Is robotic right colectomy economically sustainable? A multicentre retrospective comparative study and cost analysis.

Running Head: Robotic right colectomy economic sustainability

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Abstract

Background

Following the Food and Drug Administration approval, robot-assisted colorectal surgery has gained more acceptance among surgeons. One of the open issues about robotic surgery is the economic sustainability. The aim of our study is to evaluate the economic sustainability of robotic as compared to laparoscopic right colectomy for the Italian National Health System.

Methods

We performed a retrospective multicentre case-matched study including 94 patients for each group from four different Italian surgical departments. An economic evaluation gathered from a real world data was performed to assess the sustainability of the robotic approach for right colectomy in the Italian National Health System. In particular, a differential cost analysis between the two procedures was performed.

Results

No statistical differences were found between the two groups for postoperative outcomes. After a careful review of the literature on the cost assessment for the operative room, medical devices and hospital stay according with our data, we estimated the followings: (a) the mean operative room cost for robotic group was 2179 ± 476 € vs. 1376 ± 322 € for laparoscopic group; (b) the mean hospital stay cost for robotic group was 3143 ± 1435 € vs. 3292 ± 1123 € for laparoscopic group; (c) the mean cost for instruments was 6280 € for robotic group vs. 1504 € for laparoscopic group. The total mean cost of robotic right colectomy was 11,576 ± 1915 € vs. 6196 ± 1444 € for laparoscopic right colectomy.

Conclusion

In conclusion, to date, robotic right colectomy with intracorporeal anastomosis does not provide any significant clinical advantages, which may justify the additional costs, as compared to its laparoscopic counterpart. Further evolution of robotic technology and experience may lead to a reduction of costs, especially if the robotic platform is used in an appropriate healthcare setting.

Keywords: Robotic surgery, Right Colectomy, Cost Analysis, Laparoscopic surgery, Real World Data.

Introduction

In the last decades, surgical technology has gone through a great evolution, especially in the minimally invasive field. Robot-assisted surgery represents a new trend in minimally invasive surgery and surgical literature. Nowadays, the minimally invasive approach represents the gold standard for many surgical procedures, for both benign and malignant diseases [1]. Although technically demanding, minimally invasive right colectomy with intracorporeal anastomosis may be the preferred approach for right colon cancer treatment. Several advantages including reduced short-term morbidity and faster recovery have been associated to intracorporeal as compared to extracorporeal anastomosis [2, 3].

Following the Food and Drug Administration approval, robot-assisted colorectal surgery has gained more acceptance among surgeons [4, 5]. In the field of colon surgery, the robotic approach has shown no significant benefits for patients as compared to the laparoscopic approach, but some advantages have been demonstrated for surgeons, including a better view of the operative field and a better instrument for precision and easiness of movement [6, 7]. Thus, robotic assistance could enhance the ability of the surgeon to perform a totally minimally invasive right colectomy with intracorporeal anastomosis.

One of the critical issues about robotic surgery is the economic sustainability [6]. In fact, despite the advantages for the surgeon and the possibility to easily tutor more surgeons due to the dual console, further investigation is warranted when considering routine use of the robotic platform for colectomies [8].

In our multicentre study, we performed a retrospective case-matched analysis of 94 patients who underwent robot-assisted right colectomy (RRC) compared with a group of patients who underwent laparoscopic right colectomy (LRC). The main aim of our study is to evaluate the economic sustainability of RRC as compared to LRC for the Italian National Health System.

Materials and Methods

After the ethical committee approval, all consecutive patients who underwent elective LRC or RRC for cancer from January 2012 to August 2017 at four Italian surgical departments (*Department of General and Minimally Invasive Surgery, San Camillo Hospital, Trento; Department of Surgical Specialities and Nephrology, University of Naples Federico II; Department of Surgery, Division of General Surgery, Hospital of Arezzo; Department of Abdominal Surgery, Casa Sollievo della Sofferenza Research Hospital, San Giovanni Rotondo)*, were included in the study. Using prospective colorectal surgery unit databases, 275 patients were identified.

Among these, 159 patients underwent LRC and 116 had RRC. In order to reduce the risk of bias due to the patient selection in the robotic group, we performed a case-matched analysis using the Mantel-Haenszel method. The two groups were matched according to their biometric features. After matching, a total of 188 patients were analysed, namely 94 patients in each group.

Preoperative (age, sex, BMI, previous abdominal surgery, ASA score and tumour location), intraoperative (operative time, complications, conversion rate) and postoperative (pathologic stage according to Wittekind et al. [9], length of specimen, number of harvested lymph nodes, postoperative return of bowel function, hospital stay, complications according to the Clavien-Dindo classification [10], reoperation and mortality rates) data were reviewed.

Conversion was defined as the unplanned change from laparoscopy to the open procedure or from the robotic approach to either the laparoscopic or the open approach. Anastomotic leakage was considered along with all conditions with clinical or radiologic features of anastomotic dehiscence in accordance with the UK Surgical Infection Study Group [11]. We considered operative time as the time from the first skin incision until the last scar was sutured.

All procedures in both groups were carried out by four highly experienced laparoscopic colorectal surgeons [12]. All surgeons had completed the learning curve of robotic colorectal surgery before the inclusion of cases in this series [13].

Follow-up was conducted by a clinical examination at 7, 30, 180 days and then each year after surgery.

Cost Analysis

The differential cost analysis was conducted from an Italian hospital perspective, including medical costs (use of operating room, length of stay and medical devices) only, as performed in previous studies [14, 15], and from a National Health System (NHS)/Health care payer perspective.

According to the existing literature [16], the differential cost analysis is widely used for healthcare decisions. In particular, differential cost analysis was used to assess the difference between the cost of two alternative decisions (RRC vs. LRC). The concept is usually used when there are two or multiple possible options to pursue, and a choice must be made to select one option and drop the others.

The costing search was based on the economic assessment methodology adopted in Health Technology Assessment and was performed by two clinicians (UB and GM) and two biomedical engineers (RC and LP). Postoperative costs were also included in the cost analysis.

To assess the cost of the two procedures from the hospital perspective, we considered the mean operative time, mean length of stay and mean cost of medical devices in both groups. According to our previous study, we estimated that the cost of theatre per minute and the cost of length of stay per day were 10.7 € and 780 €, respectively [14]. The cost of hospital stay also included the cost of both daily drugs and health staff. We calculated the mean costs for medical devices (e.g., trocar) from the National Health Price List (NHPL) and as reported by Ho et al. [17].

To evaluate the differential costs from the NHS perspective, we estimated that the mean reimbursement for right colectomy for cancer was 6838 ± 900 €, which was calculated performing the average reimbursement of Diagnosis Related Group (DRG) codes for each Italian region. These results did not consider the fixed maintenance costs of equipment, which are extremely variable in structure and must be distributed on the total amount of procedures performed.

Statistical Analysis

The statistical analysis was carried out using IBM SPSS Statistics 25. Continuous data were expressed as mean ± standard deviation (SD). To compare continuous variables, an independent sample T-test was performed. The Chi-square test was employed to analyse categorical data. Logistic regression was performed in order to understand if some factors could influence operative time or length of stay. Regarding non-parametric variables (such as time to flatus and length of stay), we used a Mann-Whitney U test.

All the results are presented herein as 2-tailed values with statistical significance if the p-values were below 0.05.

Perioperative Management

Mechanical bowel preparation was not administered, and no diet restriction was applied before surgery. Intravenous antibiotic prophylaxis was given to all patients. Antiemetics were administrated regularly for 72 hours postoperatively. On the first postoperative day the patient could drink, if tolerated, and a normal diet was offered from day 2 onwards. Early mobilization and low molecular weight heparin were used for deep venous thrombosis prophylaxis. Pain management was achieved by a peridural catheter and administration of nonsteroidal anti-inflammatory drugs, if required. Discharge criteria included tolerance of oral intake, absence of nausea or vomiting, return of bowel function, absence of abdominal distention, no evidence of complications, adequate mobility, patient acceptance [14]. When a postoperative complication required reoperation, a minimally invasive approach was preferred [18].

Surgical Technique

LRC

The patient was placed supine in the Trendelenburg position (30°) and right flank rotation. Pneumoperitoneum was established with the Veress technique [19]. We used the same technique described in our previous study [12]. After abdominal exploration, in order to exclude the presence of metastases, the ileo-colic vessels were ligated and divided. A medial-to-lateral dissection was conducted between the Toldt's fascia and the Gerota's fascia. If present, the right colic vessels were isolated and divided. Once the transverse colon was pulled up, its mesentery was dissected from the root and the right branches of the middle colic vessels were identified and divided. Then, we mobilized the right colon by dissecting the gastro-colic and parieto-colic ligaments. Complete division of the ileal mesentery allowed for full mobilization of the right colon. The transverse colon and terminal ileum were transected intracorporeally by a blue- and white-cartridge linear stapler, respectively. A side-to-side isoperistaltic ileo-colic anastomosis was performed by a 45-mm linear stapler with a blue cartridge. The enterotomy was closed with a double layer running suture [12, 20]. The mesentery was closed by absorbable sutures or fibrin glue. The specimen was retrieved through a Pfannenstiel incision or umbilical scar enlargement [21].

RRC

For the RRC, we performed the same technique described for the laparoscopic approach. Trocars' position is reported by Spinoglio et al. [22]. In the first 35 robotic cases, a Da Vinci Si surgical system was used, while a DaVinci Xi platform was used in the subsequent cases.

Results

We performed a case-matched analysis comparing two homogeneous group of 94 patients each. Patient features are reported in Table 1.

Operative time was significantly longer for RRC than LRC (135.5 ± 33.9 min in the LRC group vs. 207.5 ± 44.9 min in the RRC group; $p < 0.05$). As reported in Table 2, no differences were recorded in terms of intraor postoperative complications and length of stay (4.2 ± 1.4 days in the LRC group vs. 4.0 ± 1.8 days in the RRC group, $p = 0.475$) between the two groups. Three cases in the RRC group required conversion to open surgery compared to none in the laparoscopic group ($p = 0.080$). They were all due to advanced colon cancer. As reported in Table 2, only 3 Clavien-Dindo III complications were recorded in each group. In particular, there were 2 anastomotic bleedings requiring endoscopic management and one anastomotic leakage in both groups.

At the 30-day follow-up, there were neither reinterventions nor deaths, and only one readmission was recorded in the LRC group due to heart failure. At a mean follow-up of 51.7 ± 12.6 months, 5 deaths were recorded, two in the RRC group and three in the LRC group. Logistic regression did not show any association between operative time or length of stay and the other variables analysed, including age, BMI, time to flatus and pathologic stage.

After a careful review of the literature on the cost assessment for operative room, medical devices and hospital stay according with our data, we estimated the followings: (a) the mean operative room cost for the RRC group was 2179 ± 476 € vs. 1376 ± 322 € for the LRC group; (b) the mean hospital stay cost for the RRC group was 3143 ± 1435 € vs. 3292 ± 1123 € for the LRC group; (c) the mean cost for instruments was 6280 € for the RRC group vs. 1504 € for the LRC group. The total mean cost of RRC was 11,576 ± 1915 € vs. 6196 ± 1444 € for LRC. Data from cost analysis are reported in Table 3.

Discussion

Over the last years, there has been a rapid increase in the use of the robotic approach to colorectal surgery, although the real benefits over laparoscopy in terms of outcomes still remain unclear [23, 24]. Thus, the adoption of robotic surgery must be examined against a backdrop of burdening an already expensive healthcare system [25].

In our evaluation, we found that postoperative short-term outcomes of RRC and LRC performed with intracorporeal anastomosis are similar. To date, a few studies included intracorporeal anastomosis when comparing RRC and LRC. A recent retrospective multicentre analysis of 389 patients did not find any difference in terms of time-to-first flatus, postoperative complications and hospital stay, although RRC was associated with a lower 90-day readmission rate. In this series, LRC group comprised only 84 of 389 cases, and data on costs of both procedures are not presented [23]. The unbalanced number between the two groups is consistent with the results of a recent meta-analysis, which found a higher rate of intracorporeal anastomosis in the robotic group [26]. Indeed, the robotic platform decreases the difficulty of intracorporeal suturing [27]. Since intracorporeal anastomosis is associated with faster recovery and lower morbidity as compared to extracorporeal anastomosis, the use of the robotic approach aiming to increase the number of intracorporeal anastomosis may be advisable [23]. Moreover, for surgeons early in their career, robotic assistance may shorten the learning curve of minimally invasive right colectomy as compared to the laparoscopic approach [24].

In agreement with published studies, operative time was significantly longer in the RRC group also in this cohort. This could be due to the docking time, which may prolong the duration of the robotic procedure [23]. The learning curve effect has also been reported to play a role in increasing operative time. As in most published series, all surgeons involved in our study were more highly experienced in laparoscopic rather than robotic colorectal surgery, and this may have partially affected length of surgical time. However, they had completed the learning curve of robotic colorectal surgery at the beginning of the study. Although not analysed in our series, operative time may decrease over time, as the number of performed procedures increases. In a series of 101 procedures, a statistically significant difference was found between the earlier and the later robotic series (329 vs. 266 min). The authors also reported a significant reduction in the conversion rate, claiming a benefit in performing both dissection and intracorporeal anastomosis by robotic assistance [22]. This was not confirmed in the present study, where a significantly higher conversion rate was observed in the RRC group than in the LRC group. A more meticulous dissection of tissues has also been suggested as a potential reason for the increased duration of the robotic procedure [23].

Pathologic outcomes were comparable between RRC and LRC. Some authors suggested that the number of harvested lymph nodes may be higher with robotic assistance [23]. Moreover, RRC appears to achieve similar long-term survival rates as compared with LRC [28].

Robot-assisted procedures are increasing since laparoscopic surgeons are incorporating robotics into their normal practice [25]. Experienced laparoscopic surgeons may be able to overcome – at least partly – the technical drawbacks of conventional laparoscopy and be equally proficient at both procedures [24]. In the future, it might be expected that a better robotic experience will show considerable clinical advantages of RRC compared to LRC.

Although the costs of RRC exceed those of LRC, data are still based on a limited number of procedures available from different health systems [26, 27]. In a meta-analysis of five studies, Solaini et al. found that the mean total cost was US $10,335 for LRC vs. US $12,299 for RRC (SMD – 0.52, 95% CI – 1 to – 0.04, p = 0.035). Moreover, based on the results of three studies, surgery-only related costs were higher in the robotic group ($5953 vs. $3930, SMD – 2.8, 95% CI − 5.53 to 0.02, p = 0.051) [26]. Indeed, the higher costs of RRC are primarily attributable to surgery, including consumables and longer operative times [28].

A retrospective analysis of the 2012-2014 Healthcare Cost and Utilization Project-National Inpatient Sample (NIS) was recently conducted in the United States. In a cohort of 7685 colectomies, RRC was 20.1% more costly than LRC ($15,027 ± 6049 vs. $12,516 ± 5281), even if the length of stay was 4.3 ± 2 in the laparoscopic group versus 3.8 ± 1.6 in the robotic group. This may suggest that, to date, the additional costs related to robotic procedures are not compensated by the savings from shorter hospital stay. However, these costs may be lower in centres with higher volume cases, where more experienced surgeons and staffs can optimize the operating room time. Studies using costs from single hospital systems may be more informative for a detailed cost analysis as compared to national database analysis. In fact, the latter provides total charges for each admission but not the actual cost, and details of costs related to supplies and instruments are not reported [29]. Similarly, a matched analysis of 1066 patients from the Premier Hospital Database found significantly higher hospital costs and longer operative times in the robotic group, while length of stay was similar for both surgical approaches [8].

A review of a hospital cost-accounting database including 111 patients who underwent elective minimally invasive colectomy (18 robotic surgeons) over a 1-year period showed that the cost of robotic colectomy was 53% greater than laparoscopic colectomy ($7806 vs. $5096, $p < 0.001$). No significant difference in overall costs between different surgeons was demonstrated despite varied training, experience levels and operative techniques. This demonstrates that total costs are relatively institutionally fixed and minimally influenced by variations in individual surgeon practice preferences [30]. There are no data about cost-analysis of RRC from the Italian healthcare system. The present evaluation from Italian centers found that RRC was nearly 70% more costly than LRC, and this increased cost was primary attributable to consumables, while the costs for hospital stay were similar. Furthermore, the initial acquisition cost, depreciation, and service contract for the robotic and laparoscopic systems should be also considered [31], and they were not included in the present analysis.

A previous cost-analysis comparing laparoscopic versus open surgery for colorectal cancer in three Italian high-volume centres, found that the national DRG tariff is insufficient to remunerate the providers' activity, irrespective of the type of disease and surgical technique adopted [32]. This issue is even more compelling given the growing interest for robotic colorectal surgery. In our series, the mean reimbursement for right colectomy was 50% of total estimated costs for RRC.

Our study includes comparison of equivalent surgical procedures in a quite large sample size population from different centres, with adequate follow-up. Although it is a retrospective study, a case-matched analysis has been performed in order to reduce the risk of bias due to the selection of patients in the robotic group.

Some limitations should be considered. There is no full accounting for the costs of postoperative complications. However, the length of the hospital stay itself may be an indirect indicator of the increased cost of complicated patients. Furthermore, the incidence of complications – especially those requiring additional procedures and/or ICU management – was low and comparable between the two groups (3 vs. 3). Therefore, we considered that they did not significantly affect the differential cost analysis between the two procedures. Enhanced recovery after surgery (ERAS) protocols have been increasingly applied to colorectal surgery over the last years. As reported by many studies, such protocols seem to reduce drastically the economic impact of colorectal surgery, although the breakdowns of the costs and statistical methods are ambiguous and inconsistent among studies and institutions [33]. A structured enhanced recovery pathway has not been used in our cohort. Thus, the costs associated with implementing an ERAS program have not been evaluated. The perioperative care included only some items of the ERAS protocol and it has not significantly changed over the study period. Therefore, it did not impact on both length of stay and costs. According to the ERAS principles, the patients in this cohort did not receive preoperative MBP, although more recent evidence suggests that combination of MBP and oral antibiotics can reduce the risk of surgical site infections [33].

In conclusion, to date, RRC with intracorporeal anastomosis does not provide tangible benefits to the patients, which may justify the additional costs as compared to its laparoscopic counterpart. However, at a time when taking care of optimal resource utilization is essential, every effort should be made to support the development of robotic surgery, in the hope of developing more clinically effective tools and skills. Indeed, further development of robotics may lead to reduction of costs and improvement of outcomes, as occurred in the past for laparoscopic surgery. Moreover, although it is beyond the evaluations of our paper, the robotic approach may be particularly effective to reduce the learning curve for young surgeons [35]. The advantages of robotic surgery can be better explored and developed in any institutions with additional resources and research mandate. Further prospective studies comparing both surgical approaches with cost analysis are needed to draw robust conclusions.

Disclosure

Giovanni Merola: no conflict of interest

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Table 1. Patient characteristics

	All patients (n=188)	**Laparoscopic group (n=94)**	**Robotic group (n=94)**	***p*-value**
Age years, mean±SD[a]	70.75±10 (range 30-88)	72.09±9.54	69.41±10.31	0.066
Sex (M/F) n	121/67	61/33	60/34	0.879
BMI[b] Kg/m^2, mean±SD	27.45±5.21 (range 16.5-42)	27.97±5.73	26.94±4.61	0.178
Previous abdominal surgery, n	32	18	14	0.438
ASA[c] **score,** n				0.474
I	18	11	7	
II	101	52	49	
III	68	31	37	
IV	1	0	1	
Cancer location, n				0.813
Caecum	56	27	29	
Ascending colon	112	58	54	
Hepatic flexure	20	9	11	
Stage[d], n				0.560
I	23	13	10	
II	108	56	52	
III	54	23	31	
IV	3	2	1	

[a]Standard deviation; [b]Body mass index; [c]American Society of Anesthesiologists; [d]according to Wittekind et al. [9]

Table 2. Intra- and postoperative data

	All patients (n=188)	**Laparoscopic group (n=94)**	**Robotic group (n=94)**	***p*-value**
Operative time min, mean±SD[a]	171.47±53.64 [range 85-330]	135.46±33.86	207.47±44.93	<0.05
Length of stay days, median±IQR[b]	4±2 [range 4-25]	4±2	4±2	0.475
Intraoperative complications n, mean±SD	0	0	0	1
Passage of flatus days, mean±SD	2.21±1.01 [range 1-7]	2.20±1.24	2.23±0.7	0.178
Harvested lymph nodes n, mean±SD	22.12±4.95 [range 12-58]	22.32±3.81	21.91±5.88	0.567
Specimen length cm, mean±SD	38.43±4.69 [range 27-64]	38.92±4.75	37.94±4.61	0.154
Postoperative complications[c], n	32	15	17	0.784
Grade I	14	7	7	
Grade II	11	4	7	
Grade III	6	3	3	
Grade IV	0	0	0	
Grade V	1	1	0	
Conversion (n)	3	0	3	0.08

[a]Standard deviation; [b]Interquartile range; [c]According to the Clavien-Dindo classification [10]

Table 3. Cost-analysis[a]

	Robotic group (n=94)	Laparoscopic group (n=94)	Difference	*p*-value
Cost of instruments	6280 €	1504 €	4776 €	
Cost of operative room	2179 ± 476 €	1376 ± 322 €	803 ± 575 €	<0.005
Cost of length of stay	3143 ± 1435 €	3292 ± 1123 €	-146 ± 315 €	0.475
Final cost	11,576 ± 1915€	6196 ± 1444 €	5380 ± 471 €	<0.005

[a]Numbers are represented as mean ± standard deviation (SD)

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