antigen (CEA) levels, flexible or virtual colonoscopy, torax/abdominopelvic CT and MRI of the pelvic phased array.

NCRT included: 1) Long-term neoadjuvant chemoradiotherapy with concurrent chemotherapy using capecitabine (1600 mg/m^2 daily during radiotherapy), with a total dose of 50 Gy given in 25 fractions over five weeks. Surgery was undertaken within the timeframe of 4 to 8 weeks following the conclusion of chemoradiotherapy; 2) total neoadjuvant treatment consists of NCRT followed by consolidation chemotherapy. Consolidation chemotherapy involved concurrent administration of oxaliplatin (85 mg/m²) and leucovorin (400 mg/m²) biweekly, followed by a bolus injection of 5-fluorouracil (5-FU) (400 mg/m²), and then infusion with 5-FU (2400 mg/m²). Following June 2018, the consolidation regimen was changed to include capecitabine (1000 mg/m²) twice daily on days 1–14 in addition to oxaliplatin (130 mg/m²) on day one; this was repeated every three weeks for eight cycles; 3) A total of 25 Gy was given in five fractions over 5–7 days to the short-course neoadjuvant radiotherapy group. Within one to four weeks following the end of neoadjuvant radiation therapy, surgery was performed. When there was no chance of positive lateral margins, patients were given short-course radiotherapy.

Without the addition of oral antibiotics, all patients underwent oral mechanical bowel preparation. One hour prior to the start of the surgical incision, a single 400 mg intravenous dosage of ciprofloxacin was given.

Surgical technique

A single surgeon (O.A.), with over twenty years of experience in oncological colorectal surgery, performed all surgical procedures. The surgeries were performed at Maslak Acibadem Hospital in Istanbul, Turkey and Liv Hospital, Department of General Surgery, Istanbul, Turkey. Every patient had a detailed discussion regarding the surgical strategy, which was decided by the surgeon after considering the patient's preferences and the surgeon's assessment. Before the procedure, every patient was given thorough instructions detailing the benefits and drawbacks of both laparoscopic and robotic approach. Both laparoscopic and robotic surgical procedures were previously described in detail [8–10].

The Da Vinci Si® or Xi® platform (Intuitive Surgical, Inc., Sunnyvale, CA, USA) was used in the R-TME group.

Any unintended laparotomy that occurred during surgery, regardless of the extent of the incision, was referred to as a conversion.

Pathological report

During the data evaluation process, pathological staging was modified to conform to the 8th edition staging criteria of the American Joint Committee on Cancer (AJCC) [11]. Tumor size, number of harvested lymph nodes, distal resection margin (DRM), circumferential resection margin (CRM), and integrity of the mesorectum were all determined by a thorough analysis of all pathology specimens. The criteria established by Quirke et al. were used to assess the mesorectum's quality after dissection [12]. Positive

CRM was described as direct tumor expansion that occurred within 1 mm of the resected specimen's radial, non-peritonealized surface [13].

Postoperative outcomes and follow-up

The Clavien-Dindo classification was used to assess postoperative complications, which are defined as unfavorable events that occur within 30 days following surgery [14]. Anastomotic leaks were diagnosed and treated in accordance with the protocols set by the International Study Group of Rectal Cancer [15].

The follow-up measures included thoraco-abdominopelvic CT assessment every year, colonic examinations at the first, third, fifth, and tenth years after surgery, and monitoring of oncological markers (CEA, carbohydrate antigen 19 – 9) every three months.

Disease-free survival (DFS) was estimated from the date of surgery to the tumor's recurrence, whereas overall survival (OS) was calculated from the date of surgery to the date of death or the last follow-up. Histological confirmation or radiographic identification of expanding lesions established the diagnosis of recurrence. The STROBE declaration principles for cohort studies were followed by this study [16].

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, NY, USA) and 95% confidence level was used. For categorical (qualitative) variables, frequency and percentage (n (%)), for numerical (quantitative) variables mean, standard deviation (mean ± ss), minimum, maximum statistics are given. In the pairwise comparison of the measurements determined in the study according to the groups, LSD/Mann Whitney One-way ANOVA/Kruskal Wallis test was used for intergroup comparisons and Chi-square test was used for the relationships between grouped variables. Chi-square test is a test technique used to determine the relationships between grouped variables. LSD/Mann Whitney is a test technique used to compare two independent groups in terms of a quantitative variable. One-way ANOVA/Kruskal Wallis is a test technique used to compare more than two independent groups (k = group > 2) in terms of a quantitative variable.

Result

Clinical outcomes

A total of 672 patients with rectal cancer were enrolled into two groups: L-TME group (n = 489, 72.7%) and R-TME (n = 183, 37.3%). Table 1 shows patients' clinical and demographic details. Patients in the R-TME group were younger (54.2 ± 12.8 and 57.2 ± 12.8 years for R-TME and L-TME, respectively) (p = 0.007). Male patients made up to 54% of the L-TME group and 75.4% of the R-TME group, respectively. This was statistically significant (p < 0.001).

Table 1
Patients characteristics

	R-TME (n = 183)	L-TME (n = 489)	p
Age	54.2 ± 12.8	57.2 ± 12.8	0.007 [t]
Sex			
Male	138 (75.4%)	280 (57.3%)	0.008[K]
Female	45 (24.6%)	209 (42.7%)	
ASA Score			0.010 [t]
1	20 (11%)	48 (10%)	0.010 [t]
2	138 (75.4%)	323 (66%)	
3	25 (13.6%)	118 (24%)	
BMI	26.994 ± 2.622	26.740 ± 2.537	0.252 [t]
Localisation			
Mid-low	156 (85%)	267 (54.6%)	< 0.001 [K]
Proximal	27 (15%)	222 (45.4%)	
Mean: Average SS: Standard Deviation t: Independent sample t-test K: Pearson chi-square test			
The American Society of Anesthesiologists Score: ASA Body Mass Index (BMI)			

Mid-low rectal cancers were significantly more common in the R-TME group (85% and 54.6% for R-TME and L- TME, respectively) ($p < 0.001$).

Perioperative outcomes

Table 2 lists the perioperative outcomes. No cases of 30-day death was reported. With R-TME, the operation time was substantially longer (158.9 ± 39.1 vs. 116.1 ± 31.7 min, $p < 0.001$). In terms of estimated blood loss and postoperative hospital stay, there was no significant difference seen. While the majority of patients in both groups were cT3 and node-positive, there was a greater percentage of cT4 patients in the L-TME group (14.8% in R-TME and 24% in L-TME, respectively). Neoadjuvant therapy was administered to most patients however, the R-TME group received more (84.1% and 52.3% for R-TME and L-TME, respectively; $p < 0.001$).

Table 2
Perioperative outcomes

	R-TME (n = 183)	L-TME (n = 489)	p
Overall operation time, min	158.9 ± 39.1	116.1 ± 31.7	< 0.001 *t*
Hospital stay, days	4 ± 2.100	3.946 ± 1.135	0.675 *t*
Clinical Stage, *n (%)*			
cT1	8 (4.4)	17 (3.5)	0.291 *z*
cT2	16 (8.7)	39 (7.9)	0.369
cT3	132 (72.1%)	316 (64.6%)	0.032
cT4	27 (14.8)	117 (24)	< 0.001
cN negative	39 (21.4%)	113 (23.1%)	0.308
cN positive	144 (78.6%)	376 (76.8%)	
Neoadjuvant treatment, *n (%)*			
Yes	154 (84.1%)	256(52.3%)	< 0.001 *z*
No	29 (15.9%)	233 (47.7%)	
TME procedure, *n (%)*			
APR	3 (1.7%)	25 (5%)	< 0.001 *K*
Anterior resection	16 (8.7)	152 (31.1)	< 0.001
Low-anterior resection	100 (54.6)	223(45.6)	0.187
Intersphincteric resection	64 (35)	89(18.2)	< 0.001
Sphincter preserving	180 (98.3%)	464 (95%)	0.274
Diverting ileostomy	157 (85.8)	231 (47.3)	< 0.001 z
Yes	23(12.5)	233 (47.7)	
No			
Conversion rates, n (%)	0 (0)	3 (0.6)	0.146 *z*

Mean: Average SS: Standard Deviation t: Independent sample t-test z: Two ratio z-test K: Pearson chi-square test

Total mesorectal excision : TME Abdominoperineal resection :APR

The R-TME group's patients received more low anterior resections (54.6% vs. 45.6% p = 0.187) and intersphincteric resections (35% vs. 18.2% p < 0.001) because they mostly had distal tumors. Conversely, the L-TME group had a higher frequency of proximal tumors, and there was a marked predilection for anterior resections (8.7% vs. 31.1%, p < 0.001) in this group.

Three patients (1.7%) had APR in the R-TME group, while twenty-five patients (5%) received APR in the L-TME group (p < 0.001). Three patients (0.6%) in the L-TME group had open conversions, whereas there were none in the R-TME group.

Histopathological outcomes

Even though R-TME had a larger mean number of excised lymph nodes, the difference between the two groups was not statistically significant (24.6 ± 9.3 vs 23.5 ± 10.8, p = 0.125). The mean distance of the resection margin (DRM) was longer in L-TME (15.2 ± 14.7 mm and 20.8 ± 15.6 mm for R-TME and L-TME, respectively). Eight (4.3%) patients in R-TME and sixteen (3.2%) patients in L-TME had positive CRM involvement (p = 0.236).

A statistical difference was reported between R-TME and L-TME regarding specimen quality (98.9% vs. 94.2%, p < 0.001). There were no notable variations in other histopathology results (Table 3).

Table 3
Histopathological outcomes

	R-TME (n = 183)	L-TME (n = 489)	p
DRM, mm	15.2 ± 14.7	20.8 ± 15.6	< 0.001 [t]
Involved CRM, n (%)	8 (4.3%)	16 (3.2%)	0.236
Tumor size, mm	34.4 ± 15.3	41.2 ± 18.8	< 0.001 [t]
Macroscopic quality of TME specimen			
Complete	181 (98.9%)	461 (94.2%)	< 0.001 [z]
Incomplete	2 (1.1%)	28 (5.8%)	
Pathological Stage, n (%)			
ypT0	22 (12)	27 (5.5)	< 0.001
ypT1	24 (13.2)	40 (8.1)	0.222
ypT2	55 (30)	81 (16.6)	< 0.001
ypT3	74 (40.4)	250 (51.1)	0.013
ypT4	8 (4.4)	91 (18.6)	< 0.001
ypN negative	178(60%)	165(54%)	0.052 [K]
ypN positive	119(40%)	143(46%)	
Harvested LN, n (%)	24.6 ± 9.3	23.5 ± 10.8	0.125
Mean: Average SS: Standard Deviation t: Independent sample z: Two ratio z-test			
CRM: circumferential resection margin, DRM: Distal resection margin, LN: lymph node			

Postoperative complications

Table 4 shows that the overall complication rate was 17.5% for L-TME and 16.8% for R-TME (p = 0.132). Symptomatic anastomotic leakage occurred in 16 (8.7%) R-TME patients and 47 (9.6%) L-TME patients. All instances of anastomotic leakage were managed conservatively, involving the maintenance of pelvic drainage until clinical resolution of the infection, with selective use of endo-sponge drainage.

Table 4
Postoperative complications

	R-TME (n = 183)	L-TME (n = 489)	p
Overall complications, n (%)	32 (16.7)	86 (17.5)	0.4
Anastomotic leak	16 (8.7)	47 (9.6)	0.034 [z]
Anastomotic stricture	2 (1)	4 (0.8)	0.401
Rectourethral fistula	2 (1)	2 (0.4)	0.176
Rectovaginal fistula	2 (1)	5 (1)	0.5
Colonic ischemia	1 (0.5)	1 (0.2)	0.257
Ileus	4 (2)	12 (2.5)	0.351
Pelvic hematoma	2(1)	8 (1.6)	0.280
Pelvic abscess	3 (1.5)	7 (1.4)	0.460
Clavien–Dindo morbidity, n (%)			0.397
I–II	22 (11.5)	53 (10.8)	0.238
III–IV	10 (5.2)	32 (6.7)	
z: Two ratio z-test			

Rectovaginal fistula occurred in five patients in the L-TME group and two patients in the R-TME group.

Two patients, one with R-TME and the other with L-TME, experienced an immediate onset of colonic ischemia. On the third postoperative day, these patients underwent an urgent laparoscopic colon resection and re-anastomosis.

According to Clavien-Dindo's classification, there was no significant difference in postoperative morbidity

Oncological outcomes

The mean follow-up were 70.7 months (interval 18–138) for R–TME and 60 months (interval 14–140) for L–TME. R-TME and L-TME had 5-year OS rates of 89.6% and 88.7%, respectively. The 5-year DFS rates for R-TME and L-TME were 81.1% and 84.1%. The Kaplan–Meier curves for OS and DFS are reported in Fig. 1.

Local recurrence occurred in fourteen (7.6%) of the R-TME group and in thirty-one (6.3%) of the L-TME group of patients (p = 0.276). During the follow-up period, 20 patients (10.9%) in the R-TME group and 62 patients (12.6%) in the L-TME group were found to have distant metastases. However, there was no significant statistical difference between the groups.

Discussions

The purpose of this study was to compare the perioperative and long-term oncological results of L-TME and R-TME patients with rectal cancer. R-TME was associated with a statistically significant prolonged operation time compared to L-TME ($p < 0.001$). There were three (0.6%) conversions to open surgery in L-TME, and none in the R-TME group. The conversion rates in previously published randomized controlled trials showed different rates: COLOR II (16%), CLASICC (16%), ACOSOG Z6051 (11%), ALaCaRT (9%), and COREAN (1.2%) [2–3, 17–19]. The present study showed that the conversion rate (0.6%) is significantly lower than the aforementioned studies. This may be explained by the standardization of techniques, surgeons' experiences, and the learning curve [20, 21]. A study conducted between 2005 and 2012 by the same group showed a 6.5% conversion rate in L-TME [20]. We believe that conversion to open surgery had a negative effect on the survival of rectal cancer patients. In fact, the 10-year results of the aforementioned study showed inferior outcomes in the converted group (DFS 50.0% vs. 78.3% and OS 46.7% vs. 68.5%) [22].

There was no statistically significant difference in the CRM involvement rate between L-TME and R-TME ($p = 0.236$). Completeness of mesorectum was higher in R-TME with statistical difference (98.9% vs. 94.2%; $p < 0.001$). The mesorectal completeness and margin-free CRM are key histopathologic factors for achieving improved local recurrences rates [12, 13]. The overall CRM positivity rates were 19% in a Dutch study, 13% in the CLASSİC trial, 10.0% COLOR II, 5.7% ROLARR, and 4.1% COREAN trial [2–3, 17, 23–24]. In the current investigation the R-TME and L-TME showed 3.2% and 4.3% CRM involvement, respectively. There was no statistically significant difference in the CRM involvement between the laparoscopic and robotic low-anterior resection groups in the prospective study conducted by Baik et al. [25].

The quality of specimen is considered as a parameter for the evaluation of prognosis. The majority of studies consistently showed that preventing incomplete mesorectum might greatly enhance OS and dramatically lower the chance of recurrence following TME surgery. Classification of a mesorectal specimen was described by Quirke et al. in the CR07 trial, which included 1,156 patients [12]. Surgery was considered complete in 604 (52%), near complete in 398 (34%), and incomplete in 154 (13%). Additionally, they observed that the three-year local recurrence for each of the three groups was 4% for complete, 7% for nearly complete, and 13% for incomplete ($p = 0.0039$), indicating the greatest possible association between the local recurrence and mesorectal integrity. According to our research, the robotic group had more mesorectal completeness (98.9% vs. 94.2% $p < 0.001$). This outcome is in line with our earlier results [9–10, 26–28].

Comparable 5-year OS and DFS rates were seen in the L-TME and R-TME groups ($p = 0.741$ and $p = 0.368$., respectively). This study revealed similar results in terms of local recurrence rate ($p = 0.274$). The distant metastasis rates were also comparable in L-TME and R-TME ($p = 0.27$). In contrast to the present study, our previous research, which compared L-TME and R-TME procedures in male patients with mid-low rectal tumors, revealed substantial differences [27]. Specifically, the R-TME group of male patients exhibited significantly superior rates of improved local recurrence, as well as mesorectal completeness.

These studies once again demonstrated that robotic approach can potentially overcome some technical challenges related to pelvic anatomical differences between sexes compared to laparoscopy. However, our two previously published studies indicated that robotic approach did not provide any benefit in female patients with rectal cancer when compared with laparoscopy [29–30].

There is a possible bias in the present study between the two groups: 1) since robotic surgery was introduced in our study in 2013, laparoscopic cases performed during the same period were included for comparison; 2) the robotic approach was preferred in male patients; 3) due to the high cost of robotics in Turkey, we opted for the robotic approach in technically difficult cases (narrow pelvis, obese patients).

This study has several limitations. Firstly, it constitutes a retrospective analysis of data collected prospectively from a single surgeon's experience. Secondly, the number of R-TME procedures is lower than L-TME. To validate our results, a large prospective randomized study is necessary. Thirdly, we did not evaluate comparative functional outcomes. Lastly, cost-effectiveness was not investigated in this study. However, the strength of this study lies in its long median follow-up and standardized single surgeon setting, coupled with extensive colorectal expertise.

Conclusion

This study reports a higher rate of mesorectal integrity, no conversions to open and/or abdominoperineal resection, and a lower postoperative complication rate in patients undergoing R-TME. R-TME was associated with a longer operative time. Both R-TME and L-TME showed good OS, DFS, and local recurrence rates.

Declarations

Author contributions

Conceptualization: Oktar Asoglu, Niyaz Shadmanov, Vusal Aliyev; Methodology: Oktar Asoglu; Niyaz Shadmanov; Formal analysis and investigation: Niyaz Shadmanov, Oktar Asoglu; Writing- original draft preparation: Niyaz Shadmanov, Vusal Aliyev, Oktar Asoglu; Writing- review and editing: Niyaz Shadmanov, Vusal Aliyev, Guglielmo Niccolò Piozzi, Barıs Bakır, Suha Goksel, Oktar Asoglu; Supervision: Oktar Asoglu

Disclosure of potential conflicts of interest

The authors have no relevant financial or non-financial interests to disclose.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Ethics approval

This study was conducted in compliance with the Principles of the Declaration of Helsinki. Institutional Review Board (IRB) approval was waived following the retrospective nature of the study.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Availability of data and materials

The datasets used or analysed during the current study are available from the corresponding author upon reasonable request.

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Figures

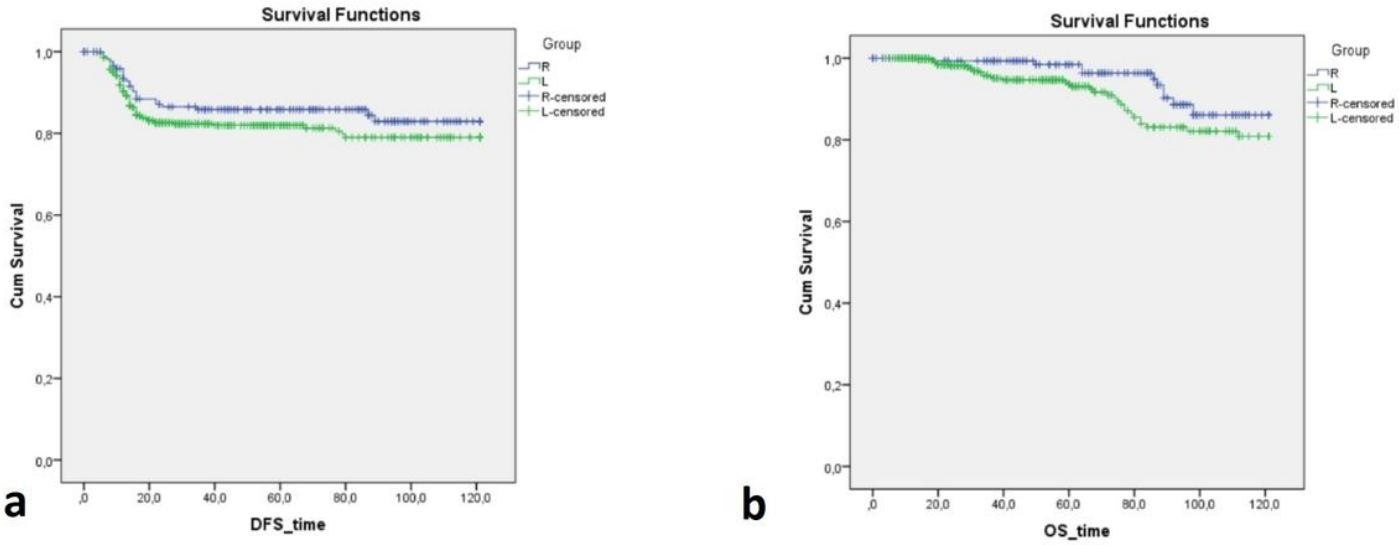


Figure 1

Kaplan-Meier curves of disease-free survival (a) and overall survival (b).