Surg Endosc (2016) 30:3933–3942
DOI 10.1007/s00464-015-4704-x

Laparoscopic right hemicolectomy: short- and long-term outcomes of intracorporeal versus extracorporeal anastomosis

Mark H. Hanna[1] · Grace S. Hwang[3] · Michael J. Phelan[2] · Thanh-Lan Bui[1] · Joseph C. Carmichael[1] · Steven D. Mills[1] · Michael J. Stamos[1] · Alessio Pigazzi[1]

Received: 20 April 2015 / Accepted: 20 November 2015 / Published online: 29 December 2015
© Springer Science+Business Media New York 2015

Abstract
Background The use of laparoscopy for right hemicolectomy has gained popularity allowing the option of a totally laparoscopic intracorporeal anastomosis (IA) for intestinal reconstruction. This technique may alleviate some of the technical limitations that a surgeon faces with a laparoscopic-assisted extracorporeal anastomosis (EA).
Methods A retrospective chart review of 195 consecutive patients who underwent laparoscopic right hemicolectomy by four colorectal surgeons at three institutions from March 2005 to June 2014 was performed. Multivariate regression analysis was used to compare postoperative and oncologic outcomes.
Results A total of 195 patients underwent laparoscopic right hemicolectomy over the study period, with 86 (44 %) patients receiving IA and 109 (56 %) patients receiving an EA. The most common indication for surgery in both groups was cancer: 56 (65 %) of IA cases and 57 (52 %) of EA cases. IA had a significantly higher rate of minor complications but no difference in serious complications compared to EA. Conversion to open resection was higher in EA. Using multivariate analysis to compare IA versus EA, there was no significant difference in length of stay, return of bowel function, risk of anastomotic leak, risk of intraabdominal abscess or risk of wound complications. Amongst cancer resections, there was no significant difference in the median number of lymph nodes harvested (18 LNs in IA group vs. 19 LNs in EA group, $P > 0.05$). There was also no significant difference in overall survival and disease-free survival at 5.7 years between the two groups.
Conclusions IA in laparoscopic right hemicolectomy is associated with similar postoperative and oncologic outcomes compared to EA. IA may possess advantages in terms of conversion and flexibility of specimen extraction, but this is counterbalanced by a higher incidence of minor complications. These findings suggest that IA represents a valid technique in the arsenal of the experienced colorectal surgeon without compromising outcomes.

Keywords Intracorporeal anastomosis · Laparoscopy · Right hemicolectomy · Outcomes

Laparoscopic colectomy is gaining popularity as a feasible, safe and effective approach in terms of short-term, long-term and oncologic outcomes in contemporary colorectal surgical practice [1–3]. However, laparoscopic right colectomy continues to be utilized in a minority of procedures [4]. This is despite the ample evidence in the literature showing improved outcomes with laparoscopic resection [5, 6]. The majority of laparoscopic right colectomies continue to be performed with an extracorporeal anastomosis (EA) due to inherent technical difficulties in acquiring advanced laparoscopic suturing skills [7]. The recent emphasis on minimally invasive surgical techniques has given new impetus for surgeons to perform colorectal

Presented at the SAGES 2015 Annual Meeting, April 15–18, 2015, Nashville, Tennessee.

✉ Mark H. Hanna
markhh@uci.edu

[1] Department of Surgery, University of California, Irvine School of Medicine, 333 City Blvd. West Suite 850, Orange, CA 92868, USA

[2] Department of Statistics, University of California Irvine, Irvine, CA, USA

[3] Department of Surgery, University of Southern California, Los Angeles, CA, USA

resections with the construction of a totally laparoscopic intracorporeal anastomosis (IE).

There has been abundant evidence of the benefit of laparoscopic-assisted right colectomy with EA compared to purely open or hand-assisted resections [8]. The laparoscopic approach with EA has been shown to have equivalent oncologic outcomes with earlier return of bowel function, less postoperative pain and shorter hospital stay with the caveat of longer operative duration compared to conventional open resection [9–11]. The theoretical advantages of a totally laparoscopic IA are that it would allow the surgeon to avoid having to extract the bowel and mesentery through a thick abdominal wall in obese patients; it would avoid the possible twisting of the mesentery and bowel during the extracorporeal anastomotic construction and thus may promote even faster return of bowel function; last but not least, the IA allows the surgeon to select the optimal bowel extraction site which has a dramatic role in incisional hernia formation. On the other hand, the additional technical difficulty of an IA makes this procedure within the reach of only a small percentage of surgeons.

The evidence assessing the outcomes of intracorporeal anastomosis during laparoscopic right colectomy is growing, but is still limited to small series with short follow-up [12, 13]. We conducted a large consecutive case series comparing the postoperative and oncologic outcomes of IA versus EA for laparoscopic right hemicolectomy.

Materials and methods

Approval for this study was obtained from the institutional review board of the University of California Irvine Medical Center. We performed a retrospective review of 195 consecutive patients who underwent laparoscopic right hemicolectomy performed by four colorectal surgeons between March 2005 and June 2014 at City of Hope National Medical Center, Huntington Memorial Hospital and University of California Irvine Medical Center. The majority of the cases (>80 %) were done at the University of California Irvine Medical Center. Cases were divided into two groups: those with an intracorporeal ileocolic anastomosis (IA) and those with an extracorporeal anastomosis (EA).

Aims

Our study had three basic aims: (1) to assess the feasibility of intracorporeal anastomosis after laparoscopic right hemicolectomy, (2) to compare the postoperative outcomes between intracorporeal and extracorporeal anastomosis after right hemicolectomy and (3) to elucidate the short- and long-term oncologic outcomes of laparoscopic right hemicolectomy performed with either intracorporeal or extracorporeal anastomosis in patients with colon cancer. Based on our clinical experiences and previously published studies, endpoints of clinical relevance were selected a priori to compare between IA and EA through multivariate regression analysis. These outcomes included: patient demographics, operative parameters, postoperative complications, disease recurrence and survival. Patients in each group were assigned a comorbidity score calculated based on the validated Charlson comorbidity model [14]. Conversion was defined as conversion to open surgery in both cohorts. In IA group, the need for an incision for any part of the operation other than for specimen extraction was defined as a conversion. In EA group, the need for an incision for any part of the operation other than for anastomosis construction or specimen extraction was defined as a conversion. Anastomotic leak was defined clinically. Thus, only leaks that required an intervention (either percutaneously or operatively) were counted as an anastomotic leak in both cohorts. Finally, wound infection was defined as a superficial incisional infection that occurred within 30 days after the operation and only involved the skin or subcutaneous tissue of the incision and had at least one of the following prerequisite findings: (1) purulent drainage, with or without laboratory confirmation, from the superficial incision, (2) organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision or (3) at least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness or heat.

Surgical technique

Amongst 195 patients, 86 patients underwent IA and 109 patients underwent EA. The choice of anastomotic technique was left at the discretion of the operating surgeon. The medial-to-lateral dissection technique was employed in all cases. An extracorporeal anastomosis was constructed by first exteriorization of the colon and then creation of a side-to-side anti-peristaltic ileocolic anastomosis. This was done by making an extension of the midline incision of the umbilical port, which allowed exteriorization of the colon, or by creation of a right-sided transverse incision lateral to the rectus muscle. The anastomosis was then constructed by firing an open 75-mm stapler cartridge in a side-to-side anti-peristaltic fashion. Finally, the enterotomies are closed using two-layer, running Vicryl sutures. On the other hand, an intracorporeal anastomosis was preformed using a totally laparoscopic right hemicolectomy technique. This was constructed by firing one 60-mm linear stapler load in an isoperistaltic side-to-side

manner. The enterotomies were then closed using a two-layer, running 3–0 Vicryl suture laparoscopically.

The mesenteric defect and the mesocolon after the construction of either type of anastomosis were not closed. In the intracorporeal group, specimen extraction was done either through a Pfannenstiel incision in the majority of cases or less commonly through trans-vaginal extraction. A trans-vaginal extraction method was confined to female patients who had small tumours, benign pathology and were not sexually active. In these cases, the vagina was closed via a trans-vaginal approach. In the extracorporeal group, specimen extraction was done by extension of one of the pre-existing port incisions, preferentially of the periumbilical midline incision. Finally, in terms of post-operative management, it should be noted that while we did not strictly adhere to an ERAS programme postoperatively during the time period of the data collection, the cases were done by four colorectal surgeons who practised similar postoperative recovery (ERAS type) protocols.

Statistical analysis

Statistical analysis was performed with the SAS and R statistical programs. Demographics and comorbidity data were summarized using means/medians for continuous variables and percentage proportions for categorical variables. The Chi-squared test or Fisher exact probability test for categorical variables and Student's *t* test for continuous variables were used to test significance of differences between the groups. IA and EA cases were analysed using multivariate risk-adjusted analysis. *P* values for significance testing were two sided and considered to be of statistical significance when $P < 0.05$. Our analysis controlled for age, gender, race, ASA class, BMI and the Charlson comorbidity score. Furthermore, all cases with faecal diversion were excluded from anastomotic leak analysis. Adjusted mean differences and adjusted odds ratios (OR) were calculated with 95 % confidence intervals (CI).

Results

Patient demographics and indications

We reviewed a total of 195 patients, with 86 patients undergoing IA and 109 patients undergoing EA (Fig. 1). Table 1 summarizes the patient demographics, comorbidities and indications of patients undergoing laparoscopic right hemicolectomy. The majority of patients in the EA cohort were female (58 %) while the gender distribution was more even in the IA cohort (52 % female). The IA cohort was older by a median of 7 years than the EA cohort. The ASA distribution was similar between both cohorts with at least 90 % of patients in both groups having an ASA class of II or III. Interestingly, at least 50 % of patients in both groups had a prior abdominal surgery, with prior surgery being more common in EA patients (58 %). With regard to indications, cancer was the most common indication accounting for at least 50 % of cases in both cohorts. Inflammatory bowel disease was the second most common indication amongst EA cases as opposed to IA cases where benign adenoma was the second most common indication for operation. Comorbidity scores were higher amongst the IA group.

Operative and postoperative outcomes

Table 2 summarizes the unadjusted operative and postoperative outcomes of patients undergoing laparoscopic right hemicolectomy during the study period. Our study revealed a steady improvement in operative time (time from induction to awakening), from an average of 240 min in 2005 to an average of 170 min by 2014. Operative time was almost identical between the two groups with a median case duration of $\sim$180 min. Similarly, estimated blood loss (50 cc) and postoperative length of stay (median of 5 days) were similar between IA and EA cases. On the other hand, patients who received an intracorporeal anastomosis had a faster rate of resumption of a regular diet by 1 day. With regard to conversion, all right colectomies were completed laparoscopically in the IA cohort. There were ten cases that were converted to an open resection in the EA, resulting in a conversion rate of 9 % compared to no conversions amongst IA cases; this difference in conversion rate, however, was not found to be statistically significant ($P > 0.05$). The majority of these conversions were due to adhesions and one case of intraoperative bleeding. We then preformed a subset analysis comparing the patient characteristics of the ten converted EA cases to those EA cases that were completed successfully laparoscopically. There was no correlation between risk of conversion and characteristics such as age, sex, ASA class or indications for resection. Amongst ten EA patients who were converted, nine patients underwent resection for cancer and one patient for IBD. We did see a trend towards a higher BMI (median BMI 28.15 vs. 25.0 kg/m^2, $P = 0.15$) in the converted group. This was in line with our anecdotal experience as the majority of these conversions occurred in patients who were morbidly obese.

With regard to specimen extraction site, the majority of the EA specimens were extracted through the midline. In our IA group, we primarily employed a Pfannenstiel incision for specimen extraction, and thus, the majority of those were extracted through that incision. There were only five cases of trans-vaginal extraction of specimens and those only occurred amongst the IA cohort and were

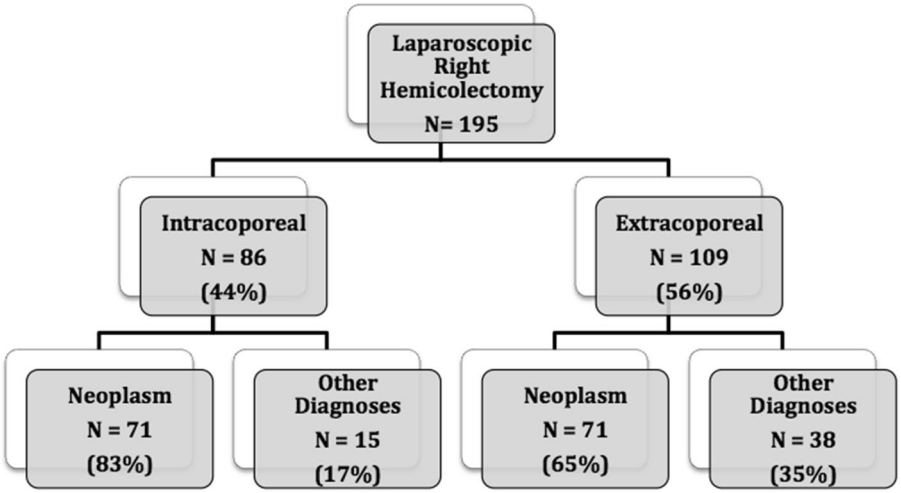

Fig. 1 Flow chart showing the distribution of laparoscopic right hemicolectomy resections

Table 1 Characteristics of patients undergoing laparoscopic right colectomy

Variable	Extracorporeal ($n = 109$)	Intracorporeal ($n = 86$)	P value
Age (years)	59.00 (45.00–72.00)	66.00 (53.00–77.00)	<0.05
Sex			NS
F	63 (57.80 %)	45 (52.33 %)	
M	46 (42.20 %)	41 (47.67 %)	
ASA class			NS
I	0 (0.00 %)	0 (0.00 %)	
II	50 (45.87 %)	36 (41.86 %)	
III	53 (48.62 %)	42 (48.84 %)	
IV	6 (5.50 %)	8 (9.30 %)	
Median BMI (kg/m^2)	25.1 (21.6–30.0)	25.9 (23.1–29.6)	NS
Prior abdominal surgery			NS
N	46 (42.20 %)	42 (48.84 %)	
Y	63 (57.80 %)	44 (51.16 %)	
Indications			<0.05
Cancer	57 (52.29 %)	56 (65.12 %)	
Adenoma	12 (11.01 %)	15 (17.44 %)	
IBD	32 (29.36 %)	7 (8.14 %)	
Diverticulitis	2 (1.83 %)	0 (0.00 %)	
Bowel obstruction	1 (0.92 %)	1 (1.16 %)	
GI bleed	1 (0.92 %)	0 (0.00 %)	
Other	4 (3.67 %)	7 (8.14 %)	
Charlson comorbidity index	2.00 (0.00–4.00)	3.00 (1.00–4.00)	NS

Continuous variables are reported as medians (interquartile ranges), and categorical variables are reported as per cent proportions

ASA American Society of Anaesthesiologists' classification of physical health, *IBD* inflammatory bowel disease, *BMI* body mass index, *NS* not significant ($P > 0.05$)

reserved for known benign indications only. To date, two extraction site hernias have been reported in this group, whereas five patients in the EA group developed a post-operative incisional hernia at the midline incision site for specimen extraction and extracorporeal anastomosis. Despite these differences, extraction site was not found to be a significant predictor of wound infection or incidence of hernia postoperatively ($P > 0.05$).

Postoperative complications are summarized in Table 3 according to the Clavien–Dindo classification of surgical complications. We found a significantly higher incidence of overall complications amongst the IA cohort (53 vs.

Table 2 Unadjusted operative and postoperative outcomes of patients undergoing laparoscopic right hemicolectomy

Variable	Extracorporeal ($n = 109$)	Intracorporeal ($n = 86$)	P value
Operative time (min)	184.50 (138.00–232.50)	183.00 (140.00–217.00)	NS
Estimated blood loss (cc)	50.00 (40.00–100.00)	50.00 (30.00–100.00)	NS
Length of stay (days)	5.00 (4.00–7.00)	5.00 (3.00–7.00)	NS
Days to regular diet	4.00 (3.00–5.00)	3.00 (1.00–5.00)	NS
Conversion			<0.05
No	99 (90.83 %)	86 (100.00 %)	
Yes	10 (9.17 %)	0 (0.00 %)	
Extraction site			<0.05
Midline	100 (91.74 %)	0	
Pfannenstiel	9 (8.26 %)	81 (94.19 %)	
Trans-vaginal	0	5 (5.81 %)	

Continuous variables are reported as medians (interquartile ranges), and categorical variables are reported as per cent proportions

NS Not significant ($P > 0.05$)

Table 3 Clavien–Dindo classification of complications of patients undergoing laparoscopic right hemicolectomy

	Extracorporeal ($n = 109$)	Intracorporeal ($n = 86$)	P value
Grade I	17 (16 %)	14 (16 %)	NS
Fever	10	8	
Urinary tract infection	7	6	
Grade II	15 (14 %)	28 (33 %)	<0.05
Ileus/bowel obstruction	9	19	
Wound infection	6	9	
Grade IIIa	7 (6 %)	3 (3 %)	NS
Anastomotic leak	3	0	
Intraabdominal abscess	4	3	
Grade IIIb	2 (2 %)	1 (1 %)	NS
Anastomotic leak requiring reoperation	2	1	
Grade IV	0	0	NS
Grade V	0	0	NS
Serious complications (≥Grade III)	9 (8 %)	4 (5 %)	NS
Overall complications	41 (38 %)	46 (53 %)	<0.05

NS Not significant ($P > 0.05$)

38 %, respectively, $P < 0.05$). This was due to a significantly higher incidence of Grade II complications including a higher incidence of superficial wound infections and a higher incidence of ileus/bowel obstruction after IA (33 vs. 14 %, respectively, $P < 0.05$). Despite these findings, there was no significant difference in the incidence of serious complications (Grade III, IV and V) between the two treatment modalities. There were five anastomotic leaks amongst the EA cohort resulting in a rate almost four times higher compared to IA (4.6 vs. 1.2 %, respectively). However, this higher rate of anastomotic leak amongst EA was not found to be statistically significant ($P > 0.05$). We evaluated the impact of age, sex, ASA class and type of anastomosis via multivariate analysis, but none of these factors were identified as significant risk predictors of anastomotic leak. Conversely, the rate of ileus/bowel obstruction amongst IA patients was double the rate of EA patients. IA patients were more likely to develop wound infections compared to their EA counterpart, although these infections occurred in the earlier period of the analysis. All wound infections were at the specimen extraction site. There was no 30-day mortality in either anastomotic cohort.

Table 4 summarizes the adjusted operative and postoperative outcomes of patients undergoing laparoscopic right hemicolectomy during the study period. Using multivariate analysis to compare IA cases against EA cases, there was no significant difference in length of stay between the two

Table 4 Adjusted mean difference/odds ratio of IA versus EA selected endpoints

Endpoint	Adjusted mean difference (ratio)/OR (95 % CI)	Adjusted *P* value
Length of stay (days)	−0.04 (−1.54, 1.45)	NS
Days to regular diet	0.91 (0.69, 1.19)	NS
Anastomotic leak	0.31 (0.03, 2.95)	NS
Intraabdominal abscess	0.89 (0.14, 5.46)	NS
Wound infection	1.77 (0.63, 5.00)	NS

The extracorporeal anastomosis group (EA) was used as the reference group

Confounding variables controlled for included: age, gender, race, ASA class, BMI and the Charlson comorbidity score

Linear regression for continuous variables and logistic regression for categorical variables were used, respectively

NS Not significant ($P > 0.05$)

groups (AOR −0.05 days, 95 % CI −1.53 to 1.43, $P > 0.05$). There was a mild trend towards faster return of bowel function with IA that failed to reach significance (AOR 0.91, 95 % CI 0.69–1.19, $P > 0.05$). Notably, there was a strong trend towards a lower risk of anastomotic leak with IA that failed to reach significance (AOR 0.29, 95 % CI 0.03–2.79, $P > 0.05$). Finally, there was a trend towards a higher risk of intraabdominal abscess and wound complications with IA compared to EA resection.

Cancer-specific outcomes

Amongst the total cohort of 195 patients, 69 patients in the EA cohort and 71 patients in the IA cohort underwent laparoscopic right hemicolectomy for neoplasm. Table 5 summarizes the oncologic outcomes between IE and EA resections in patients with a neoplasm. The distribution of oncologic staging was similar between the two groups. Stage III colorectal cancer accounted for at least one-third of resections in both groups. This was followed by stage I colorectal cancer and benign adenoma. The median number of lymph nodes retrieved was 18 for IA patients and 19 for EA patients ($P > 0.05$). At least 80 % of patients in either group had greater than 12 lymph nodes harvested successfully in the specimen ($P > 0.05$). There were no significant differences in both disease-free survival (86 % in IA vs. 84 % in EA) and overall survival (66 % in IA vs. 78 % in EA) at 5.7 years of surveillance ($P > 0.05$) (Fig. 3).

Discussion

Our analysis represents one of the largest consecutive experiences comparing IA and EA during laparoscopic colon resection. Our study revealed no significant difference in length of stay, return of bowel function, risk of anastomotic leak, risk of intraabdominal abscess or risk of wound complications between IA and EA (Fig. 2). Furthermore, we found no compromise in oncologic outcomes with no significant difference in the median number of lymph nodes harvested and no difference in overall survival and disease-free survival at 5.7 years of follow-up between the two groups (Fig. 3).

Table 5 Oncologic outcomes of IE and EA in patient undergoing laparoscopic right colectomy for neoplasm

Variable	Extracorporeal ($n = 69$)	Intracorporeal ($n = 71$)	*P* value
Stage			NS
0	11 (15.94 %)	16 (22.54 %)	
I	15 (21.74 %)	17 (23.94 %)	
II	8 (11.59 %)	9 (12.68 %)	
III	29 (42.03 %)	25 (35.21 %)	
IV	5 (7.25 %)	4 (5.63 %)	
Lymph nodes harvested (number)	19.00 (14.00–25.50)	18.00 (13.00–29.50)	NS
Recurrences	5 (7.46 %)	5 (7.69 %)	NS
Wound complications	4 (5.80 %)	9 (12.68 %)	NS
Follow-up (months)	10.15 (2.23–26.91)	7.33 (1.91–24.77)	NS

Continuous variables are reported as medians (interquartile ranges), and categorical variables are reported as per cent proportions

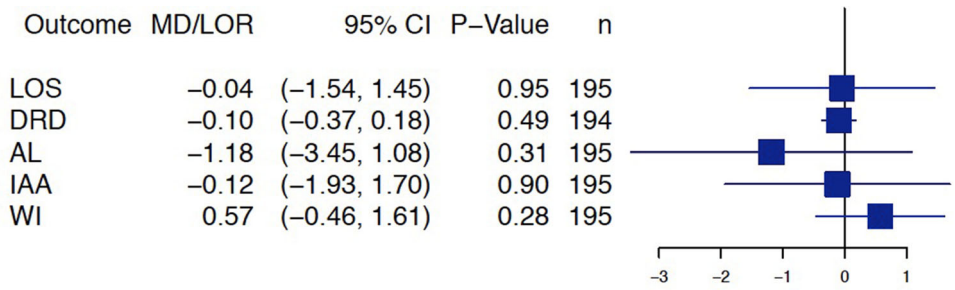

Fig. 2 Forest plot for co-primary outcomes. Adjusted mean difference (MD) or log odds ratio (LOR) for intracorporeal versus extracorporeal anastomosis. MD for length of stay (LOS) and days to regular diet (DRD). LOR for anastomotic leak (AL), intraabdominal abscess (IAA) and wound infection (WI)

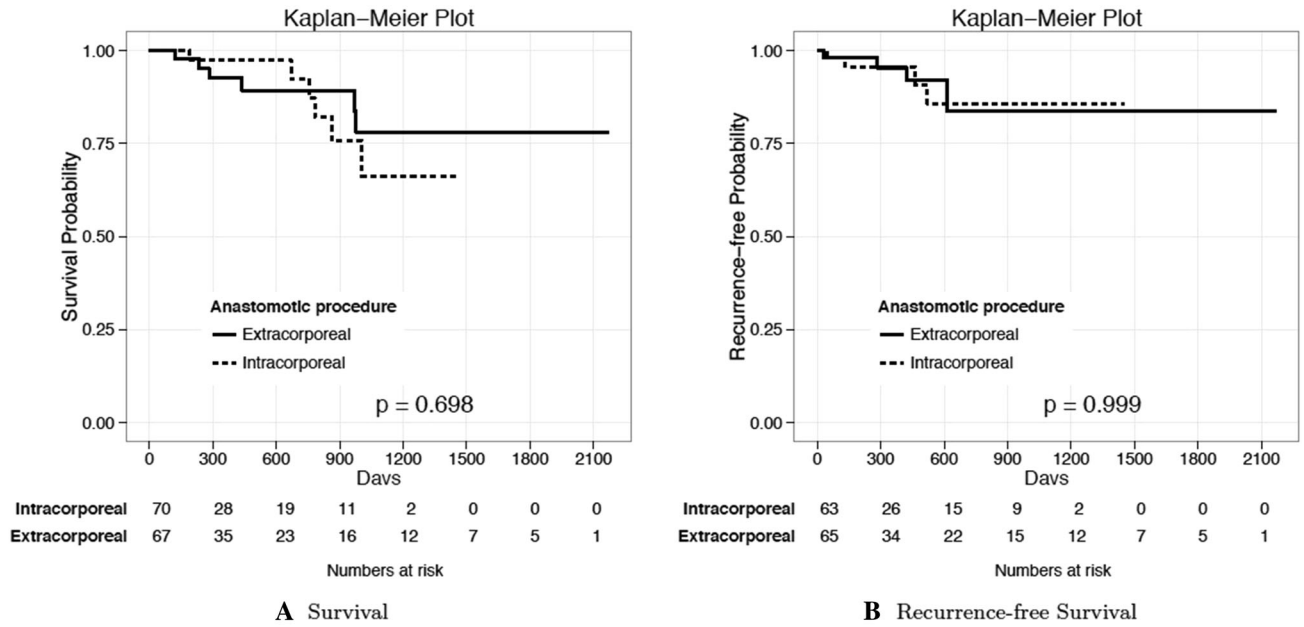

Fig. 3 Kaplan–Meier **a** overall survival and **b** recurrence-free survival curves amongst patients who underwent laparoscopic right colectomy for neoplasm: intracorporeal (IA) versus extracorporeal anastomosis (EA)

We saw a steady improvement in operative time by our four surgeons from an average of 240 min in 2005 to an average of 170 min by 2014. Median operative time was almost identical between the two groups in our analysis. These findings are in line with a prior retrospective analysis by our group of a smaller sample [15]. The literature is hard to council on this endpoint. Chaves et al. [16] analysed 25 patients and found a shorter operative duration with EA, which did not reach statistical significance. There have been multiple recent analyses that have failed to show any difference in operative time between the two techniques [17–19]. On the other hand, Fabozzi et al. [20] analysed 50 IAs and saw a significant decrease in operative time. While our analysis could not confirm the equivalence of IA and EA in terms of operative time, we did see a steady trend of improvement as our surgeons ascended the learning curve of IA. This signifies that in the hands of surgeons well versed in IA creation, operative times should be comparable to EA.

We did not find any significant differences in length of stay between the two groups. We found a faster return of bowel function by 1 day amongst the IA cohort. This difference, however, was not found to be statistically significant. Furthermore, the length of stay in both IA and EA cohorts was found to be equivalent despite IA patients having a quicker resumption to regular diet by 1 day, meaning that the faster return to regular diet seen in the IA cohort may not be clinically relevant. Roscio et al. [19] studied 30 patients with IA and found a significantly faster return of bowel function that coincided with a significantly shorter length of stay ($P < 0.05$). On the other hand, larger studies [18, 20] have failed to replicate these findings and

found no significant difference in length of stay between the two anastomotic techniques. The theoretical advantages of IA include less need for bowel manipulation and thus less traction on the mesentery leading to fewer bowel obstructions. Our findings and prior studies have not been able to validate these theories yet.

Of potential importance, our analysis revealed a lower risk of anastomotic leak with IA that failed to reach statistical significance (AOR 0.29, 95 % CI 0.03–2.79, $P > 0.05$). Potential explanations for this are technical factors as well as a possible patient selection bias where more tenuous or technically challenging anastomoses were done using the EA technique. Fabozzi's [20] retrospective analysis of 50 patients was the only recent analysis to find a significant decrease in the risk of anastomotic leak ($P < 0.05$). This, however, was not replicated by any other retrospective analysis, all of which found no significant difference in the incidence of anastomotic leak between the two techniques [15, 18, 20]. Furthermore, a 2014 systematic review and meta-analysis of 484 patients undergoing laparoscopic right colectomy with 272 IA cases and 212 EA cases failed to show any difference in the rate of anastomotic leak (OR 0.98, 95 % CI 0.30–3.15) [21]. These findings suggest that the potential benefit or harm of the IA technique in terms of anastomotic leak rate remains unclear; larger, randomized studies are needed to further investigate this endpoint.

All right colectomies were completed laparoscopically in the IA cohort with no conversion to EA or open technique in our experience. This was in contrast to the EA cohort in which ten cases were converted to an open resection resulting in a conversion rate of 9 %. It should be noted, however, that despite this higher rate of conversion to open resection in the EA group, that this difference in conversion rate was not found to be statistically significant ($P > 0.05$). We did see a trend towards a higher BMI (median BMI 28.15 vs. 25.0 kg/m^2, $P = 0.15$) in the converted group. This was in line with our anecdotal experience as the majority of these conversions occurred in patients who were morbidly obese. The issue of conversion is especially crucial in the obese patient population where frequently the transverse colon or terminal ileum cannot be easily exteriorized due to a short and heavy mesentery and a thick abdominal wall. Furthermore, undue traction on the mesentery may lead to vascular complications including mesenteric and portal vein thrombosis [22] or bleeding. These technical limitations in the right colon resection of obese patients increase the likelihood of converting an EA technique to a fully open resection. Thus, a totally laparoscopic IA technique may be desirable in obese patients as it may help avoid larger incisions and higher complication rates compared to that of a laparoscopic-assisted EA technique [23]. Additionally, the benefits of smaller incisions achieved by an IA technique decreasing the risk of postoperative pain and incisional hernias have been well established [24, 25]. Our preliminary findings suggest that IA has potential theoretical advantages in terms of avoiding conversion to an open resection, particularly beneficial in the obese population.

Another potential advantage of the IA technique is it increases the surgeon's flexibility in determining the location of the specimen extraction site. This benefit is reinforced by the evidence that midline extraction sites typically employed in an EA are more likely in the long term to result in an incisional hernia compared to Pfannenstiel and off-midline extraction incisions [26, 27]. Multiple studies have shown that using IA with a Pfannenstiel incision for extraction site resulted in a significantly shorter incision length when compared to EA specimen extraction incision [17–20]. The advantage of the IA technique extends to the freedom to use any abdominal location for extraction site, while amongst EA resections the incision is often confined by the planned location of the anastomosis. We also performed trans-vaginal specimen extraction in a small sample within our IA cohort, leaving the patients with a minimal number of small incisions and scars that maximized cosmetic outcomes. Again, a larger analysis with a longer follow-up period may be able to discern whether these potential advantages of IA are clinically relevant.

Our analysis showed no significant differences in the median number of lymph nodes harvested (18 LNs in IA group vs. 19 LNs in EA group, $P > 0.05$), as the majority of specimens had at least 12 lymph nodes in the final surgical specimen. There was also no difference in overall survival and disease-free survival at 5.7 years between the two groups. Other studies have actually shown a significantly higher number of lymph nodes harvested and wider negative resection margins when IA was used [16–20]. This can be explained by the fact that all the aforementioned technical limitations of an EA technique including shortened mesentery, difficulty in exposure of the base of the mesentery and the need to keep the incision small may compromise a proper high mesenteric ligation, thereby limiting the extent of resection [24, 28].

Comparing the incidence of postoperative complications between the IA and EA techniques, our analysis found a significantly higher incidence of overall complications amongst the IA cohort (53 vs. 38 %, respectively, $P < 0.05$). This was due to a significantly higher incidence of Grade II complications including a higher incidence of superficial wound infections and a higher incidence of ileus/bowel obstruction after IA (33 vs. 14 %, respectively, $P < 0.05$). The majority of these complications were encountered in the first half of our IA experience, and we saw a steady decrease in the frequency of these

complications as our surgeons became more comfortable with the IA technique. These findings suggest that the initial learning curve of IA may contribute to an increase in Grade II complications in the short term as surgeons ascend the technical learning curve. Despite these findings, there was no significant difference in the incidence of serious complications (Grade III, IV and V) between the two treatment modalities. This does suggest that despite an initial increase in mild complications, the IA technique is similar in safety to EA with no significant increase in serious morbidity or mortality. On the other hand, these findings raise the concern that while the IA technique may have theoretical advantages over EA in terms of conversion rate that this is counterbalanced by a significant risk of Grade I and II complications, especially early on in the learning curve. These findings implore us to recommend that surgeons clamouring to learn and adapt the IA technique into their practice, do so under expert supervision and mentoring to try and minimize these complications as they ascend the learning curve of IA.

The main drawback of our analysis is that it is retrospective and observational. Despite being one of the largest reported series to date, it still comprises a relatively small number of patients. As a result, our study was underpowered to truly discern statistically significant differences in various clinical endpoints that we analysed. Our study is also prone to inherent patient and surgeon selection bias where our analysis may be skewed by the tendency of surgeons to choose the totally laparoscopic approach in simpler cases, thus positively influencing the outcomes in the IA cohort. Finally, differences in certain endpoints such as return to regular diet, incidence of ileus and length of stay might have been influenced by variations in surgeon and institutional postoperative recovery practices.

Conclusions

Our large experience reveals that intracorporeal anastomosis in laparoscopic right hemicolectomy is associated with similar postoperative and non-inferior oncologic outcomes compared to extracorporeal anastomosis. Probable benefits of IA technique include freedom of specimen extraction sites, smaller incisions and lower risk of conversion to open resection especially in morbidly obese patients. These potential advantages are counterbalanced by an increase in non-serious complications, at least initially, as surgeons ascend the technical curve of IA. These findings suggest that IA represents a valid technical approach in the arsenal of the experienced colorectal surgeon without compromising outcomes. Large prospective trials are needed to validate these findings.

Acknowledgments Dr. Hanna and Dr. Pigazzi had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Author contributions All authors made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting the article and revising it critically for important intellectual content and final approval of the version to be published.

Compliance with ethical standards

Disclosures Dr. Stamos has had Ethicon, Olympus and Covidien training grant support paid to the University of California, Irvine, for clinical immersion courses for lap colectomy. He has also been a consultant and speaker for Ethicon, Olympus, Gore, NiTi/NovoGI and Novadaq. Pigazzi has been a consultant for Intuitive Surgical, Cook, Ethicon, Covidien, Cubist. Mills and Carmichael have had Ethicon educational grant paid to the Department of Surgery, University of California, Irvine. Mark H. Hanna, Grace S. Hwang, Michael J. Phelan and Thanh-Lan Bui have no conflicts of interest or financial ties to disclose.

References

1. Braga M, Frasson M, Zuliani W, Vignali A, Pecorelli N, Di Carlo V (2010) Randomized clinical trial of laparoscopic versus open left colonic resection. Br J Surg 97:1180–1186
2. Buunen M, Veldkamp R, Hop WC, Kuhry E, Jeekel J, Haglind E, Pahlman L, Cuesta MA, Msika S, Morino M, Lacy A, Bonjer HJ (2009) Survival after laparoscopic surgery versus open surgery for colon cancer: long-term outcome of a randomized clinical trial. Lancet Oncol 10:44–52
3. Fleshman J, Sargent DJ, Green E, Anvari M, Stryker SJ, Beart RW Jr, Hellinger M, Flanagan R Jr, Peters W, Nelson H, The Clinical Outcomes of Surgical Therapy Study Group (2007) Laparoscopic colectomy for cancer is not inferior to open surgery based on 5-year data from the COST Study Group trial. Ann Surg 246:655–664
4. Kang CY, Halabi WJ, Luo R, Pigazzi A, Nguyen NT, Stamos MJ (2012) Laparoscopic colorectal surgery: a better look into the latest trends. Arch Surg 147(8):724–731. doi:10.1001/archsurg.2012.358
5. Liang JT, Huang KC, Lai HS, Lee PH, Jeng YM (2007) Oncologic results of laparoscopic versus conventional open surgery for stage II or III left-sided colon cancers: a randomized controlled trial. Ann Surg Oncol 14:109–117
6. Pascual M, Alonso S, Parés D, Courtier R, Gil MJ, Grande L, Pera M (2011) Randomized clinical trial comparing inflammatory and angiogenic response after open versus laparoscopic curative resection for colonic cancer. Br J Surg 98:50–59
7. Jamali FR, Soweid AM, Dimassi H, Bailey C, Leroy J, Marescaux J (2008) Evaluating the degree of difficulty of laparoscopic colorectal surgery. Arch Surg 143:762–767
8. Abdel-Halim MR, Moore HM, Cohen P, Dawson P, Buchanan GN (2010) Impact of laparoscopic right hemicolectomy for colon cancer. Ann R Coll Surg Engl 92:211–217
9. Senagore AJ, Delaney CP, Brady KM, Fazio VW (2004) Standardized approach to laparoscopic right colectomy: outcomes in 70 consecutive cases. J Am Coll Surg 199:675–679
10. Franklin ME Jr, Gonzalez JJ Jr, Miter DB et al (2004) Laparoscopic right hemicolectomy for cancer: 11-year experience. Rev Gastroenterol Mex 69(Suppl 1):65–72
11. Tekkis PP, Senagore AJ, Delaney CP, Fazio VW (2005) Evaluation of the learning curve in laparoscopic colorectal surgery:

comparison of right-sided and left-sided resections. Ann Surg 242:83–91
12. Bergamaschi R, Schochet E, Haughn C, Burke M, Reed JF 3rd, Arnaud JP (2008) Standardized laparoscopic intracorporeal right colectomy for cancer: short-term outcome in 111 unselected patients. Dis Colon Rectum 51:1350–1355
13. Grams J, Tong W, Greenstein AJ, Salky B (2010) Comparison of intracorporeal versus extracorporeal anastomosis in laparoscopic assisted hemicolectomy. Surg Endosc 24:1886–1891
14. Sharabiani Mansour, Aylin Paul, Bottle Alex (2012) Systematic review of comorbidity indices for administrative data. Med Care 50(12):1109–1118. doi:10.1097/MLR.0b013e31825f64d0
15. Lee KH, Ho J, Akmal Y, Nelson R, Pigazzi A (2013) Short- and long-term outcomes of intracorporeal versus extracorporeal ileocolic anastomosis in laparoscopic right hemicolectomy for colon cancer. Surg Endosc 27(6):1986–1990. doi:10.1007/s00464-012-2698-1
16. Chaves JA, Idoate CP, Fons JB et al (2011) A case-control study of extracorporeal versus intracorporeal anastomosis in patients subjected to right laparoscopic hemicolectomy. Cir Esp 89:24–30
17. Scatizzi M, Kroning KC, Borrelli A, Andan G, Lenzi E, Feroci F (2010) Extracorporeal versus intracorporeal anastomosis after laparoscopic right colectomy for cancer: a case-control study. World J Surg 34:2902–2908
18. Hellan M, Anderson C, Pigazzi A (2009) Extracorporeal versus intracorporeal anastomosis for laparoscopic right hemicolectomy. JSLS 13:312–317
19. Roscio F, Bertoglio C, De Luca A, Frattini P, Scandroglio I (2012) Totally laparoscopic versus laparoscopic assisted right colectomy for cancer. Int J Surg 10:290–295
20. Fabozzi M, Allieta R, Contul RB et al (2010) Comparison of short- and medium-term results between laparoscopically assisted and totally laparoscopic right hemicolectomy: a case-control study. Surg Endosc 24:2085–2091
21. Carnuccio P, Jimeno J, Pares D (2014) Laparoscopic right colectomy: a systematic review and meta-analysis of observational studies comparing two types of anastomosis. Tech Coloproctol 18(1):5–12. doi:10.1007/s10151-013-1029-4
22. Baixauli J, Delaney CP, Senagore AJ, Remzi FH, Fazio VW (2003) Portal vein thrombosis after laparoscopic sigmoid colectomy for diverticulitis: report of a case. Dis Colon Rectum 46:550–553
23. Pikarsky AJ, Saida Y, Yamaguchi T et al (2002) Is obesity a high-risk factor for laparoscopic colorectal surgery? Surg Endosc 16:855–858
24. Senagore AJ, Delaney CP (2006) A critical analysis of laparoscopic colectomy at a single institution: lessons learned after 1000 cases. Am J Surg 191:377–380
25. Schwenk W, Haase O, Neudecker J, Muller JM (2005) Short term benefits for laparoscopic colorectal resection. Cochrane Database Syst Rev. doi:10.1002/14651858.CD003145.pub2
26. Singh R, Omiccioli A, Hegge S, McKinley C (2008) Does the extraction-site location in laparoscopic colorectal surgery have an impact on incisional hernia rate? Surg Endosc 22:2596–2600
27. Tisdale BE, Kapoor A, Hussain A, Piercey K, Whelan JP (2007) Intact specimen extraction in laparoscopic nephrectomy procedures: Pfannenstiel versus expanded port site incisions. Adult Urol 69:241–244
28. Kaltoft B, Gogenur I, Rosenberg J (2011) Reduced length of stay and convalescence in laparoscopic vs. open sigmoid resection with traditional care: a double blinded randomized clinical trial. Colorectal Dis 13:e123–e130