ORIGINAL CONTRIBUTION

Robot-Assisted Abdominoperineal Resection: Clinical, Pathologic, and Oncologic Outcomes

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BACKGROUND: The extralevator approach to abdominoperineal resection is associated with a decreased incidence of rectal perforation and circumferential resection margin positivity translating to lower recurrence rates. The abdominoperineal resection, as such, is an operation associated with poorer outcomes in comparison with low anterior resections, and any improvements in short-term outcomes are likely to be related to surgical technique. Robot assistance in extralevator abdominoperineal resection has shown improvement in these pathologic outcomes. Because these are surrogate markers for local recurrence and disease-free survival, long-term survival data are needed to assess the efficacy of this robot-assisted technique, exclusively in a dedicated abdominoperineal resection cohort.

OBJECTIVE: We assessed the perioperative, pathologic, and oncologic outcomes of the robot-assisted extralevator abdominoperineal resection for rectal cancer.

DESIGN: This study was a review of a prospective database of patients over a 5-year period.

SETTING: Procedures were performed in the colorectal division of a tertiary hospital from April 2007 to July 2012.

PATIENTS: Patients with rectal cancer were operated on robotically. Indications for abdominoperineal resection were low rectal cancers invading the sphincter complex or location in the anal canal precluding anastomosis.

INTERVENTIONS: All patients received a robot-assisted extralevator abdominoperineal resection.

MAIN OUTCOME MEASURES: Operative and perioperative measures, pathologic outcomes, and disease-free survival and overall survival were documented and assessed.

RESULTS: Twenty-two patients (15 men) with a mean age of 65.5 years and mean BMI of 28.6 kg/m^2 underwent robotic abdominoperineal resection. Circumferential resection margin was positive in 13.6%. There was 1 tumor/rectal perforation. At a mean follow-up of 33.9 months, overall survival was 81.8% with a disease-free survival of 72.7%. Local recurrence was 4.5%.

LIMITATIONS: This was a single-institution study with no comparative open or laparoscopic group.

CONCLUSION: Robot-assisted abdominoperineal resection is safe, feasible, and oncologically sound with short-term and long-term outcomes comparable to open and laparoscopic surgery.

KEY WORDS: Rectal neoplasms; Extralevator abdominoperineal excision; Robotic surgical procedures; Oncologic outcomes; Pathologic outcomes; Survival rate.

Standard abdominoperineal resection (APR) is associated with high rates of circumferential resection margin (CRM) positivity and intraoperative perforation (IOP).[1] Abdominoperineal resection by itself is associated with high rates of CRM positivity in comparison with low anterior resections (LARs): 10.6% for APR versus 5% for LAR in the pooled analysis by den Dulk et al[1] and 26.5% versus 12.6% in the study by Nagtegaal et al.[2] These factors are associated with local recurrence and a decrease in disease-free survival.[2] The tapering, or anatomical coning, of the mesorectum toward the anorectal junction

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along with poor visibility are possible reasons for high CRM positivity of tumors within 5 cm of the anal verge.[3]

Extralevator APR has been introduced as a means of achieving a wider excision of the levator muscle perineally after a total mesorectal excision (TME) abdominally. This technique has oncologic superiority over the standard ("hour-glass") approach APR secondary to decreased IOPs and a decreased rate of CRM positivity, lowering the rate of local recurrence.[4,5] Of interest, an analysis of perforations in Nagtegaal's study revealed that most perforations occur in the anal canal and not in the mesorectum, often located posteriorly.[2] The perforation rate was 13.7% in the APR group, compared with 2.5% in the LAR group. The authors postulate that this finding is due to the mechanical stretch and manipulation of the specimen from above and to the anal canal curving forward when APR is performed open, with the extralevator dissection attempted from above. The robot may provide the best of both worlds: an ability to visualize the distal mesorectum from above combined with controlled levator transection, which potentially would lead to lower CRM positivity, and specimen violations, manifesting as perforations.

Robot-assisted TME for rectal cancer is feasible and safe with acceptable long-term oncologic outcomes including a disease-free survival rate of 79% and an overall survival rate of 90%.[6] Robot assistance provides a stable surgical platform, endo-wristed instrumentation improving dexterity, and magnified 3-dimensional vision, facilitating the performance of TME.

Although perioperative and short-term oncologic outcomes are encouraging with robot-assisted APR,[3,7] there is a paucity of studies with long-term outcomes data. Furthermore, analysis of outcomes as it pertains to mode of levator transection, whether done transabdominally-robotically (RILT, robotic intra-abdominal levator transection) or perineally, is required.

MATERIALS AND METHODS

Over a 5-year period, 51 patients with rectal adenocarcinoma underwent an APR, 22 of which were done with robot assistance (Fig. 1). There were no exclusion criteria apart from contraindications to the minimally invasive approach, such as tumors with adjacent organ infiltration necessitating multivisceral resection. All patients were evaluated by a colorectal surgeon and underwent an endoscopy and endorectal ultrasound in addition to CT scan of the chest, abdomen, and pelvis for staging. All cases underwent multidisciplinary tumor board review. Patients with mesorectal infiltration or mesorectal nodes that appeared malignant (T3/T4N0 or N+) were treated with preoperative concurrent chemoradiotherapy and operated on an average 8 to 10 weeks later. Magnetic resonance imaging of the pelvis was used in patients with tumors that were inaccessible or impassable with the endorectal ultrasound probe or those with a threatened radial margin. The hospital institutional review board approved this study.

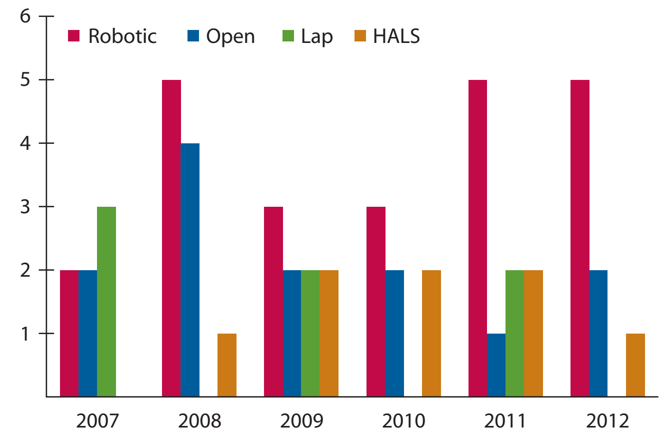

FIGURE 1. Histogram depicting yearwise distribution of robotic, open, laparoscopic/HALS APR. APR = abdominoperineal resection; HALS = hand-assisted laparoscopic surgery.

Surgical Approach

All patients were operated on by using the da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA) after bowel preparation and prophylactic antibiotics. Colon mobilization and lymphadenectomy were performed using the robot-assisted approach or a partially laparoscopic (hybrid) approach. The TME was performed robotically in all patients by 3 colorectal surgeons (L.M.P, J.P.P, and S.J.M). Resection of the levators was performed either transabdominally-robotically (RILT) or perineally. Patients were placed either in the lithotomy or prone position for the perineal portion of the operation.

Port Position and Robotic Docking

Pelvic dissection involved a camera port (12 mm) at or 1 cm above and to the right of the umbilicus. Three 8-mm robotic ports were as follows: 1) arm 1, right iliac fossa along a line drawn from the umbilicus to the anterior superior iliac spine, one-third of the way from the anterior superior iliac spine; 2) arm 3, in the left flank as a mirror image of arm 1; and 3) arm 2, left hypochondrium at the level of umbilicus (midway between camera port and arm 3. Assistant ports (5 mm) were placed in the right hypochondrium and the suprapubic region. The robotic cart was placed between the legs for the entire procedure (single position with single docking).

Postoperative Care and Follow-up

Patients were managed with standard protocols for minimally invasive surgery. On postoperative day 1, all patients were started on clear liquids. Diet rapidly progressed to full liquids and then a soft diet on passage of gas in the stoma bag. Patients were discharged once their pain was well controlled on oral analgesics and they were able to walk safely and tolerate a soft diet.

All patients were followed postoperatively according to the National Comprehensive Cancer Network guidelines. For the first 2 years, they were seen every 3 to 4 months; and, for the next 3 years, they were seen every 6 months for clinical examination, liver function tests, and CEA assay. Annual CT scans of the abdomen and thorax were performed. Survival was calculated from the time of surgery to the last follow-up or the time of death. Postoperative mortality was defined as death within 30 days from surgery or as in-hospital mortality.

Statistical Analysis

Demographic data, operative measures, and oncologic outcomes were recorded in a prospective database by the colorectal fellows. Means and SDs were used for all the continuous data. Numbers and percentages were calculated for all the categorical data. Kaplan-Meier curves and 95% CIs were calculated for overall survival (OS) and disease-free survival (DFS) at 3 years. Univariate analysis included Student *t* tests, Mann-Whitney *U* test, χ^2 test, and Fisher exact tests. The variables that were statistically significant on univariate analysis were included in logistic regression models to further assess their impact on local and distant recurrence. A 2-tailed $p < 0.05$ was considered statistically significant for all the analyses. All data were analyzed by using SPSS for Windows, version 22 (SPSS Inc, Chicago, IL).

RESULTS

Patient Demographics

There were 15 men and 7 women in the study. Mean age and BMI were 65.5 ± 13.5 years and 28.6 ± 6.7 kg/m². The mean tumor distance from the anal verge was 4.6 cm ± 1.4 cm. Preoperative chemoradiation was received by 91% of patients (Table 1).

TABLE 1. Patient demographics and tumor characteristics

Variable (n = 22)	
Age, y, mean ± SD	65.5 ± 13.5
Sex, n (%)	
Male	15 (68.2)
Female	7 (31.8)
BMI, kg/m², mean ± SD	28.6 ± 6.7
BMI>30	8 (36.4)
BMI≤30	14 (63.6)
ASA class, n (%)	
2	14 (63.6)
3	8 (36.4)
Prior abdominal surgery, n (%)	10 (45.5)
Tumor location (from anal verge), n (%)	
Mid (5.1–10.0 cm)	3 (13.6)
Lower (0.0–5.0 cm)	19 (86.4)
Preoperative chemoradiation, n (%)	20 (90.9)

Operative Measures

All patients underwent robot-assisted TME. The mean total operating time was 380 ± 91 minutes; robotic TME time was 114 ± 37 minutes. The mean blood loss was 259 ± 175 mL. Colon mobilization was done robotically in 16 patients (72.7%) and laparoscopically or with hand-assisted laparoscopy in 6 (27.3%) patients. Levator transection was accomplished via the perineal approach in 17 patients (77.3%) and via RILT in 5 patients (22.7%). The perineal portion of the operation was done in the prone position in 12 patients (54.5%) and in the lithotomy position in 10 patients (45.4%). All patients received an end colostomy, with the exception of 1 patient who needed an end ileostomy secondary to total proctocolectomy for low rectal cancer arising in a background of long-standing ulcerative colitis. One patient was converted to open secondary to difficult anterior mobilization of the rectum after nearly circumferential robotic rectal dissection. This patient had a BMI of 27.6 kg/m². Two patients were converted from an ultralow anterior resection to a robotic APR, one of whom had an intraoperative perforation of the rectum and a concern of a positive margin, where the rectum was adherent to the levator ani. The other patient was converted to a robotic APR secondary to a positive anterior margin that was adherent to the prostatic capsule on frozen section. Another patient had bladder wall involvement and underwent a pelvic exenteration after the robotic colon and rectal mobilization. There were 2 concomitant en bloc sacrectomies (S3 and S4 level). Mean operative time was significantly longer in the prone position (447 ± 65 minutes) compared with the lithotomy position (341 ± 117 minutes; $p = 0.01$). An omental pedicle flap was created at the time of surgery in 10 patients (45.5%) (Table 2).

TABLE 2. Operative measures

Procedure, n (%)	
Colon mobilization	
LA/HALS	6 (27.3)
Robotic	16 (72.7)
Perineal portion position	
Prone	12 (54.5)
Lithotomy	10 (45.5)
Levator transection approach	
Open perineal	17 (77.3)
Robotic transabdominal	5 (22.7)
Omental pedicle flap placement	10 (45.5)
Conversion to open	1 (4.5)
Conversion to exenteration	1 (4.5)
Concomitant sacrectomy	2 (9.1)
End colostomy	21 (95.5)
End ileostomy	1 (4.5)
Perineal position, mean ± SD	Operative time
Prone	447 ± 65 min*
Lithotomy	341 ± 117 min*

LA/HALS = laparoscopic/hand-assisted laparoscopic surgery.
*$p = 0.01$.

TABLE 3. Postoperative complications

Variable	*n (%)*
Minor complications	5 (22.7)
SBO (nonoperative management)	1
High ileostomy output	1
Neuropathy (chemotherapy related)	2
Perineal wound infection (nonoperative management)	1
Moderate complications	5 (22.7)
DVT	1
Aspiration pneumonia	2
Atrial fibrillation	1
Foot drop (postsacrectomy)	1
Severe complications	7 (31.8)
Clostridium difficile colitis	1
Septic shock	1
Gastric perforation	1
Omental pedicle necrosis, reexplored	1
Perineal wound bleed, reexplored	1
Perineal wound necrosis debrided	2
30-day mortality	1 (4.5)
Total patients with complications	16 (72.7)
Late complications (>30 days)	12 (54.5)
Incisional hernia	3
Parastomal hernia	2
SBO (operative management)	4
Stoma prolapse	1
Stoma retraction	1
Small-bowel fistula (operative management)	1

DVT = deep vein thrombosis; SBO = small-bowel obstruction.

TABLE 4. Pathologic outcomes

Variable	*n (%)*
Pathologic American Joint Committee on Cancer stage	
Stage 0 (pCR)	1 (4.5)
Stage I	8 (36.4)
Stage II	4 (18.2)
Stage III	7 (31.8)
Stage IV	2 (9.1)
Lymph node yield	13.2 ± 6.3
CRM positive, ≤1 mm	3 (13.6)
IOP	1 (4.5)
Tumor differentiation and histology	
Adenocarcinoma	18 (81.8)
Mucinous adenocarcinoma	3 (13.6)
Signet-ring adenocarcinoma	1 (4.5)
Mesorectal grade	
Grade II	2 (9.1)
Grade III	20 (91.0)
Additional pathologic features	
LVSI	5 (22.7)
PNI	1 (4.5)
Mesorectal deposits	4 (18.2)
PNE	2 (9.1)

CRM = circumferential resection margin; pCR = complete pathologic response; IOP = intraoperative perforation; LVSI = lymphovascular space invasion; PNE = pudendal nerve entrapment; PNI = peripheral nerve injury.

Postoperative Outcomes

The mean time to a clear liquid diet was 1.8 ± 1 days and 2.8 ± 1.1 days for ostomy function. The median length of stay was 6 (range, 3–36) days. There were 16 complications, based on the Accordion grading system, in 22 patients (72.7%; Table 3). One patient in our series died in the hospital on postoperative day 21. He aspirated and developed respiratory failure complicated by gastric perforation as a terminal event. There were 5 patients (22.7%) with perineal wound complications, 4 of whom had an omental pedicle flap placed at time of surgery. There was 1 readmission within 30 days of surgery. During the study period, there were 4 deaths, 2 because of progressive disease and 2 from unrelated causes.

Pathologic Outcome Measures

A complete pathologic response (stage 0) was seen in 1 patient (4.5%). The pathologic American Joint Committee on Cancer stages are documented in (Table 4). The mean node yield was 13.2 ± 6.3 nodes. Circumferential resection margin positivity was seen in 3 patients (13.7%), and IOP occurred in 1 patient (4.5%) during the initial intention of sphincter-sparing procedure. Of the 3 patients who had CRM positivity, 1 underwent pelvic exenteration for invasion into the bladder wall, and 1 had local recurrence. Mesorectal grade, according to the Quirke method, was classified as good (intact) in 20 patients (90.9%) and moderate in 2 patients (9.1%).[8] Fourteen patients (63.6%) received adjuvant chemotherapy.

Oncologic Outcomes

At a median follow-up of 31 (range, 1–69) months and a mean follow-up of 33.9 ± 19.9 months, the 3-year OS was 81.8% (95% CI, 61.5%–92.7%) and the 3-year DFS was 72.7% (95% CI, 51.9%–86.9%; Figs. 2A and B). The 3-year OS in patients with BMI ≥30 kg/m^2 was 75% (95% CI, 41%–92.9%), and, in patients with BMI <30 kg/m^2, the 3-year OS was 85.7% (95% CI, 60.1%–96%; $p = 0.72$; Fig. 2C). The 3-year DFS in patients with BMI ≥30 kg/m^2 was 62.5% (95% CI, 30.6%–86.3%), and, in patients with BMI <30 kg/m^2, the 3-year DFS was 78.6% (95% CI, 52.4%–92.4%; $p = 0.90$; Fig. 2D).

We did not find a difference in survival as it pertains to a perineal versus a robotic-transabdominal (RILT) resection of the levators. Prone versus lithotomy position also did not show a difference in survival; however, there was a significantly longer operative time with prone positioning than with lithotomy. One patient had local recurrence (4.5%); this patient had a positive CRM. There were 5 patients (22.7%) with systemic recurrences; one had chemoembolization of hepatic metastasis and another underwent a pulmonary metastatectomy.

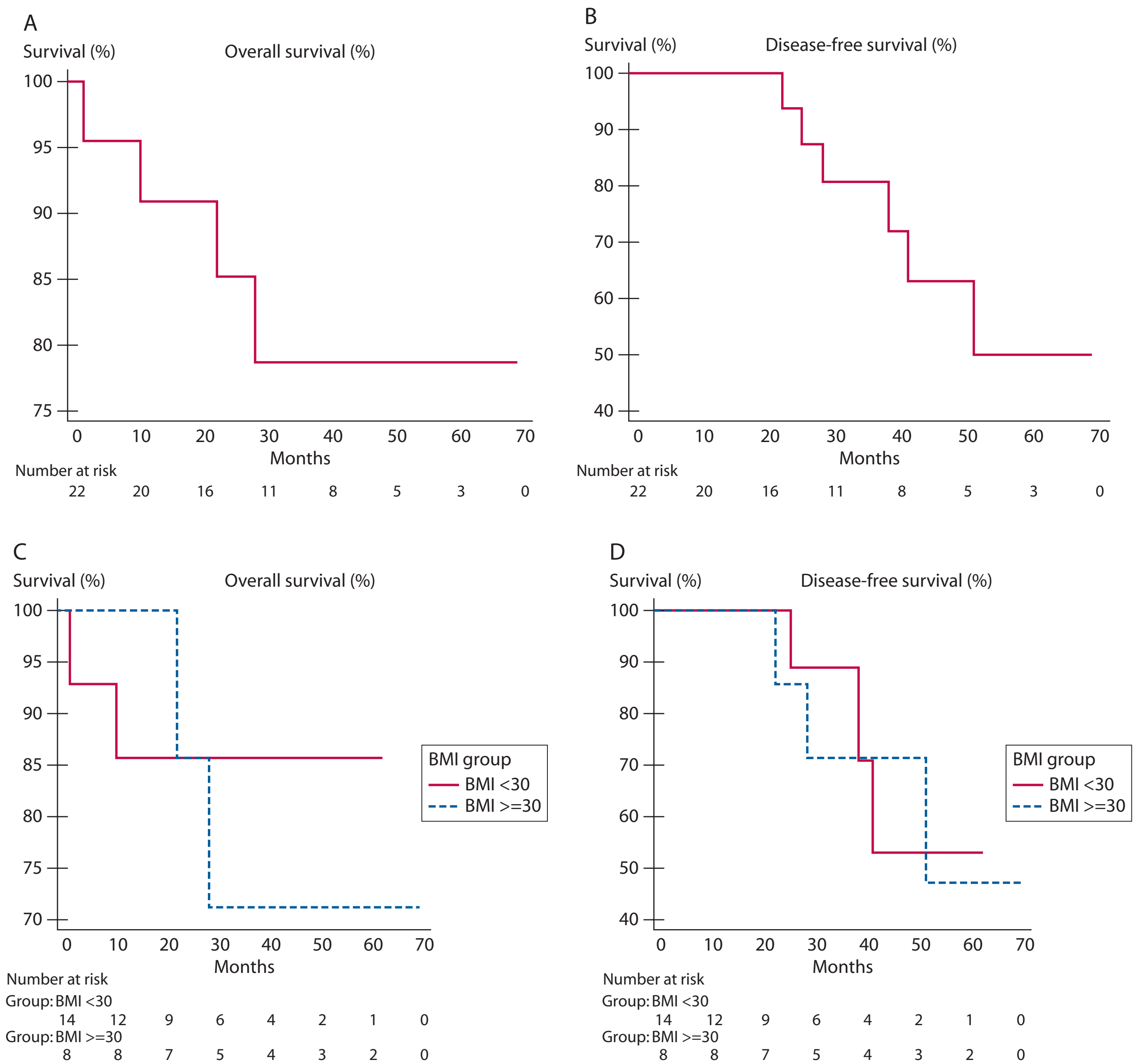

FIGURE 2. A, Three-year overall survival for rAPR. B, Three-year disease-free survival for rAPR. C, Three-year overall survival for BMI. D, Three-year disease-free survival for BMI. rAPR = robotic abdominoperineal resection.

DISCUSSION

Robot-assisted TME for rectal cancer is feasible and can be performed safely with oncologic outcomes comparable to open and laparoscopic surgery.[6,9–11] Robotic APR cohorts have however been grouped with LAR without stratification as it pertains to oncologic outcomes. An earlier report from our group (Marecik et al[3]), described a series of 5 patients who underwent the robotic technique of extralevator APR through a controlled incision of the levator muscles performed transabdominally without incidence of positive CRM or IOP. Kim et al[7] compared this technique in 21 patients versus 27 conventional open APR patients with improved pathologic outcomes in the robotic group, noting no IOP and negative CRM in comparison with the open cohort. Our aim is to present long-term survival data further quantifying the efficacy as specifically related to the robot-assisted APR.

In Comparison with Open and Laparoscopic APR

Data with open extralevator or cylindrical APR shows OS rates between 58% and 76% and DFS rates between 47% and 72% in 3- to 5-year follow-up cohorts.[5] Including the MRC CLASICC trial, the laparoscopic APR literature's 3- to 5-year OS and DFS rates are between 65.2% to 75% and 49.8% to 78%.[12,13] In comparison, our robotic APR series presents as favorable regarding OS rate at 81.8% and DFS rate at 72.7% with 3-year follow-up. Our CRM positivity of 13.7% is within the range of the open APR

TABLE 5. Comparison of open and laparoscopic APR

Author	No. of patients	CRM +, %	IOP +, %	LR, %	OS, %	DFS, %	Follow-up
Palmer et al[22]	193	20	10	6	60	67	5 y
Stelzner et al[5]	1100	9.6	4.1	6.6	58–76	47–72	3–5 y
West et al[4a]	176	20.3	8.2	–	–	–	–
Nagtegaal et al[2b]	373	29	13.7	–	–	–	5 y
Den Dulk et al[1b]	897	10.6	–	19.7	59.5	–	5 y
Ng et al[13c]	51	5.9	0	5	75	78	5 y
CLASICC[23c]	–	–	–	15.1	65.2	49.8	3 y
Present study	22	13.7	4.5	4.5	81.8	72.7	3 y

Comparative pathologic/oncologic outcome data: open and laparoscopic extralevator APR.
APR = abdominoperineal resection; CRM = circumferential resection margin; DFS = disease-free survival; IOP = intraoperative perforation; LR = local recurrence; OS = overall survival.
[a]Open/laparoscopic.
[b]Standard APR.
[c]Laparoscopic.

literature (9.6%–20%), along with our IOP rate of 4.5% (4.1%–10%). Our local recurrence rate at 4.5% compared favorably to 6.6% in the open-cohort literature and 5% to 17.7% in laparoscopic outcome groups (Table 5).

Survival with Respect to BMI

The previously cited study by Kim et al[7] in 2014 reported no intraoperative perforation and no CRM positivity in 21 robotic APR patients in a short-term operative and oncologic outcomes comparison of robotic versus open APR. The average BMI of the robotic cohort in this study, $22.9 \pm 2.4\,kg/m^2$, is lower than in our group ($28.6 \pm 6.7\,kg/m^2$). Obesity is an epidemic in the United States with an estimated 35.7% of Americans classified as obese (BMI $\geq 30\,kg/m^2$),[14] and is a well-accepted factor in degree of difficulty with dissection as reflected by higher conversion rates in laparoscopic rectal surgery.[15] In the 1 conversion we had to open APR, the patient's BMI was $27.6\,kg/m^2$ at time of surgery. Despite the increased technical difficulty of operating on patients with obesity, we did not find statistically significant improvement in survival with respect to BMI of $<30 kg/m^2$.

Levator Transection: RILT versus Perineal

With the robot-assisted APR, levator transection under direct visualization was facilitated. This approach – characterized by the direct visualization of the levator origin and its components, the pubococcygeus, iliococcygeus, and coccygeus muscles – has benefits in minimizing the risk of accidental injury to the neurovascular structures along the lateral pelvic compartment and could potentially avoid extensive resection of the coccyx as almost universally done to facilitate surgical exposure in a perineal extralevator approach.[3] The abdominal approach to levator transection has been replicated in open, laparoscopic APR and robotic (RILT) groups with resultant CRM positivity rates between 0% and 8.3% and no recorded IOP in 38 patients.[3,7,16] Our series includes the RILT approach and the perineal approach. Early in the study, we used the perineal dissection exclusively (n = 17, 77.3%); toward the end of the study period, and at present, we use the RILT approach (n = 5, 22.7%) routinely and perform perineal extralevator transection only in open cases. We did not record a positive CRM or IOP in the RILT cohort; however, patients were not randomly stratified between approaches, which introduced possible bias. There was not a significant difference between abdominal versus perineal approach to resection of levators in terms of DFS. Although the RILT approach appears to provide better short-term oncologic outcomes as qualified by the pathologist, the numbers are too small to draw a definite conclusion, and further study in a randomized fashion is required.

Position of Perineal Portion of APR: Prone versus Lithotomy

Open cylindrical, extralevator APR in its development to reduce "waisting," IOP and CRM positivity, and subsequently local recurrence has traditionally had the perineal portion of the operation performed in the prone position.[17] This study had 12 patients (54.5%) in the prone position for the perineal portion and 10 patients in the lithotomy position (45.4%). In our series, we did not notice a significant difference in DFS as it pertains to position for perineal dissection. The 1 patient with IOP was in the prone position. Of the 3 patients who had positive CRM, 2 were in the lithotomy position, and one of those patients had a local recurrence. Anderin et al[18] showed significantly decreased IOP and CRM positivity in prone perineal portions of open APR versus lithotomy, with a nonsignificant relative risk reduction in local recurrence. However, the 2 groups were not controlled for type of surgery (cylindrical APR or conventional APR) with respect to the perineal position. Oncologic outcomes were not significantly affected by surgical positioning during the perineal portion of an APR as shown in the Cleveland Clinic study in 2011.[19] Our study did not show significance with positioning as well, but more adequate power is needed, because our sample size is small.

Long-term Morbidity in Robotic APR

Abdominoperineal resection has increased morbidity with perineal wound complications reported in up to 50% of patients that could be associated with decreased survival.[20,21] Wider excisions with the extralevator approach along with radiotherapy are significant factors in increased wound morbidity.[4,20,21] Our overall perineal wound complication incidence is at 22.7%, which includes 3 (13.6%) perineal wound infections and 1 (4.5%) perineal hematoma. We did not observe perineal hernias or wound dehiscence. We reported 1 incident of erectile dysfunction, but no voiding difficulties. This is comparable to the series by Kim et al[7] that reported 9.5% perineal wound infection rate, 3 incidences (27%) of male sexual dysfunction, and 2 cases of voiding dysfunction. Neoadjuvant radiation significantly increases perineal wound complication in extralevator APR at rates of 37.6%.[20] With 91% of our patients receiving neoadjuvant chemoradiation, our overall perineal wound complication incidence was 22.7%. Robot-assisted APR series, including the present study, are too small to draw definitive conclusions regarding long-term morbidity, including sexual dysfunction, and dedicated morbidity studies are needed with this approach.

Conclusion

Robot-assisted APR for low rectal cancer is technically feasible and can be safely accomplished. Short- and mid-term outcomes are acceptable and comparable to open and laparoscopic series. Abdominoperineal resection continues to be a technically demanding and disadvantaged operation for a group of patients with biologically aggressive tumors and a decreased survival in comparison with LAR. The ability to visualize and transect the levators under vision in a controlled manner robotically (RILT) ensures radicality with a decrease in perforations and margin positivity while potentially preventing damage to the neurovascular bundles on the lateral pelvic wall, which should translate into better function and fewer wound complications. Further prospective and randomized multicenter studies are needed to establish the role of robot-assisted APR and to clarify the role of abdominal versus perineal transection and that of positioning as related to pathologic and long-term outcomes.

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