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REVIEW

Robotic versus laparoscopic right colectomy: an updated systematic review and meta-analysis

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Abstract

Background In the right colon surgery, there is a growing literature comparing the safety of robotic right colectomy (RRC) to that of laparoscopic right colectomy (LRC). With this paper we aim to systematically revise and meta-analyze the latest comparative studies on these two minimally invasive procedures.

Methods A systematic review of studies published from 2000 to 2017 in the PubMed, Scopus, and Embase databases was performed. Primary endpoints were postoperative morbidity and mortality. Secondary endpoints were blood loss, conversion to open surgery, harvested lymph node anastomotic leak, postoperative hemorrhage, abdominal abscess, postoperative ileus, time to first flatus, non-surgical complications, wound infections, hospital stay, and incisional hernia and costs. A subgroup analysis was performed on those series presenting only extracorporeal anastomosis in both arms.

Results After screening 355 articles, 11 articles with a total of 8257 patients were eligible for inclusion. Operative time was found to be significantly shorter for the laparoscopic procedures in the pooled analysis (SMD −0.99 95% CI −1.4 to −0.6, $p<0.001$). Conversion to open surgery was more common during laparoscopic procedures than during the robotic ones (RR 1.7; 95% CI 1.1–2.6, $p=0.02$). No significant differences in mortality (RR 0.47; 95% CI 0.18–1.23, $p=0.124$) and postoperative complications (RR 1.05; 95% CI 0.9–1.2, $p=0.5$) were found between LRC versus RRC. The pooled mean time to first flatus was higher in the laparoscopic group (SMD 0.85 days; 95% CI 0.16–1.54, $p=0.016$). Hospital costs were significantly higher in RRCs (SMD −0.52; 95% CI −0.52 to −0.04, $p=0.035$).

Conclusions RRC can be regarded as a feasible and safe technique. Its superiority in terms of postoperative recovery must be confirmed by further large prospective series comparing RRC and LRC performed with the same anastomotic technique. RRC seemed to be associated with higher costs than LRC.

Keywords Robotic · Laparoscopy · Minimally invasive colectomy · Right hemicolectomy · Meta-analysis

Minimally invasive approach in colorectal disease is recognized as safe and feasible [1, 2]. In particular, robotic colorectal surgery appears to have technical advantages over the conventional laparoscopic approach due to higher degrees of rotation, articulation, and tri-dimensional imaging [1]. In the right colon surgery, there is a growing literature comparing the safety of robotic right colectomy (RRC) to that of laparoscopic right colectomy (LRC) [3–7]. In trying to meta-analyze these experiences, five studies were published between 2014 and early 2016 [8–12]. Nevertheless, only a few papers [3–5, 7, 13, 14] could be included and, thus, these meta-analyses were conducted on a limited number of patients, returning conflicting results. After that, several experiences, including larger series comparing RRC versus LRC, have been published [15–20], adding further data and allowing for a more comprehensive analysis.

In the light of these new experiences an updated systematic review of the literature was here performed in order to re-apprise evidences on the use of the robotic system versus standard laparoscopy to perform right colectomy.

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Methods

Literature search strategy

This study was conducted and reported according to the 2010 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [21]. A systematic literature search was performed in PubMed, Embase, and Scopus databases for pertinent studies published between January 1st 2000 and May 11th 2017. Search terms used were right AND robot* AND (laparosc* OR "minimally invasive") AND [(colo* AND resection) OR (colectomy OR hemicolectomy)]. "Related articles" function and manual reference screening were also used.

Results from the databases were compared to obtain a single list of articles for screening. Titles, abstracts and, subsequently, full-text articles, were screened and selected independently by two authors. (LS and AC). Disagreement on eligibility was addressed by discussion and followed by consensus. Additional articles were searched in the International Clinical Trials Registry Platform (ICTRP), which includes clinicaltrials.gov, without retrieving any additional available study. Grey literature search was not considered in the present study.

Eligibility criteria

Only full-text studies in English language which specifically compared RRC versus LRC were included. Comparative studies with less than 15 patients per arm and on pediatric patients were excluded. Abstract, editorials, and reviews were also excluded from the analysis at this point of study selection.

Primary endpoints were postoperative morbidity and mortality. Secondary endpoints were blood loss, conversion to open surgery, harvested lymph node anastomotic leak, postoperative hemorrhage, abdominal abscess, postoperative ileus, time to first flatus, non-surgical complications, wound infections, hospital stay, and incisional hernia and costs.

For overlapping series, only the most recent paper was included.

Assessment of methodological quality and data extraction

Methodological quality was assessed independently by two authors (LS and AC). Jadad scoring [22] was used to evaluate the quality of randomized controlled trials while the methodological index for non-randomized studies (MINORS) [23] scale was used for cohort studies.

Data extracted included study characteristics (country of origin, study period, study design), patients' characteristics [age, sex, and body mass index (BMI), indication for surgery, American Society of Anesthesiologists (ASA) score], intraoperative (type of anastomosis, operative time, blood loss, conversion to open surgery, and harvested lymph nodes) and postoperative variables (in-hospital mortality, overall morbidity, anastomotic leak, postoperative hemorrhage, abdominal abscess, postoperative ileus, time to first flatus, non-surgical complications, wound infections, hospital stay, and incisional hernia), and costs (surgery only and total costs).

Subgroup analysis

As the majority of the comparative studies differed for the technique adopted for the ileocolic anastomosis, a subgroup analysis was performed on those series presenting only extracorporeal anastomosis in both arms.

Statistical analysis

For categorical variables, the weighted pooled rates with 95% confidence intervals (95% CI) were obtained by the Freeman–Tukey transformation [24] and comparisons were reported as relative risk (RR). Continuous variables were pooled in weighted means and 95% CI exploiting the inverse variance method. Comparisons were reported as standardized mean difference (SMD). When continuous variables were shown as median and interquartile range (or median and range), they were transformed in mean and standard deviation (SD) as suggested by Hozo et al. [25]. Funnel plots were also constructed to look for potential publication bias. Heterogeneity between included studies was explored by inconsistency (I^2) statistics [26]. I^2 values of $<25\%$ were interpreted as low heterogeneity, between 25 and 50% as medium, between 50 and 75% as substantial, and above 75% as considerable. Statistical analysis was performed using MedCalc Statistical Software version 15.8 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2015).

Results

Literature search results

Database search and manual screening of reference lists yielded a total of 175 potentially relevant articles (Fig. 1). Of these, 11 studies published between 2007 and 2017 were considered eligible for data extraction and were therefore included in the meta-analysis [3–7, 15–20]. A total of 8257 individual patients who underwent RRC ($n=869$) or LRC ($n=7388$) from 2007 to 2017 were identified. The quality assessments for each study are summarized in Table 1.

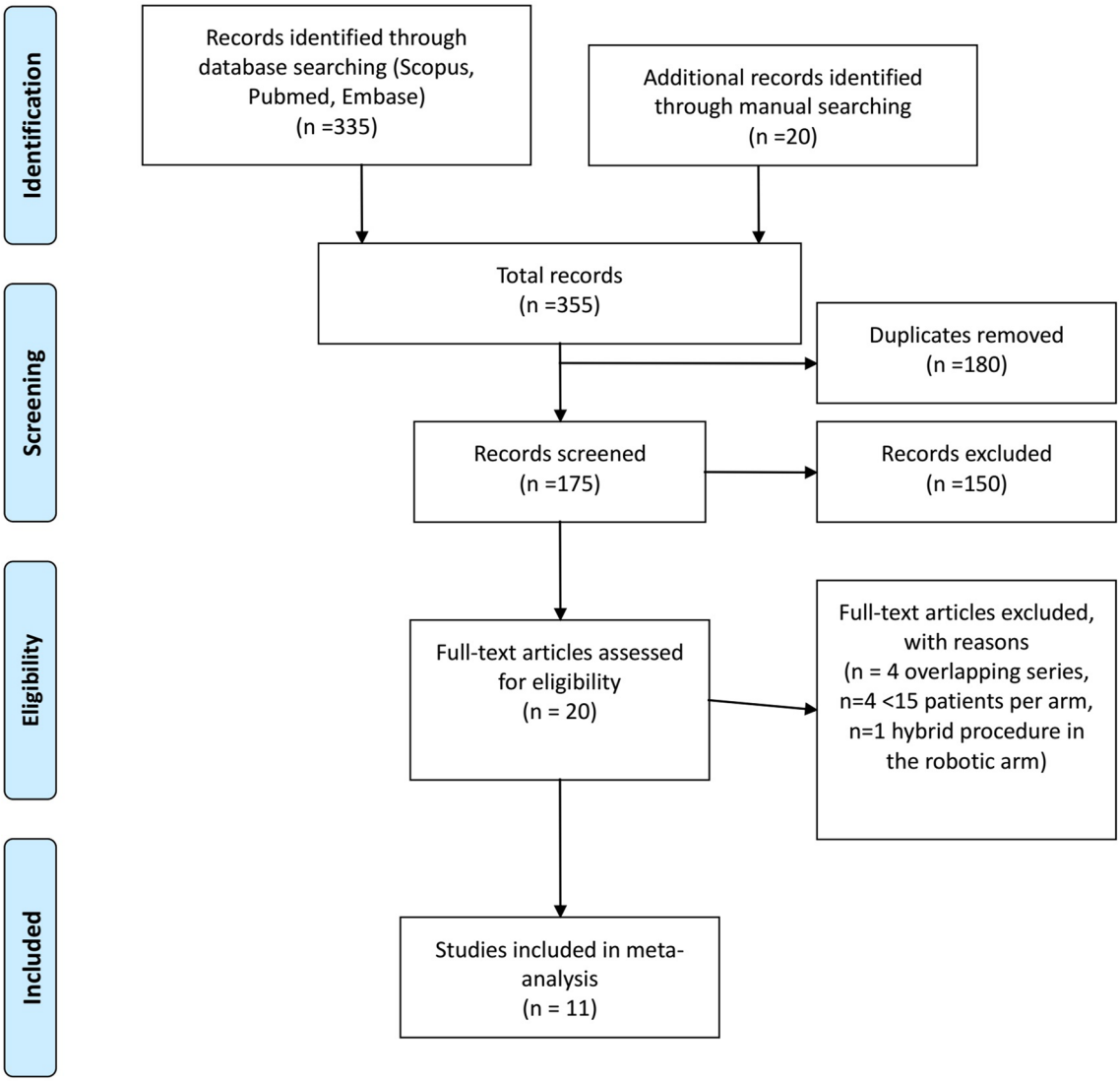

Fig. 1 Flow-chart of included articles

Funnel plots did not show evidence of significant bias among studies.

Study and patient characteristics

Details of included study are reported in Table 1. Only one RCT [6] was included. Trastulli et al. [20] reported a comparison between intracorporeal anastomosis during RRC and LRC and extracorporeal anastomosis in LRC only; for this paper we considered as a control group only those 40 patients who had LRC with intracorporeal anastomosis.

Patients' characteristics are reported in Table 2. Preoperative variables did not significantly differ between the two groups. Overall, pooled intracorporeal anastomosis rate, which was not reported by the studies with the largest sample size [15, 17], was higher in the robotic group (RRC 39.7% vs LRC 7.1%, $p=0.105$).

Perioperative outcomes

Perioperative outcomes are reported in Tables 3 and 4. Operative time, which could be extracted from all included papers, was found to be significantly shorter for the laparoscopic procedures in the pooled analysis (SMD −0.99 95% CI −1.4 to −0.6, $p<0.001$). Conversion to open surgery was more common during laparoscopic procedures than during the robotic ones (RR 1.7; 95% CI 1.1–2.6, $p=0.02$). In the robotic group, 27 conversions were to open surgery and 2 [5] to laparoscopic single-incision right hemicolectomy. There was a tendency towards statistical significance for a higher

Table 1 Studies' details and quality assessment

First author	Study type	Institution city, country	Study period	Study design	LRC (*n*)	RRC (*n*)	Quality assessment
Rawlings [7]	Single	Peoria, IL, USA	2002–2005	Prospective	15	17	14/24
deSouza [4]	Single	Chicago, IL, USA	2005–2009	Retrospective	135	40	18/24
Park [6]	Single	Daegu, South Korea	–	RCT	35	35	3/5
Deutsch [5]	Single	Manhasset, NY, USA	2004–2009	Retrospective	47	18	15/24
Casillas [3]	Single	Ann Arbor, MI, USA	2005–2012	Prospective	110	52	14/24
Kang [18]	Single	Seoul, South Korea	2007–2011	Retrospective	43	20	18/24
Trastulli [20]	Multicenter	Grosseto–Terni, Italy	2005–2014	Retrospective	40[a]	102	19/24
Davis [15]	Multicenter	Cincinnati, OH, USA	2009–2011	Retrospective	207	207	15/24
Dolejs [17]	Multicenter	ACS-NSIQ	2012–2014	Retrospective	6521	259	15/24
Lujan [19]	Single	USA	2009–2015	Retrospective	185	89	18/24
De Angelis [16]	Single	Paris, France	2012–2015	Retrospective	50	30	17/24

LRC laparoscopic right colectomy, *RRC* Robotic right colectomy, *RCT* randomized controlled trial

[a]Only patients undergone LRC with intracorporeal anastomosis considered

Table 2 Meta-analysis of patients' characteristics in the retrieved studies

Variable	No. of pts.	LRC	RRC	*p*	I^2 (95% CI)	References
Age (years)	1063	68.9 (66.8–71)	67.9 (65.6–70.3)	0.524	55.3 (23.5–81.9)	[3–7, 16, 18–20]
Asa > 2	7537	41.5 (27.4–56.4)	29.7 (16.7–44.5)	0.440	98.2 (83.0–97.1)	[3–6, 16–18, 20]
BMI (Kg/m^2)	1063	25.9 (24.7–27.1)	26 (24.9–27.1)	0.205	26.6 (0.0–65.7)	[3–7, 16, 18–20]
Female	7843	47.1 (42.7–51.5)	44.6 (34.5–55.1)	0.496	76.9 (57.4–87.4)	[3–7, 16–20]
Neoplasm	7843	86.2 (68.9–97.5)	91.9 (75.7–99.6)	0.126	69.2 (27.5–86.9)	[3–7, 16–20]
Intracorporeal anastomosis	1063	7.1 (0.02–25)	39.7 (3.8–84.6)	0.105	92.2 (80.5–96.9)	[3–7, 16, 18–20]

Continuous variables are reported in mean and categorical as percentages, both with respective 95% confidence intervals

LRC laparoscopic right colectomy, *RRC* robotic right colectomy

Table 3 Meta-analysis of intraoperative outcomes

Variable	No. of pts.	LRC	RRC	*p*	Relative risk/SMD (95% CI)	I^2 (95% CI)	References
Lymph nodes harvested	705	23.4 (15.5–31.2)	24.3 (18.6–29.9)	0.057	−0.16 (−0.3 to 0.004)	0 (0–75.7)	[3, 6, 18–20]
Operative time (min)	8257	159 (136–183)	206 (180–231)	**< 0.001**	−0.99 (−1.4 to −0.6)	94.7 (92.2–96.4)	[3–7, 15–20]
Blood loss (ml)	888	80 (36–123)	69 (38–99)	0.222	0.19 (−0.12 to 0.51)	77.2 (54.7–88.5)	[3, 5–7, 16, 18–20]
Conversion	7843	5.3 (2.5–9.2)	4.1 (2.4–6.2)	**0.020**	1.7 (1.1 to 2.6)	5.3 (0–66.9)	[3–7, 16–20]

Bold values indicate statistically significant difference ($p < 0.05$)

LRC laparoscopic right colectomy, *RRC* robotic right colectomy, *SMD* standardized mean difference

number of lymph node retrieval during RRC than LRC (23.4 versus 24.3), $p = 0.057$.

As shown in Table 4, there were no significant differences in mortality (RR 0.47; 95% CI 0.18–1.23, $p = 0.124$) and postoperative complications (RR 1.05; 95% CI 0.9–1.2, $p = 0.5$) between the two procedures. The pooled mean time to first flatus was higher in the laparoscopic group (SMD 0.85 days; 95% CI 0.16–1.54, $p = 0.016$). Other complications such as anastomotic leak, postoperative hemorrhage, ileus, wound infection, abdominal abscess, and incisional hernia did not differ between the groups.

Table 4 Meta-analysis of postoperative outcomes

Variable	No. of pts.	LRC	RRC	*p*	Relative risk/SMD (95% CI)	I^2 (95% CI)	References
Mortality	7843	0.4 (0.3–0.6)	0.88 (0.31–0.73)	0.124	0.5 (0.2 to 1.2)	0 (0–58.2)	[3–7, 16–20]
Postoperative complications	7843	23.4 (19–28.2)	21.4 (17.4–25.8)	0.5	1.05 (0.9 to 1.2)	0 (0–48.4)	[3–7, 16–20]
Time to first flatus (days)	694	3.3 (2.1–4.4)	2.3 (1.9–2.7)	**0.016**	0.8 (0.2 to 1.5)	93.4 (88.3–96.3)	[5, 6, 16, 18–20]
Incisional hernia	708	1.7 (0.4–3.8)	0.5 (0.004–1.9)	0.286	2.6 (0.4 to 14.6)	0 (0–84)	[3–5, 7, 19]
Non-surgical complications	7569	8.9 (6.3–11.8)	6.88 (3.6–11.1)	0.956	1 (0.7 to 1.3)	0 (0–33.4)	[3–5, 16–18, 20]
Postoperative hemorrhage	547	4.3 (1.21–9.3)	4.87 (2.5–7.9)	0.780	0.9 (0.3 to 2.3)	7.47 (0–81.9)	[4–7, 18, 20]
Postoperative ileus	7843	7.7 (5.1–10.6)	5.2 (2.8–8.2)	0.784	1.04 (0.8 to 1.4)	0 (0–53.9)	[3–7, 16–20]
Wound infection	7698	5.2 (3.8–6.8)	4 (2.6–5.6)	0.082	1.5 (0.9 to 2.4)	0 (0–12.4)	[3, 4, 6, 7, 17–20]
Anastomotic leak	7780	2.2 (1.2–3.7)	2.3 (1.3–3.6)	0.982	1 (0.5 to 1.9)	0 (0–5.6)	[3–7, 16, 17, 19, 20]
Abdominal abscess	564	1.4 (0.4–2.9)	1.7 (0.47–3.7)	0.742	0.8 (0.2 to 3.2)	0 (0–65.6)	[4–7, 16, 20]
Hospital stay (days)	7968	6.1 (5.2–7)	5.8 (4.6–7)	0.069	0.09 (−0.06 to 0.3)	66.5 (34.6–82.3)	[3, 5–7, 15–20]
Total costs ($)	659	10,335 (6461–14,208)	12,299 (8289–16,307)	**0.035**	−0.52 (−1 to −0.04)	83.6 (62.8–92.7)	[6, 7, 15, 16, 18]
Surgery costs ($)	182	3930 (1733–6127)	5953 (2223–9684)	0.051	−2.8 (−5.53 to 0.02)	97.6 (95.4–98.7)	[6, 7, 16]

Bold values indicate statistically significant difference ($p < 0.05$)

LRC laparoscopic right colectomy, *RRC* robotic right colectomy, *SMD* standardized mean difference

Extracorporeal anastomosis subgroup analysis

Five articles [3–5, 16, 18] were included in this subgroup analysis. No significant differences were found in any intraoperative or postoperative outcome variables. In particular, the SMD of operative time and time to first flatus between LRC versus RRC were −0.71 (95% CI −1.68 to 0.256, $p = 0.149$—I^2 95.6; 95% CI 92.3–97.5, $p < 0.0001$) and 0.51 (95% CI −308 to 1.334, $p = 0.22$—I^2 86.5%; 95% CI 61.32–95.3, $p = 0.0006$), respectively. Also the pooled conversion rate did not differ between the groups (RR 0.9; 95% CI 0.34–2.39, $p = 0.831$—I^2 7.3; 95% CI 0–81.8. $p = 0.365$).

Costs

Data about total hospital costs could be extracted from five studies [6, 7, 15, 16, 18] and are reported in Table 4. The SMD of the costs between LRC versus RRC was −0.52 (95% CI −0.52 to −0.04, $p = 0.035$). The pooled mean surgery-only related costs, calculated on data from three studies [6, 7, 16], was higher in the robotic group (5953 $; 95% CI 2223–9684) than in the laparoscopic one (3930 $; 95% CI 1733–6127; $p = 0.051$).

Discussion

Robotic right colectomy could be regarded as a feasible and safe procedure, having postoperative morbidity and mortality rates comparable with the laparoscopic counterpart. In addition, specific surgical complications such as anastomotic leak, postoperative hemorrhage, postoperative ileus, wound infections, and abdominal abscess were similar between the two procedures. Results from our analysis on more than eight thousand patients confirmed some of what has already been suggested by largest series to date [8–11], and highlighted other differences not previously found.

With regards to intraoperative blood loss a few conflicting data have been reported so far: three [8, 10, 11] out of five metanalyses showed that blood loss was significantly higher in the laparoscopic group. Again, this should be interpreted in light of the limited number of studies available for those analyses which could have affected the pooled outcome. Present results, based on a more representative sample size, showed that blood loss was comparable between the two procedures in the overall and subgroup analyses. Furthermore, it must be noted that the pooled blood losses were extremely low in both groups (RRC 77 ml versus LRC 80 ml), indicating the comparable, well-established safety of both procedures.

Operative time was demonstrated to be significantly longer in RRCs. Differently from previous studies, the present analysis showed that this could have been partly due to the type of anastomosis performed. In fact, in the subgroup analysis comparing only the extracorporeal anastomoses we found no significant differences between RRC and LRC. Unfortunately we did not have enough data to perform a subgroup analysis on intraoperative anastomosis as only two papers reported this technique in the laparoscopic group [6, 20]. Only Trastulli et al. [20] reported a retrospective comparison between RRC versus LRC both performed with the intracorporeal anastomosis. The authors found that RRC had a significantly longer operative time than LRC. However, confounding factors such as docking time and learning curve could have played a role in increasing the operative time in the robotic procedures. As expected, most of the surgeons preferred to perform the intracorporeal anastomosis with the robotic system as this dramatically decreases the difficulties of intracorporeal suturing. Unfortunately, this resulted in comparative retrospective studies which were difficult to compare and further studies on RRC versus LRC with intracorporeal anastomosis are needed to understand the real value of each approach in right colonic.

Our analysis showed a tendency to a higher number of harvested lymph nodes during RRC, and this, together with a significantly reduced rate of conversions may indicate the advantage of using the robotic approach in performing the tissue dissection. However, it must be highlighted that these latter differences, even if significant, were minimal and they should be verified in future high quality randomized clinical trials.

Overall, time to first flatus was shorter in the robotic group. It must be considered that one of the included paper reported a large cohort from an ACS-NSQIP database [17]; this may have been associated with a great heterogeneity in approach, technique, and recovery pathways which may have affected the postoperative course. Still, differences in time to first flatus were not significant when extracorporeal anastomosis was performed in both the arms. This confirmed the superiority of intracorporeal anastomosis in improving the recovery of the bowel function. Costs, which were significantly higher for robotic procedures, may be the only obstacle for a routine use of the robotic system. We expect that a faster bowel recovery and thus, a shorter hospital stay may decrease general costs for the robotic procedures. Nevertheless, we found no differences in hospital stay and persistent significantly higher costs in the robotic group. Again, this should be seen in light of the fact that among all the papers reporting data on costs [6, 7, 15, 16, 18] only Park et al. [6] performed intracorporeal anastomosis in the robotic group and thus, there could be a benefit in terms of costs only for a negligible number of patients.

This meta-analysis presents a few limitations. First, it included only one randomized controlled trial as the remaining were only retrospective comparative series. Second, most of the papers (also the RCT) presented an intergroup difference in terms of the technique used to perform the anastomosis which could have significantly biased the comparison between the groups. Third, operative and postoperative outcomes of few of the included studies, might be affected by learning curve and results of this meta-analysis should be interpreted also in light of this variable. Finally, the data on surgery-related costs were still based on a limited number of procedures from different health systems and results from this study still need to be confirmed by further cost–benefit analysis. In conclusion, RRC can be regarded as a feasible and safe technique. Its superiority in terms of postoperative recovery should be confirmed by further large prospective series comparing RRC and LRC performed with the same anastomotic technique. In terms of costs, RRC seemed to be a more expensive procedure than LRC.

Compliance with ethical standards

Disclosures Drs. Leonardo Solaini, Francesca Bazzocchi, Davide Cavaliere, Andrea Avanzolini, Alessandro Cucchetti, and Giorgio Ercolani have no conflicts of interest or financial ties to disclose.

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