



Comparison of Robot-Assisted Surgery Versus Laparoscopic Surgery in Colorectal Surgery: A Systematic Review of Operative and Postoperative Outcomes

Gede Bayu Wedanta Netra ¹, Putu Yudis Pramana Karang ²

¹ General Practitioner, Balimed Hospital, Denpasar, Bali, Indonesia

² General Surgeon, Department of Surgery, Balimed Hospital, Denpasar, Bali, Indonesia

Corresponding Email : bayuwedanta2@gmail.com

Article History :

Received date : 2026/02/19

Revised date : 2026/03/03

Accepted date : 2026/04/16

Published date : 2026/05/24



Copyright: © 2024 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (BY NC) license (<https://creativecommons.org/licenses/by-nc/4.0/>).

E-ISSN :

ISSN 3048-1368



P-ISSN

ISSN 3048-1376



ABSTRACT

Background: Along with the increasing trend of robotic surgery adoption, various healthcare centers are beginning to consider transitioning from open or laparoscopic approaches to robot-assisted surgical techniques for the management of rectal cancer.

Methods: A literature search was conducted on the Medline (via PubMed), Google Scholar, and ResearchGate databases to find relevant articles from early 2014 to January. All randomized clinical trials (RCTs) and prospective studies comparing robotic surgery with open or laparoscopic rectal resection were included.

Results: A total of 15 RCTs and 11 prospective studies with a total of 6,922 patients were included. The review results showed that robotic surgery was associated with less blood loss, lower surgical site infection rates, shorter hospital stays, and higher rates of negative resection margins compared to open surgery. Compared

to laparoscopy, robotic surgery showed lower conversion rates, less blood loss, lower reoperation rates, and lower mortality. However, operative time and procedure costs for robotic surgery were higher compared to both approaches.

Conclusion: The robotic approach is a safe and effective option for rectal resection, with clear advantages over open surgery. For centers transitioning from laparoscopic techniques, cost considerations need to be carefully calculated.

Keywords: *rectal cancer; operative outcomes; rectal resection; costs; laparoscopic surgery; robotic surgery; systematic review*

INTRODUCTION

Colorectal cancer is the third most common cancer worldwide, and approximately 35% of these cases are rectal carcinomas. In 2020, approximately 700,000 cases of rectal cancer were recorded, with around 340,000 related deaths worldwide (1,2). This high incidence rate has led to great attention being given to the diagnosis and management of rectal cancer. To date, the primary treatment performed is surgical resection, either through sphincter-preserving proctectomy with Total Mesorectal Excision (TME) or abdominoperineal excision (3). For many years, rectal resection techniques have been performed using open and laparoscopic approaches. However, with technological advancements, robot-assisted surgery has been developed to improve the quality of minimally invasive procedures (5,7).

A number of studies have shown that rectal surgery using open and laparoscopic techniques has relatively comparable perioperative morbidity and mortality rates. Nevertheless, the laparoscopic approach tends to offer benefits such as less intraoperative bleeding, faster recovery, and shorter hospital stays compared to open surgery (8,10). On the other hand, laparoscopic techniques require specialized skills, thus demanding more intensive training for operators (11). Furthermore, this method also has technical limitations, such as limited hand movements, two-dimensional visualization, and limited instrument flexibility within the narrow pelvic cavity, which can affect resection margins (15,16,17).

These limitations were subsequently addressed with the introduction of robot-assisted surgery in 2001. This technology offers advantages such as better movement, three-dimensional visualization of the surgical field, and instruments with higher maneuverability. Additionally, robotic surgery has proven effective and efficient in managing various pelvic cancers, as it provides better control for the operator, increases procedural accuracy, and reduces physical strain during surgery (15,16,17).

Various studies have compared different rectal surgery techniques (6,18). Along with the increasing use of robotic technology, many healthcare centers are beginning to shift from open or

laparoscopic methods to robot-assisted surgery for managing rectal cancer. To determine the most optimal approach, a comprehensive understanding of the differences in surgical, pathological, oncological outcomes, and cost aspects between robotic, laparoscopic, and open methods is required. Although several systematic reviews and meta-analyses have been conducted, comprehensive studies—especially after the learning curve phase of robotic technology use—remain limited (19,21).

METHODS

This study was organized following the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (29,30). A systematic literature search was conducted on the Medline (via PubMed), Google Scholar, and ResearchGate databases to find relevant articles from early 2014 to January 2026. Additionally, the reference lists of identified studies were also searched to find additional appropriate references. The keywords used included terms related to colorectal surgery patients, robot-assisted surgery, laparoscopic surgery, and operative and postoperative outcomes. The study selection criteria for this systematic review were arranged based on the PICOS approach with certain adjustments. The included population was human patients with colorectal diseases undergoing surgical procedures. The intervention studied was robot-assisted surgery, with the comparison group being laparoscopic surgery. The types of procedures reviewed were limited to colorectal cancer surgery. Studies meeting the inclusion criteria included (1) randomized controlled trials (RCTs), cohort studies, case-control studies, or other comparative studies; (2) studies included in the analysis were those with available full text, written in English or Indonesian, and published between 2014 and 2026. The exclusion criteria included articles containing literature reviews, editorials, and case reports. Non-comparative studies were also not included. Furthermore, studies with incomplete or inadequate data for analysis, as well as studies discussing surgical procedures outside the colorectal field, were excluded from this review.

RESULTS

The systematic search yielded a total of 18,667 articles. After the deduplication process, 15,957 articles were screened based on title and abstract, and from these, 125 articles were selected

210

for in-depth review. Based on this selection process, 15 randomized clinical trials (RCTs) and 11 prospective studies met the predetermined eligibility criteria and were included in the qualitative analysis and quantitative meta-analysis. The flow of this selection process is detailed in the PRISMA flow diagram (Figure 1), while the characteristics of all included studies are presented in Table 1.

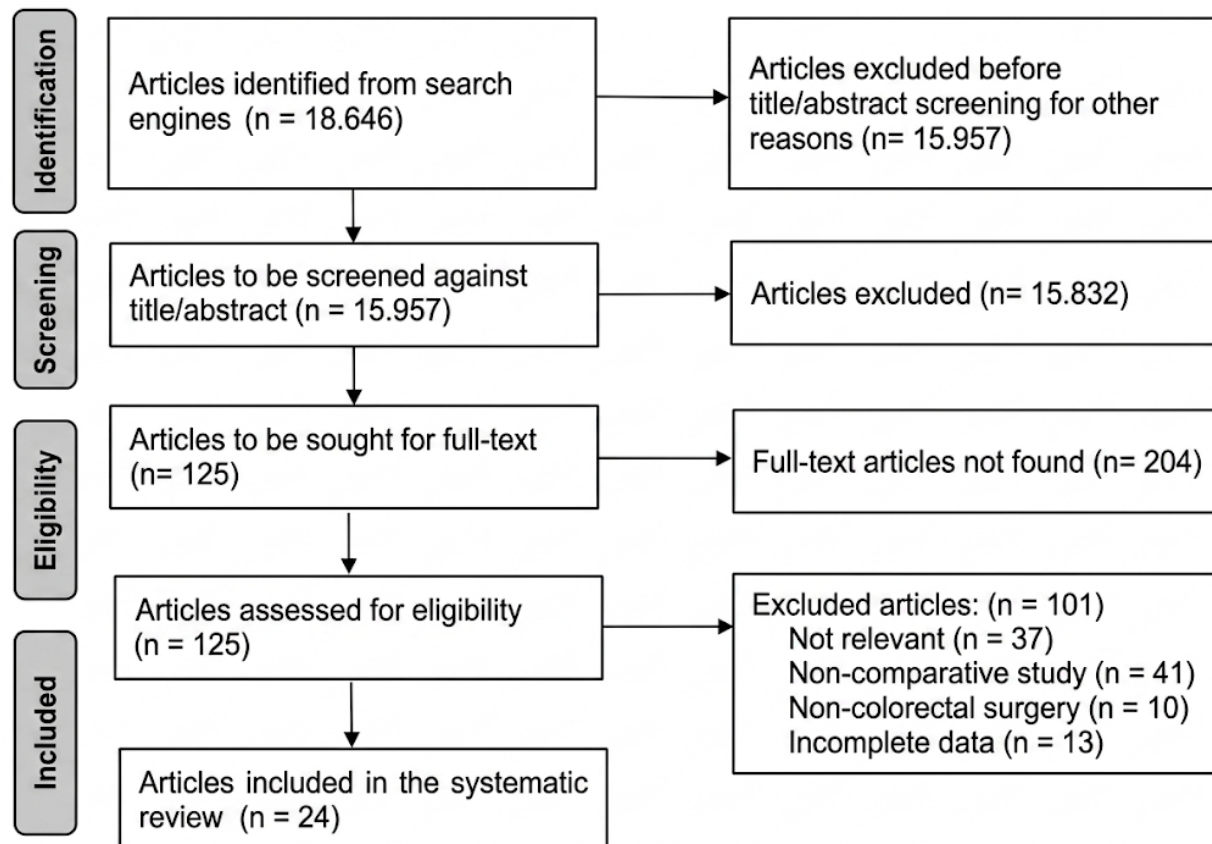


Figure 1. PRISMA Flow Diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

Overall, this study involved 6,922 patients, of which 5,348 patients came from studies comparing laparoscopic procedures with robot-assisted surgery, and the remaining 1,574 patients came from studies comparing open surgical procedures with robot-assisted surgery. The included studies originated from 13 different countries. During further review, it was found that Jayne et al.

and Corrigan et al. used data sourced from the same randomized clinical trial, namely ROLARR. Therefore, both articles were treated as a single data unit from the ROLARR clinical trial, and outcome data extraction was performed based on the cumulative data available.

Table 1. Characteristics of Studies Included in Qualitative Analysis (Representative)

Study (Year)	Design	Country	Groups	Age (Mean $\pm$ SD)	Gender (M/F)	BMI	Robotic Technique
Bertani et al. (2014)	Prospective	Italy	ROB: 52 / Open: 34	59.6 $\pm$ 11.6 63.2 $\pm$ 10.5	31/21 / 20/14	24.8 $\pm$ 3.62 25.6 $\pm$ 3.85	Full-robot
Somashekhar et al. (2015)	RCT	India	ROB: 25 / Open: 25	56.36 $\pm$ 8.21 59.56 $\pm$ 5.75	17/8 / 15/10	31.51 $\pm$ 3.02 29.84 $\pm$ 2.75	N/A
Xu et al. (2017)	RCT	China	ROB: 173 / Open: 154	N/A	N/A	N/A	N/A
Baik et al. (2014)	RCT	South Korea	ROB: 18 / LAP: 18	57.3 $\pm$ 6.3 62.0 $\pm$ 9.0	14/4 / 14/4	22.8 $\pm$ 1.8 24.0 $\pm$ 2.5	Hybrid
REAL Trial (2022)	RCT	China	ROB: 586 / LAP: 585	59.1 $\pm$ 11 / 60.7 $\pm$ 9.8	356/230 / 354/231	23.5 $\pm$ 3.3 23.5 $\pm$ 3.1	Full-robot

Feng et al. (2022)	RCT	China	ROB: 58.2 ± 108/66 / N/A	Full-robot
			174 / 9.6 / 113/60	
			LAP: 59.5 ± 173 10.2	
Quijano et al. (2020)	Prospective	Spain	ROB: 81 63.98 ± 54/37 / 25.98 ± N/A	
			/ LAP: 9.68 / 85/55 4.2 /	
			104 61.37 ± 25.23 ±	
			10.7 5.38	

ROB: Robot-Assisted Surgery; LAP: Laparoscopy; RCT: Randomized Clinical Trial; BMI: Body Mass Index; N/A: Not Available

Based on the assessment using the RoB2 instrument, eleven of the fifteen RCTs adequately described the random sequence generation method, including the use of computer-based random numbers, minimization methods, and sealed envelopes. These eleven studies were judged to have a low risk of bias, while the other three studies were categorized as having some concerns regarding bias.

Regarding allocation concealment, only five studies reported the method in detail and were judged to have a low risk of bias, whereas eight studies showed some concerns and two studies were judged to have a high risk of bias. In terms of blinding, eight studies did not provide sufficient information regarding the blinding method for participants, personnel, or outcome assessors, and were thus categorized as having some concerns for bias. Seven studies were judged to have a high risk of bias for blinding of participants and personnel, while three studies had a high risk of bias for blinding of outcome assessors. Nevertheless, five studies reported adequate methods for blinding outcome assessors, thus minimizing bias risk, and these studies were categorized as having a low risk of bias.

Regarding completeness of data, eight RCTs had no missing data or adequately explained why incomplete data would not affect the study results, and were thus categorized as having a low risk of bias. The other seven RCTs did not provide sufficient information to evaluate data completeness and were categorized as having some concerns for bias. In terms of selective

reporting, eight RCTs had published study protocols or clinical trial registrations beforehand and were judged to have a low risk of bias, whereas the other seven RCTs did not provide adequate data and were categorized as having some concerns for bias.

Table 2. Risk of Bias Assessment of RCTs Using the RoB2 Instrument (Representative)

Study (Year)	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5	Domain 6	Domain 7	Overall
Baik et al. (2014)	Low	Low	Some concern s	Some concern s	Some concern s	Some concern s	Some concern s	Some concern s
Patriti et al. (2014)	Some concern s	Some concern s	Some concern s	Some concern s	Some concern s	Some concern s	Some concern s	Some concern s
Somashekhar et al. (2015)	Some concern s	Some concern s	High	High	Some concern s	Some concern s	High	High
Jayne et al. (2017)	Low	Some concern s	Some concern s	Low	Low	Low	Low	Some concern s
M.J. Kim et al. (2018)	Low	Low	High	Low	Low	Low	Low	High
Tolstrup et al. (2017)	Low	Some concern s	High	High	Low	Some concern s	Low	High
REAL Trial (2022)	Low	Low	High	Low	Low	Low	Low	High
Feng et al. (2022)	Low	Some concern	High	Low	Low	Low	Low	High

			s					
Liu et al. (2022)	High	High	High	Some concern	Some concern	Low	Some concern	High
				s	s		s	

Domain 1: Random sequence generation; Domain 2: Allocation concealment; Domain 3: Blinding of participants & personnel; Domain 4: Blinding of outcome assessors; Domain 5: Incomplete outcome data; Domain 6: Selective reporting; Domain 7: Other bias

Regarding other sources of bias, seven studies presented adequate information on funding sources, potential industry bias, sample size calculation, and conflicts of interest, and were thus judged to have a low risk of bias. One study was judged to have a high risk of bias, and the other seven studies did not present sufficient data and were categorized as having some concerns for bias. Overall, seven studies (46.7%) were judged to have a high risk of bias, while the remaining eight studies (53.3%) were categorized as having some concerns regarding bias. Regarding non-randomized prospective studies, the overall risk of bias was judged as moderate in seven studies (63.6%) and serious in four studies (36.4%). The quality of evidence based on GRADE assessment was categorized as low to very low for most of the outcomes analyzed.

DISCUSSION

In recent decades, the increased use of minimally invasive colorectal resection techniques has enhanced patient satisfaction. This is reflected in shorter hospital stays, faster return to normal activities, and reduced complications at the surgical site. These advantages have driven the shift in surgical practice from open techniques to minimally invasive approaches (54). Laparoscopic colorectal resection shows acceptable surgical outcomes and continues to improve with instrument development and increased operator experience. Several studies report comparable operative and oncological outcomes between laparoscopic and open surgery, although some studies indicate a higher risk of positive circumferential resection margins (CRM) and incomplete total mesorectal excision (TME) in laparoscopic procedures (12,55,56).

Robotic surgery was then introduced to overcome the limitations of laparoscopic techniques through more advanced technology, such as three-dimensional visualization, articulated arms with higher degrees of freedom, and better ergonomics. These advantages are particularly beneficial in patients with a narrow pelvis, male patients, obese patients, and those with anterior tumors undergoing neoadjuvant chemotherapy (6,57).

Several randomized clinical trials (RCTs) and systematic reviews indicate that operative and oncological outcomes between robotic and laparoscopic surgery are relatively comparable, but limitations remain in these studies (58,59). Some studies only compare two methods or involve a limited number of studies and participants, while others include retrospective studies or only evaluate specific aspects such as urogenital function, quality of life, or long-term oncological outcomes (22). Studies comparing robotic and laparoscopic surgery mostly do not include RCTs and only assess pathological outcomes. Therefore, this study was designed to directly compare operative and postoperative outcomes such as anastomotic leakage, conversion to open surgery, and economic aspects between robotic and laparoscopic rectal resection, including RCTs and prospective studies to increase the strength of evidence (25,26).

The analysis results show that rectal resection using robotics has outcomes related to lower blood loss, lower surgical site infection rates, and shorter hospital stays compared to laparoscopy, although operative time is longer. There was no significant difference in complication rates between the two techniques. Compared to laparoscopy, robotic surgery also has longer operative time but shows lower conversion rates, less intraoperative blood loss, lower reoperation rates, and lower mortality rates (60,62).

Conversion to open surgery is known to be associated with increased complications, mortality, and worse oncological outcomes. In this study, conversion rates were lower in robotic surgery, possibly due to better visualization, more optimal access to the pelvic area, and higher instrument maneuverability. Furthermore, lower blood loss in robotic procedures is thought to be related to better vascular control due to magnified visualization and precision of dissection. Given that high blood loss is associated with worse prognosis in colorectal malignancy, this finding suggests a potential prognostic advantage of the robotic approach (64,65).

Longer operative duration in robotic surgery is likely due to the additional time required for preparation and setup of the robotic system (21,23,26,66). However, this duration tends to decrease with increasing experience of the surgical team, with the learning curve showing significant improvement after a certain number of procedures. Even with equivalent experience levels, some studies show that robotic operative time can be shorter than laparoscopy (67).

In terms of hospital stay and surgical site infection, the robotic approach shows better outcomes compared to open surgery, but no significant difference compared to laparoscopy. Variation in results across studies is possibly due to differences in evidence quality, study characteristics, and operator experience (68).

From an economic perspective, robotic surgery costs are higher than open and laparoscopic methods, mainly due to expensive equipment and instruments. However, these costs are expected to decrease with technological development and increased market competition, potentially improving cost-effectiveness in the future (26,28).

The learning curve is also an important consideration. Laparoscopic techniques require longer experience to achieve proficiency compared to the robotic approach. This suggests that the robotic method could be a primary choice for surgical centers wishing to transition from open to minimally invasive techniques, although cost aspects still need to be considered (69).

Laparoscopic rectal resection requires a learning curve of approximately 40–90 cases before a surgeon accustomed to open techniques achieves proficiency. In contrast, the learning curve for robotic resection is relatively shorter, approximately 21–43 cases for surgeons experienced in open procedures. This is likely due to similarities in access, visualization, and maneuverability between the open and robotic approaches (11,70).

Table 3. Summary of Outcome Comparisons: Robotic vs. Open and Laparoscopic Surgery

Outcome	Robotic vs. Open	Robotic vs. Laparoscopy	Interpretation
Blood Loss	✓ Lower in robotic	✓ Lower in robotic	Robotic superior in bleeding control in both comparisons

Operative Time	X	Longer	in	X	Longer in robotic	Robotic requires more time — related to system setup
Conversion to Open	--			✓	3x lower in robotic	Robotic significantly reduces conversion risk
Surgical Site Infection	✓	Lower in robotic	=	Not significantly different		Robotic advantage only over open surgery
Reoperation	=	Not significantly different	✓	Lower in robotic		Robotic reduces need for reoperation vs. laparoscopy
Length of Hospital Stay	✓	Shorter	in	=	Not significantly different	Robotic advantage only over open surgery
Mortality	=	Not significantly different	=	Not significantly different		No significant difference in perioperative mortality
Operative Cost	X	Higher	in	X	Higher in robotic	Robotic costs consistently higher

✓ = Robotic advantage; X = Robotic disadvantage; = No significant difference; -- = Not reported

These findings suggest that the robotic approach could be a primary choice for surgeons or healthcare centers planning to transition from open techniques to minimally invasive procedures for rectal resection, given its shorter learning curve. Nevertheless, the higher cost aspect still needs to be considered. Centers that routinely perform laparoscopic rectal resection may also consider transitioning to the robotic approach, especially if the required costs remain within reasonable limits (68,71,72).

CONCLUSION

In conclusion, the robotic approach is a safe and effective method for rectal resection. Compared to laparoscopy, this method offers significant advantages in both surgical and postoperative outcomes, so robot-assisted rectal surgery can be considered a viable alternative to replace laparoscopy or open surgery. When compared to laparoscopy, the use of the robotic

approach indeed has higher costs. However, this technique offers several advantages, such as lower conversion and reoperation rates to open surgery, less blood loss, lower anastomotic leakage, faster hospital stays, and lower mortality rates. Along with market development and the increasing use of robotic systems in clinical practice, investment and instrument costs are expected to decrease, thus potentially encouraging broader adoption of robotic surgery in rectal resection procedures.

REFERENCES

1. Hossain, M.S.; Karuniawati, H.; Jairoun, A.A.; Urbi, Z.; Ooi, J.; John, A.; Lim, Y.C.; Kibria, K.M.K.; Mohiuddin, A.K.M.; Ming, L.C.; et al. Colorectal Cancer: A Review of Carcinogenesis, Global Epidemiology, Current Challenges, Risk Factors, Preventive and Treatment Strategies. *Cancers* 2022, 14, 1732. [CrossRef]
2. Sung, H.; Ferlay, J.; Siegel, R.L.; Laversanne, M.; Soerjomataram, I.; Jemal, A.; Bray, F. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *Cancer J. Clin.* 2021, 71, 209–249. [CrossRef] [PubMed]
3. Fazeli, M.S.; Keramati, M.R. Rectal cancer: A review. *Med. J. Islam. Repub. Iran* 2015, 29, 171. [PubMed]
4. Glynne-Jones, R.; Wyrwicz, L.; Tiret, E.; Brown, G.; Rödel, C.; Cervantes, A.; Arnold, D. Rectal cancer: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann. Oncol.* 2017, 28, iv22–iv40. [CrossRef] [PubMed]
5. Senagore, A.J. Adoption of Laparoscopic Colorectal Surgery: It Was Quite a Journey. *Clin. Colon Rectal Surg.* 2015, 28, 131–134. [CrossRef]
6. Baik, S.H.; Ko, Y.T.; Kang, C.M.; Lee, W.J.; Kim, N.K.; Sohn, S.K.; Chi, H.S.; Cho, C.H. Robotic tumor-specific mesorectal excision of rectal cancer: Short-term outcome of a pilot randomized trial. *Surg. Endosc.* 2008, 22, 1601–1608. [CrossRef]
7. Denost, Q.; Adam, J.P.; Rullier, A.; Buscail, E.; Laurent, C.; Rullier, E. Perineal transanal approach: A new standard for laparoscopic sphincter-saving resection in low rectal cancer, a randomized trial. *Ann. Surg.* 2014, 260, 993–999. [CrossRef]

8. Martel, G.; Boushey, R.P. Laparoscopic colon surgery: Past, present and future. *Surg. Clin. N. Am.* 2006, 86, 867–897. [CrossRef]
9. Van der Pas, M.H.; Haglind, E.; Cuesta, M.A.; Fürst, A.; Lacy, A.M.; Hop, W.C.; Bonjer, H.J. Laparoscopic versus open surgery for rectal cancer (COLOR II): Short-term outcomes of a randomised, phase 3 trial. *Lancet Oncol.* 2013, 14, 210–218. [CrossRef]
10. Jeong, S.Y.; Park, J.W.; Nam, B.H.; Kim, S.; Kang, S.B.; Lim, S.B.; Choi, H.S.; Kim, D.W.; Chang, H.J.; Kim, D.Y.; et al. Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): Survival outcomes of an open-label, non-inferiority, randomised controlled trial. *Lancet Oncol.* 2014, 15, 767–774. [CrossRef]
11. Bege, T.; Lelong, B.; Esterni, B.; Turrini, O.; Guiramand, J.; Francon, D.; Mokart, D.; Houvenaeghel, G.; Giovannini, M.; Delpero, J.R. The learning curve for the laparoscopic approach to conservative mesorectal excision for rectal cancer: Lessons drawn from a single institution's experience. *Ann. Surg.* 2010, 251, 249–253. [CrossRef] [PubMed]
12. Fleshman, J.; Branda, M.; Sargent, D.J.; Boller, A.M.; George, V.; Abbas, M.; Peters, W.R., Jr.; Maun, D.; Chang, G.; Herline, A.; et al. Effect of Laparoscopic-Assisted Resection vs. Open Resection of Stage II or III Rectal Cancer on Pathologic Outcomes: The ACOSOG Z6051 Randomized Clinical Trial. *JAMA* 2015, 314, 1346–1355. [CrossRef] [PubMed]
13. Stevenson, A.R.; Solomon, M.J.; Lumley, J.W.; Hewett, P.; Clouston, A.D.; Gebiski, V.J.; Davies, L.; Wilson, K.; Hague, W.; Simes, J. Effect of Laparoscopic-Assisted Resection vs. Open Resection on Pathological Outcomes in Rectal Cancer: The ALaCaRT Randomized Clinical Trial. *JAMA* 2015, 314, 1356–1363. [CrossRef]
14. Weber, P.A.; Merola, S.; Wasielewski, A.; Ballantyne, G.H. Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease. *Dis. Colon Rectum* 2002, 45, 1689–1694. [CrossRef] [PubMed]
15. Stefanidis, D.; Wang, F.; Korndorffer, J.R., Jr.; Dunne, J.B.; Scott, D.J. Robotic assistance improves intracorporeal suturing performance and safety in the operating room while decreasing operator workload. *Surg. Endosc.* 2010, 24, 377–382. [CrossRef]

16. Stefanidis, D.; Hope, W.W.; Scott, D.J. Robotic suturing on the FLS model possesses construct validity, is less physically demanding, and is favored by more surgeons compared with laparoscopy. *Surg. Endosc.* 2011, 25, 2141–2146. [CrossRef]
17. Kim, M.J.; Park, S.C.; Park, J.W.; Chang, H.J.; Kim, D.Y.; Nam, B.H.; Sohn, D.K.; Oh, J.H. Robot-assisted Versus Laparoscopic Surgery for Rectal Cancer: A Phase II Open Label Prospective Randomized Controlled Trial. *Ann. Surg.* 2018, 267, 243–251. [CrossRef]
18. Corbellini, C.; Biffi, R.; Luca, F.; Chiappa, A.; Costa, S.; Bertani, E.; Bona, S.; Lombardi, D.; Tamayo, D.; Botteri, E.; et al. Open, laparoscopic, and robotic surgery for rectal cancer: Medium-term comparative outcomes from a multicenter study. *Tumori* 2016, 102, 414–421. [CrossRef]
19. Jayne, D.; Pigazzi, A.; Marshall, H.; Croft, J.; Corrigan, N.; Copeland, J.; Quirke, P.; West, N.; Rautio, T.; Thomassen, N.; et al. Effect of Robotic-Assisted vs. Conventional Laparoscopic Surgery on Risk of Conversion to Open Laparotomy Among Patients Undergoing Resection for Rectal Cancer: The ROLARR Randomized Clinical Trial. *JAMA* 2017, 318, 1569–1580. [CrossRef]
20. Somashekhar, S.P.; Ashwin, K.R.; Rajashekhar, J.; Zaveri, S. Prospective Randomized Study Comparing Robotic-Assisted Surgery with Traditional Laparotomy for Rectal Cancer-Indian Study. *Indian J. Surg.* 2015, 77, 788–794. [CrossRef]
21. Prete, F.P.; Pezzolla, A.; Prete, F.; Testini, M.; Marzaioli, R.; Patriti, A.; Jimenez-Rodriguez, R.M.; Gurrado, A.; Strippoli, G.F.M. Robotic Versus Laparoscopic Minimally Invasive Surgery for Rectal Cancer: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Ann. Surg.* 2018, 267, 1034–1046. [CrossRef]
22. Qiu, H.; Yu, D.; Ye, S.; Shan, R.; Ai, J.; Shi, J. Long-term oncological outcomes in robotic versus laparoscopic approach for rectal cancer: A systematic review and meta-analysis. *Int. J. Surg.* 2020, 80, 225–230. [CrossRef] [PubMed]
23. Tang, B.; Lei, X.; Ai, J.; Huang, Z.; Shi, J.; Li, T. Comparison of robotic and laparoscopic rectal cancer surgery: A meta-analysis of randomized controlled trials. *World J. Surg. Oncol.* 2021, 19, 38. [CrossRef] [PubMed] *Cancers* 2023, 15, 839 32 of 34

24. Han, C.; Yan, P.; Jing, W.; Li, M.; Du, B.; Si, M.; Yang, J.; Yang, K.; Cai, H.; Guo, T. Clinical, pathological, and oncologic outcomes of robotic-assisted versus laparoscopic proctectomy for rectal cancer: A meta-analysis of randomized controlled studies. *Asian J. Surg.* 2020, 43, 880–890. [CrossRef] [PubMed]
25. Ryan, O.K.; Ryan, É.J.; Creavin, B.; Rausa, E.; Kelly, M.E.; Petrelli, F.; Bonitta, G.; Kennelly, R.; Hanly, A.; Martin, S.T.; et al. Surgical approach for rectal cancer: A network meta-analysis comparing open, laparoscopic, robotic and transanal TME approaches. *Eur. J. Surg. Oncol.* 2021, 47, 285–295. [CrossRef]
26. Simillis, C.; Lal, N.; Thoukididou, S.N.; Kontovounisios, C.; Smith, J.J.; Hompes, R.; Adamina, M.; Tekkis, P.P. Open Versus Laparoscopic Versus Robotic Versus Transanal Mesorectal Excision for Rectal Cancer: A Systematic Review and Network Meta-analysis. *Ann. Surg.* 2019, 270, 59–68. [CrossRef]
27. Guo, Y.; Guo, Y.; Luo, Y.; Song, X.; Zhao, H.; Li, L. Comparison of pathologic outcomes of robotic and open resections for rectal cancer: A systematic review and meta-analysis. *PLoS ONE* 2021, 16, e0245154. [CrossRef]
28. Liao, G.; Li, Y.B.; Zhao, Z.; Li, X.; Deng, H.; Li, G. Robotic-assisted surgery versus open surgery in the treatment of rectal cancer: The current evidence. *Sci. Rep.* 2016, 6, 26981. [CrossRef]
29. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Int. J. Surg.* 2010, 8, 336–341. [CrossRef]
30. Kalkum, E.; Klotz, R.; Seide, S.; Hüttner, F.J.; Kowalewski, K.F.; Nickel, F.; Khajeh, E.; Knebel, P.; Diener, M.K.; Probst, P. Systematic reviews in surgery-recommendations from the Study Center of the German Society of Surgery. *Langenbecks Arch. Surg.* 2021, 406, 1723–1731. [CrossRef]
31. Sterne, J.A.C.; Savović, J.; Page, M.J.; Elbers, R.G.; Blencowe, N.S.; Boutron, I.; Cates, C.J.; Cheng, H.Y.; Corbett, M.S.; Eldridge, S.M.; et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. *BMJ* 2019, 366, 14898. [CrossRef] [PubMed]

32. Sterne, J.A.; Hernán, M.A.; Reeves, B.C.; Savović, J.; Berkman, N.D.; Viswanathan, M.; Henry, D.; Altman, D.G.; Ansari, M.T.; Boutron, I.; et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 2016, 355, i4919. [CrossRef] [PubMed]
33. Atkins, D.; Best, D.; Briss, P.A.; Eccles, M.; Falck-Ytter, Y.; Flottorp, S.; Guyatt, G.H.; Harbour, R.T.; Haugh, M.C.; Henry, D.; et al. Grading quality of evidence and strength of recommendations. *BMJ* 2004, 328, 1490. [CrossRef] [PubMed]
34. Corrigan, N.; Marshall, H.; Croft, J.; Copeland, J.; Jayne, D.; Brown, J. Exploring and adjusting for potential learning effects in ROLARR: A randomised controlled trial comparing robotic-assisted vs. standard laparoscopic surgery for rectal cancer resection. *Trials* 2018, 19, 339. [CrossRef]
35. Debaek, Y.; Zaghloul, A.; Farag, A.; Mahmoud, A.; Elattar, I. Robotic-Assisted versus Conventional Laparoscopic Approach for Rectal Cancer Surgery, First Egyptian Academic Center Experience, RCT. *Minim. Invasive Surg.* 2018, 2018, 5836562. [CrossRef]
36. Jiménez Rodríguez, R.M.; Díaz Pavón, J.M.; De La Portilla de Juan, F.; Prendes Sillero, E.; Hisnard Cadet Dussort, J.M.; Padillo, J. Prospective randomised study: Robotic-assisted versus conventional laparoscopic surgery in colorectal cancer resection. *Cir. Esp.* 2011, 89, 432–438. [CrossRef]
37. Patriti, A.; Ceccarelli, G.; Bartoli, A.; Spaziani, A.; Biancafarina, A.; Casciola, L. Short- and medium-term outcome of robot-assisted and traditional laparoscopic rectal resection. *J. Soc. Laparoendosc. Surg.* 2009, 13, 176–183.
38. Tolstrup, R.; Funder, J.A.; Lundbeck, L.; Thomassen, N.; Iversen, L.H. Perioperative pain after robot-assisted versus laparoscopic rectal resection. *Int. J. Colorectal. Dis.* 2018, 33, 285–289. [CrossRef]
39. Wang, G.; Wang, Z.; Jiang, Z.; Liu, J.; Zhao, J.; Li, J. Male urinary and sexual function after robotic pelvic autonomic nerve-preserving surgery for rectal cancer. *Int. J. Med. Robot. Comput. Assist. Surg.* 2017, 13, e1725. [CrossRef]

40. Xu, J.; Wei, Y.; Ren, L.; Feng, Q.; Chen, J.; Zhu, D.; Chang, W.; Yi, T.; Yang, L.; Qin, X. Robot-assisted vs. laparoscopic vs open abdominoperineal resections for low rectal cancer: Short-term outcomes of a single-center prospective randomized controlled trial. *Ann. Oncol.* 2017, 28, v161–v162. [CrossRef]
41. Feng, Q.; Yuan, W.; Li, T.; Tang, B.; Jia, B.; Zhou, Y.; Zhang, W.; Zhao, R.; Zhang, C.; Cheng, L.; et al. Robotic versus laparoscopic surgery for middle and low rectal cancer (REAL): Short-term outcomes of a multicentre randomised controlled trial. *Lancet. Gastroenterol. Hepatol.* 2022, 7, 991–1004. [CrossRef] [PubMed]
42. Feng, Q.; Tang, W.; Zhang, Z.; Wei, Y.; Ren, L.; Chang, W.; Zhu, D.; Liang, F.; He, G.; Xu, J. Robotic versus laparoscopic abdominoperineal resections for low rectal cancer: A single-center randomized controlled trial. *J. Surg. Oncol.* 2022, 126, 1481–1493. [CrossRef] [PubMed]
43. Liu, Y.; Liu, M.; Lei, Y.; Zhang, H.; Xie, J.; Zhu, S.; Jiang, J.; Li, J.; Yi, B. Evaluation of effect of robotic versus laparoscopic surgical technology on genitourinary function after total mesorectal excision for rectal cancer. *Int. J. Surg.* 2022, 104, 106800. [CrossRef]
44. European Society of Coloproctology collaborating group. An international multicentre prospective audit of elective rectal cancer surgery; operative approach versus outcome, including transanal total mesorectal excision (TaTME). *Color. Dis.* 2018, 20, 33–46. [CrossRef]
45. Asklid, D.; Gerjy, R.; Hjern, F.; Pekkari, K.; Gustafsson, U.O. Robotic vs. laparoscopic rectal tumour surgery: A cohort study. *Color. Dis.* 2019, 21, 191–199. [CrossRef] [PubMed]
46. Bertani, E.; Chiappa, A.; Biffi, R.; Bianchi, P.P.; Radice, D.; Branchi, V.; Cenderelli, E.; Vetrano, I.; Cenciarelli, S.; Andreoni, B. Assessing appropriateness for elective colorectal cancer surgery: Clinical, oncological, and quality-of-life short-term outcomes employing different treatment approaches. *Int. J. Color. Dis.* 2011, 26, 1317–1327. [CrossRef] *Cancers* 2023, 15, 839 33 of 34

47. Dulskas, A.; Albandar, M.; Samalavicius, N.E.; Han, Y.D.; Kim, N.K. Laparoscopic and Robotic Surgery for Rectal Cancer— Comparative Study Between Two Centres. *Indian J. Surg.* 2021, 83, 48–54. [CrossRef]
48. Galata, C.; Vassilev, G.; Haas, F.; Kienle, P.; Büttner, S.; Reißfelder, C.; Hardt, J. Clinical, oncological, and functional outcomes of Da Vinci (Xi)-assisted versus conventional laparoscopic resection for rectal cancer: A prospective, controlled cohort study of 51 consecutive cases. *Int. J. Color. Dis.* 2019, 34, 1907–1914. [CrossRef]
49. Kim, H.J.; Choi, G.S.; Park, J.S.; Park, S.Y.; Yang, C.S.; Lee, H.J. The impact of robotic surgery on quality of life, urinary and sexual function following total mesorectal excision for rectal cancer: A propensity score-matched analysis with laparoscopic surgery. *Color. Dis.* 2018, 20, O103–O113. [CrossRef]
50. Kim, J.Y.; Kim, N.K.; Lee, K.Y.; Hur, H.; Min, B.S.; Kim, J.H. A comparative study of voiding and sexual function after total mesorectal excision with autonomic nerve preservation for rectal cancer: Laparoscopic versus robotic surgery. *Ann. Surg. Oncol.* 2012, 19, 2485–2493. [CrossRef]
51. Miura, T.; Sakamoto, Y.; Morohashi, H.; Suto, A.; Kubota, S.; Ichisawa, A.; Kuwata, D.; Yamada, T.; Tamba, H.; Matsumoto, S.; et al. Robotic surgery contributes to the preservation of bowel and urinary function after total mesorectal excision: Comparisons with transanal and conventional laparoscopic surgery. *BMC Surg.* 2022, 22, 147. [CrossRef] [PubMed]
52. Polat, F.; Willems, L.H.; Dogan, K.; Rosman, C. The oncological and surgical safety of robot-assisted surgery in colorectal cancer: Outcomes of a longitudinal prospective cohort study. *Surg. Endosc.* 2019, 33, 3644–3655. [CrossRef]
53. Quijano, Y.; Nuñez-Alfonse, J.; Ielpo, B.; Ferri, V.; Caruso, R.; Durán, H.; Díaz, E.; Malavé, L.; Fabra, I.; Pinna, E.; et al. Robotic versus laparoscopic surgery for rectal cancer: A comparative cost-effectiveness study. *Tech. Coloproctol.* 2020, 24, 247–254. [CrossRef] [PubMed]

54. Park, J.S.; Choi, G.S.; Lim, K.H.; Jang, Y.S.; Jun, S.H. Robotic-assisted versus laparoscopic surgery for low rectal cancer: Casematched analysis of short-term outcomes. *Ann. Surg. Oncol.* 2010, 17, 3195–3202. [CrossRef] [PubMed]
55. Martínez-Pérez, A.; Carra, M.C.; Brunetti, F.; De'Angelis, N. Pathologic Outcomes of Laparoscopic vs Open Mesorectal Excision for Rectal Cancer: A Systematic Review and Meta-analysis. *JAMA Surg.* 2017, 152, e165665. [CrossRef] [PubMed]
56. Stevenson, A.R.L.; Solomon, M.J.; Brown, C.S.B.; Lumley, J.W.; Hewett, P.; Clouston, A.D.; Gebiski, V.J.; Wilson, K.; Hague, W.; Simes, J. Disease-free Survival and Local Recurrence After Laparoscopic-assisted Resection or Open Resection for Rectal Cancer: The Australasian Laparoscopic Cancer of the Rectum Randomized Clinical Trial. *Ann. Surg.* 2019, 269, 596–602. [CrossRef]
57. Liu, G.; Zhang, S.; Zhang, Y.; Fu, X.; Liu, X. Robotic Surgery in Rectal Cancer: Potential, Challenges, and Opportunities. *Curr. Treat. Options Oncol.* 2022, 23, 961–979. [CrossRef]
58. Wee, I.J.Y.; Kuo, L.J.; Ngu, J.C. Urological and sexual function after robotic and laparoscopic surgery for rectal cancer: A systematic review, meta-analysis and meta-regression. *Int. J. Med. Robot. Comput. Assist. Surg.* 2021, 17, 1–8. [CrossRef]
59. Kowalewski, K.F.; Seifert, L.; Ali, S.; Schmidt, M.W.; Seide, S.; Haney, C.; Tapking, C.; Shamiyeh, A.; Kulu, Y.; Hackert, T.; et al. Functional outcomes after laparoscopic versus robotic-assisted rectal resection: A systematic review and meta-analysis. *Surg. Endosc.* 2021, 35, 81–95. [CrossRef]
60. Clancy, C.; O'Leary, D.P.; Burke, J.P.; Redmond, H.P.; Coffey, J.C.; Kerin, M.J.; Myers, E. A meta-analysis to determine the oncological implications of conversion in laparoscopic colorectal cancer surgery. *Color. Dis.* 2015, 17, 482–490. [CrossRef]
61. Guillou, P.J.; Quirke, P.; Thorpe, H.; Walker, J.; Jayne, D.G.; Smith, A.M.; Heath, R.M.; Brown, J.M. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): Multicentre, randomised controlled trial. *Lancet* 2005, 365, 1718–1726. [CrossRef] [PubMed]

62. Rottoli, M.; Bona, S.; Rosati, R.; Elmore, U.; Bianchi, P.P.; Spinelli, A.; Bartolucci, C.; Montorsi, M. Laparoscopic rectal resection for cancer: Effects of conversion on short-term outcome and survival. *Ann. Surg. Oncol.* 2009, 16, 1279–1286. [CrossRef] [PubMed]
63. Bianchi, P.P.; Ceriani, C.; Locatelli, A.; Spinoglio, G.; Zampino, M.G.; Sonzogni, A.; Crosta, C.; Andreoni, B. Robotic versus laparoscopic total mesorectal excision for rectal cancer: A comparative analysis of oncological safety and short-term outcomes. *Surg. Endosc.* 2010, 24, 2888–2894. [CrossRef] [PubMed]
64. Mörner, M.E.; Gunnarsson, U.; Jestin, P.; Svanfeldt, M. The importance of blood loss during colon cancer surgery for long-term survival: An epidemiological study based on a population based register. *Ann. Surg.* 2012, 255, 1126–1128. [CrossRef] [PubMed]
65. Basilico, V.; Griffa, B.; Radaelli, F.; Zanardo, M.; Rossi, F.; Caizzone, A.; Vannelli, A. Anastomotic leakage following colorectal resection for cancer: How to define, manage and treat it. *Minerva Chir.* 2014, 69, 245–252. [PubMed]
66. Memon, S.; Heriot, A.G.; Murphy, D.G.; Bressel, M.; Lynch, A.C. Robotic versus laparoscopic proctectomy for rectal cancer: A meta-analysis. *Ann. Surg. Oncol.* 2012, 19, 2095–2101. [CrossRef] [PubMed]
67. Park, J.S.; Choi, G.S.; Lim, K.H.; Jang, Y.S.; Jun, S.H. S052: A comparison of robot-assisted, laparoscopic, and open surgery in the treatment of rectal cancer. *Surg. Endosc.* 2011, 25, 240–248. [CrossRef]
68. Flynn, J.; Larach, J.T.; Kong, J.C.H.; Waters, P.S.; Warriar, S.K.; Heriot, A. The learning curve in robotic colorectal surgery compared with laparoscopic colorectal surgery: A systematic review. *Color. Dis.* 2021, 23, 2806–2820. [CrossRef]
69. Brodie, A.; Vasdev, N. The future of robotic surgery. *Ann. R. Coll. Surg. Engl.* 2018, 100, 4–13. [CrossRef]
70. Son, G.M.; Kim, J.G.; Lee, J.C.; Suh, Y.J.; Cho, H.M.; Lee, Y.S.; Lee, I.K.; Chun, C.S. Multidimensional analysis of the learning curve for laparoscopic rectal cancer surgery. *J. Laparoendosc. Adv. Surg. Tech. Part A* 2010, 20, 609–617. [CrossRef] *Cancers* 2023, 15, 839 34 of 34

71. Jiménez-Rodríguez, R.M.; Díaz-Pavón, J.M.; De la Portilla de Juan, F.; Prendes-Sillero, E.; Dussort, H.C.; Padillo, J. Learning curve for robotic-assisted laparoscopic rectal cancer surgery. *Int. J. Color. Dis.* 2013, 28, 815–821. [CrossRef] [PubMed]
72. Yamaguchi, T.; Kinugasa, Y.; Shiomi, A.; Sato, S.; Yamakawa, Y.; Kagawa, H.; Tomioka, H.; Mori, K. Learning curve for robotic-assisted surgery for rectal cancer: Use of the cumulative sum method. *Surg. Endosc.* 2015, 29, 1679–1685. [CrossRef] [PubMed]