Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Robotic Complete Mesocolic Excision with Central Vascular Ligation for Right-Sided Colon Cancer: A Narrative Review of Oncological Outcomes, Reproducibility and Learning Curve

Amelia Simenacz
Guy's and St Thomas' NHS Foundation Trust
Christos Damaskos
NIMTS Hospital
Constantinos Zografos
London North West Healthcare NHS Trust
Linda Ferrari
Guy's and St Thomas' NHS Foundation Trust
Konstantinos Kossenas
Laiko General Hospital of Athens
Nikolaos Karountzos
Laiko General Hospital of Athens
Bhargab Ghoshal
bhargab.ghoshal.21@ucl.ac.uk
University College London
Nikolaos Garmpis
Guy's and St Thomas' NHS Foundation Trust

Systematic Review

Keywords: robotic surgery, complete mesocolic excision, central vascular ligation, D3 lymphadenectomy, learning curve

Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11706409/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Complete mesocolic excision with central vascular ligation (CME/CVL) aims to improve the oncological quality of right colectomy through intact mesocolic resection and central lymphovascular dissection. Robotic platforms may facilitate these technically demanding procedures. However, whether enhanced technical precision translates into improved oncological outcomes, more reproducible surgical quality, and meaningful clinical benefit is uncertain. We carried out a literature review to evaluate robotic CME/CVL and compare it to modified CME, or equivalent radical/D3 right colectomy for right-sided colon cancer. We identified 25 studies, which included prospective and retrospective cohorts, comparative and propensity-matched analyses, randomised trials, implementation studies, learning-curve analyses, and relevant image-guided studies.

Overall, robotic CME/CVL is a feasible approach to oncological right colectomy, with low conversion rates, high R0 resection rates, and lymph-node yields mostly between 20 and 40, but current evidence does not establish superiority over laparoscopic CME. The only randomised pilot trial comparing robotic or laparoscopic right hemicolectomy, RoLaCaRT-1, reported similar R0 resection rates and mesocolic quality, with a lower postoperative complication burden after robotic surgery. Large cohorts reported favourable intermediate and long-term oncological outcomes, but a survival advantage attributable to robotics has not been established. Training and implementation studies suggested that robotic CME/CVL can be introduced within structured training programmes, with reported operating-time learning-curve plateaus after approximately 8–20 cases. Robotics may facilitate technically demanding dissections, although longer operating times and higher costs remain limitations. Larger randomised trials assessing standardised pathological outcomes, long-term survival, learning curves, and cost-effectiveness are required to establish its added clinical value.

Background

Colorectal cancer is one of the most common malignancies worldwide, and surgical resection remains the cornerstone of curative treatment for localised colon cancer. Beyond achieving negative margins, increasing emphasis has been placed on standardising the anatomical quality of oncological colectomy. Complete mesocolic excision (CME) with central vascular ligation (CVL) extends the principles of total mesorectal excision, aiming to remove the tumour and its lymphovascular drainage within an intact embryological fascial plane, with vascular division close to the vessels' origin [1].

Hohenberger et al. established the principles of CME, encompassing sharp dissection along embryological planes, preservation of mesocolic integrity and central vascular ligation [1]. Initial institutional outcomes showed increased lymph-node yield, reduced local recurrence and improved cancer-related survival [1]. However, implementation remains heterogeneous, with CME, CVL and D3 lymphadenectomy often used interchangeably despite representing distinct but overlapping surgical concepts [2, 3]. A systematic review of radical right colectomy revealed substantial heterogeneity in operative definitions and reporting, with central arterial ligation the only consistently reported

component, whereas mesocolic integrity, superior mesenteric vein (SMV) exposure and the extent of lymphadenectomy varied considerably [3]. This lack of standardisation limits comparisons between studies and limits the extent to which observed differences in oncological outcomes can be attributed to the surgical technique itself.

The oncological benefit of CME remains debated. Although studies generally report increased lymph-node yield and improved pathological outcomes, evidence of a survival advantage remains inconsistent [2, 4, 5]. These potential benefits must be weighed against the technical complexity of central dissection and the risk of injury to adjacent structures, including the superior mesenteric vessels, pancreas and duodenum, which may increase perioperative morbidity [4, 5]. Randomised evidence has reinforced this uncertainty. In the RELARC phase III trial, 1,072 patients with right-sided colon cancer were randomised to laparoscopic CME/D3 or conventional D2 lymphadenectomy. Although CME/D3 achieved more extensive nodal dissection, it did not significantly improve 3-year disease-free survival in the overall population and was associated with a higher risk of intraoperative vascular injury [6]. Conversely, interim results from the multicentre CoME-in trial showed that CME with CVL increased lymph-node yield and improved pathological indicators of surgical quality without increasing postoperative morbidity [7]. Collectively, these findings suggest that CME may improve pathological measures of resection quality, although its survival benefit and perioperative safety profile remain uncertain.

This uncertainty is particularly relevant to right-sided colectomy, where CME and CVL are technically demanding owing to anatomical variability in the ileocolic, right colic and middle colic vessels and their proximity to the superior mesenteric vessels. Minimally invasive central vascular dissection remains technically challenging, even for experienced laparoscopic surgeons [2, 4]. Robotic platforms may mitigate these challenges through stable three-dimensional visualisation, articulated instrumentation, tremor filtration and enhanced ergonomics, potentially facilitating precise dissection around the superior mesenteric vessels, preservation of embryological planes and intracorporeal reconstruction [8, 9].

The key question extends beyond the technical feasibility of robotic CME to whether it improves oncological resection quality, enables safe and reproducible implementation beyond high-volume specialist centres, and justifies increased operating time and costs. Robotic surgery may therefore facilitate standardisation of technically demanding oncological dissection, although its independent impact on cancer survival remains uncertain.

This review synthesises clinical evidence on robotic CME with CVL for right-sided colon cancer, focusing on oncological outcomes, perioperative safety, learning curves, reproducibility and clinical value, to determine whether it offers meaningful advantages over high-quality laparoscopic surgery.

Materials and Methods

A narrative review was conducted using PubMed, Scopus, Web of Science, and Google Scholar to identify primary clinical studies of robotic CME, CVL, modified CME, or equivalent radical/D3 right colectomy for right-sided colon cancer. Search terms included robotic surgery, right colectomy, right

hemicolectomy, CME, CVL, D3 lymphadenectomy, colon cancer, oncological outcomes, learning curves, and implementation.

Eligible studies comprised prospective and retrospective cohorts, comparative studies, propensity score-matched analyses, randomised controlled trials (RCTs), learning-curve and implementation studies, and clinically relevant image-guided robotic CME studies. Reviews, meta-analyses, editorials, case reports, video-only technical reports, and studies lacking a defined CME/CVL or equivalent radical oncological component were excluded. Non-robotic CME studies were reserved for contextual discussion of the oncologic rationale and were excluded from the results evidence set. Studies reporting overlapping institutional cohorts were both retained only when they addressed distinct clinical questions or outcomes and were interpreted as non-independent evidence.

Extracted outcomes included operating time, blood loss, conversion, vascular injury, postoperative morbidity, lymph-node yield, resection margins, mesocolic quality, recurrence, survival, learning-curve parameters, implementation outcomes, and cost, where reported.

Study Selection and Characteristics

The literature search identified 98 records. After removal of duplicates and title and preliminary screening, 27 full-text articles were assessed for eligibility, of which 25 studies met the inclusion criteria (Fig. 1). Study characteristics and principal outcomes are summarised in Table 1.

Table 1
Summary of clinical studies evaluating robotic CME with CVL for right-sided colon cancer (n = 25).

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
Spinoglio *et al.*, 2016 [10][b]	Retrospective (prospective database); single centre, single surgeon; 2005–2013; n = 100	Robotic mCME + CVL + ICA (da Vinci 3-arm/Si HD)	Conversion 0% Operative time 279 min Complications 25% (CD III–IV 4%) Leak 1% Mean LN 28.2 Median follow-up 48.5 months 4-y DFS 91.4%, OS 90.3% (stage I–III) 4-y DSS 94.5% Stage III DFS 78.2% LR 1%
Spinoglio *et al.*, 2018 [11][b]	Retrospective (prospective database), non-matched; single centre, single surgeon; 101 vs 101	Robotic vs laparoscopic CME + CVL + ICA (da Vinci 3-arm/Si HD)	Conversion 0% vs 6.9% Operative time 279 vs 236 minutes CD III–IV 3.9% vs 5.9% Leak 1% vs 1% Mean LN 28.2 vs 30.4 Median follow-up 60 months 5-y DFS 85% vs 83%, OS 77% vs 73% (NS)

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			Stage III DFS 81% vs 68% (NS)
Bae *et al.*, 2019 [12]	Retrospective (prospective database); single centre, single surgeon; n = 43	Totally robotic mCME + CVL (D3) + ICA (da Vinci S/Si/Xi)	Conversion 0% Operative time 293 minutes Complications 21% (CD III 7%) Leak 2.3% Median LN 29 Median follow-up 55 months 5-y DFS 81.1%, OS 93.6% Recurrence 16.3% (LR 4.7%)
Yozgatli *et al.*, 2019 [13]	Retrospective comparative; two centres, two surgical teams; 2015–2017; 35 vs 61	Robotic CME vs conventional (non-CME) laparoscopic RH (da Vinci Xi)	Conversion 0% vs 0% Operative time 286 vs 132 minutes ($p < 0.001$) Complications 29% vs 25% (NS) CD III–IV 3% vs 7% (NS) Leak 0% vs 5% (NS) 2 robotic SMV injuries, repaired robotically Mean LOS 6 vs 6 days Mean LN 41 vs 33 ($p = 0.04$)

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			Vascular tie–colon wall distance 13 vs 11 cm (p = 0.02) R0 100% Mean follow-up 15 vs 16 months
Schulte am Esch *et al.*, 2019 [14]	Retrospective; consecutive; single centre, single surgeon; 24 vs 7	Robotic suprapubic bottom-to-up vs medial-to-lateral CME + CVL; extracorporeal anastomosis (da Vinci Xi)	Conversion 0% Operative time 284 vs 288 minutes (NS) Complications 33% vs 43% (all CD I–II) No leaks Mean LN 40.2 vs 16.3 (cancers only, 17 vs 7) < 12 LN 0% vs 29% R0 100%
Spinoglio *et al.*, 2019 [15]	Prospective clinical series; n = 20	Robotic bottom-to-up CME + ICG lymphatic mapping (da Vinci Xi, Firefly)	Conversion 0% Fluorescent nodal mapping in all patients Nodes outside the standard lymphatic basin identified and removed in 7 (35%)
Ramachandra *et al.*, 2020 [16]	Retrospective (prospective database); consecutive; single centre, single surgeon; n = 52	Robotic CME + CVL; extracorporeal anastomosis (da Vinci Xi)	Conversion 3.8% Operative time 182 minutes CD III 11.5% Leak 1.9%

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			No mortality Mean LN 28 R0 100%
Larach *et al.*, 2021 [17][b]	Retrospective (prospective database); consecutive; two centres; n = 20	Robotic SMV-first CME + CVL; ICA in 90% (da Vinci Xi)	Conversion 0% Operative time 140 minutes CD I–II 10%, no CD ≥ III No leaks Median LOS 4 days Median LN 36 R0 100%
Siddiqi *et al.*, 2021 [18][b]	Retrospective (prospective database); single centre, single surgeon; selected patients; n = 77	Robotic SMV-first CME + ICA (da Vinci X)	Conversion 0% Operative time 180 minutes Complications 11.6% (CD III 2.6%) No leaks No 90-day mortality Median LN 30 R0 96% Median follow-up 36 months 3-y DFS 94%, OS 94%

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			3-y DFS by stage I/II/III 100/91.7/92% LR 1%
Bianchi *et al.*, 2021 [19][b]	Retrospective (prospective database); consecutive; single centre; n = 161	Robotic CME + ICA; bottom-to-up 68%, medial-to-lateral 32% (da Vinci, Xi from 2016)	Conversion 3.7% (elective, locally advanced) Operative time 185 minutes Complications 16.1% (CD III–IV 3.7%) Leak 0.6% No mortality Mean LN 21.9 R0 100%
Comparative evidence and oncological precision			
Khan *et al.*, 2021 [20][b]	Retrospective (prospective database); single centre; 2:1 PSM with non-concurrent comparator; 40 vs 80	Robotic SMV-first CME + CVL + ICA (da Vinci Si/X) vs laparoscopic D2 with extracorporeal anastomosis	Conversion 0% vs 5% Operative time 180 vs 130 minutes CD III–IV 5% vs 5% Median LN 29 vs 18 Specimen 322 vs 260 mm R0 98% vs 100% Distant recurrence 8% vs 24% 3-y DFS 90% vs 78% (NS)

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			3-y OS 99% vs 90% (p = 0.045)
Larach *et al.*, 2022 [21][b]	Retrospective (prospective database); consecutive; two centres; 25 vs 26	Robotic SMV-first CME vs conventional robotic right colectomy (da Vinci Xi; Si in 3 conventional)	Conversion 0% Operative time 200 vs 190 minutes (NS) Complications 16% vs 27% (NS) No leaks Median LOS 4 vs 5 days (NS) Mean LN 37.7 vs 21.8 (p < 0.001) Specimen length 284 vs 298 mm (NS)
Tian *et al.*, 2023 [22]	Retrospective; three centres; 1:1 PSM; 142 vs 142	Robotic vs laparoscopic CME; extracorporeal anastomosis in both (da Vinci Si)	Conversion 0% vs 4.2% Operative time 201 vs 182 minutes Complications 15.5% vs 16.2% No leaks or mortality Mean LN 20.4 vs 20.5 R0 100% Cost 85,016 vs 58,266 RMB Median follow-up 18.5 vs 20 months

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			DFS 84.9% vs 87.1%, OS 83.8% vs 80.7% (NS)
Nonaka *et al.*, 2025 [23]	Retrospective (prospective database); single centre; 1:1 PSM with non-concurrent comparator; 40 vs 40	Robotic vs laparoscopic CME + D3 via cranial approach; ICA 95% vs 20% (da Vinci Xi)	Conversion 0% Operative time 194 vs 184 minutes (NS) Complications 22.5% vs 27.5% (NS) Blood loss 10 vs 28.5 mL First flatus 1 vs 2 days Median LOS 9 vs 11 days Median LN 24 vs 23 R0 100%
Pochhammer *et al.*, 2025 [24]	Prospectively recorded cohort; single centre, single surgeon; allocation by system availability; 25 vs 25 vs 25	Dexter vs da Vinci Xi vs laparoscopic CME + D3; ICA 100% vs 96% vs 56%	Conversion 0% vs 0% vs 4% Operative time 165 vs 191 vs 153 minutes Leak 4% vs 4% vs 8% Median LOS 4 vs 4 vs 5 days Median LN 22 vs 28 vs 26 (NS) Benz type 0 100% vs 91% vs 96% R0 100% Median follow-up 8 vs 17 vs 19 months

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			Survival NS
Stevenson *et al.* (RoLaCaRT-1), 2026 [25]	International multicentre randomised phase II pilot (2:1); stopped early; 18 vs 9 operated (29 randomised)	Robotic vs laparoscopic RH by accredited surgeons; ICA 100% vs 22% (da Vinci Xi)	Conversion 0% Theatre time 226 vs 187 minutes 90-day CCI median 0 vs 20.9 (p = 0.008) CD IIIa 6% vs 33% Leak 0% vs 22% Median LOS 4 vs 6 days Mean LN 25.2 vs 19.1 (NS) R0 100% Benz type 0 53% vs 50% Intact mesocolon 94% vs 100% Median follow-up 6 months
Magarini *et al.*, 2026 [31]	Retrospective (prospective database); consecutive; single centre; 2018–2025; unmatched (sex and ASA differed); 135 vs 153	Robotic vs laparoscopic CME + CVL; ICA in robotic group, NR for laparoscopic (da Vinci Xi)	Conversion 0% vs 1.3% (NS) Operative time 256.5 vs 229.9 minutes (p < 0.001) Complications 18.5% vs 32.0% (p = 0.052); CD ≥ III 3.0% vs 7.2% Reintervention 0% vs 4.6% (p = 0.012)

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			Mortality 0% vs 0.7% Transfusion 11.1% vs 23.5% (p = 0.006) First flatus 1.5 vs 1.9 days (p = 0.003) Mean LOS 5.0 vs 6.5 days (p < 0.001) Mean LN 33.5 vs 29.1 (p = 0.013) Central LN 11.7 vs 7.8 (p < 0.001); pericolic LN 22.4 vs 21.4 (NS) > 8 central LN: adjusted OR 2.94 (95% CI 1.80–4.86) Specimen 384.5 vs 366.8 mm (NS) Leak, R0 and survival NR
Nowakowski *et al.*, 2026 [32][b]	Retrospective; single centre; 2018–2022; 30 vs 29 (open group, n = 30, not shown); one surgeon performed 25/30 robotic cases[c]	Robotic vs laparoscopic CME + CVL; hand-sewn vs stapled ICA (da Vinci X)	Conversion 0% vs 17.2% Operative time 193 vs 181 minutes CD ≥ III 10.0% vs 10.3% Leak 6.7% vs 0% Mean LOS 9.9 vs 9.1 days LN numerically lower with robotic surgery Complete CME (grade 0) 80.0% vs 72.4%

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			R0 100% 90-day mortality 3.3% vs 0% Median follow-up 36 vs 34.5 months 3-y DFS 66.9% vs 66.5%, OS 70.0% vs 70.9%
Hiramatsu *et al.*, 2026 [33]	Retrospective; two centres; 2019–2025; allocation by system availability; 1:1 PSM; 22 vs 22 (51 vs 23 before matching)	Hugo RAS vs da Vinci Xi CME + CVL (D3); extracorporeal anastomosis 91% vs 82%	Conversion 0% Operative time 286 vs 246 minutes (p = 0.015) Console time 146 vs 132 minutes (NS) Roll-in to console start 10 vs 5.5 minutes (p < 0.001) Complications 13.6% vs 4.5% (NS); CD ≥IIIa 0% vs 4.5% (unrelated to surgery) No leaks, reoperations, readmissions or deaths Median LOS 8 vs 8 days Median LN 23 vs 21 (NS) R0 100% Follow-up 6 months
Learning curve, training and implementation			

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
Ferraro *et al.*, 2022 [26][b]	Retrospective (prospective database); single centre; case-matched from 161 patients; 31 vs 31	Senior vs junior surgeon (structured robotic training, no prior colorectal operating experience); CME + ICA (da Vinci Xi)	Conversion 6.4% vs 3.2% Operative time 171 vs 188 minutes (NS) Complications 19.3% vs 22.6% (NS) CD III–IV 3.2% vs 3.2% No leaks or mortality Mean LN 21.8 vs 19.0 (NS)
Van Eetvelde *et al.*, 2025 [27][b]	Retrospective (prospective databases); five European centres; consecutive; 2010–2020; 101 vs 135 vs 315 (PSM 62 per group)	Standard R-RHC vs implementation-phase CME vs established CME; ICA in all (da Vinci Si/X/Xi)	Conversion 2.0% vs 3.0% vs 1.6% Operative time 142 vs 167 vs 187 minutes CD III–IV 6.9% vs 5.9% vs 5.1% No SMV injuries Leak ≤ 3.7% Median LOS 5 days Median LN 15 vs 16 vs 25 ($p < 0.001$) No differences after PSM
Madarasz *et al.*, 2026a [28][b]	Retrospective (prospective database); single centre, three surgeons; n = 71 (2 conversions excluded)	Learning curve (CUSUM of operative time) for robotic SMV-first CME + CVL with hand-sewn ICA (da Vinci X)	Proficiency after ≈ 15–20 cases Operative time 165 min

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			Complications 25.4% (CD ≥IIIb 9.9%) Leak 5.6% (all within each surgeon's first 10 cases) No mortality Mean LN 29.6 R0 98.6% Intact mesocolon 90.1%
Madarasz *et al.*, 2026b [34][b]	Retrospective; single centre, three surgeons; 2018–2025; 95 right colectomies (of 369 robotic colorectal resections)	Surgeon-specific learning curves (CUSUM of operative time) for robotic CME + CVL + ICA (mainly da Vinci X)	CUSUM turning points at 8, 18 and 18 cases (surgeons 1–3) Median operative time 165 minutes (185, 155 and 149 minutes by surgeon) Complete CME (grade 0) 91.6% Other outcomes not reported separately for right colectomy
Generalisability and outcomes in high-risk patients			
Miyakawa *et al.*, 2026 [29]	Retrospective (prospective database); single centre, nine surgeons; 2015–2023; 80 vs 131	Obese (BMI ≥ 30) vs non-obese patients undergoing robotic SMV-first CME; ICA 38% (platform NR)	Conversion 5.0% vs 0.8% (p = 0.05) Operative time 290 vs 247 minutes Complications 18.8% vs 12.2% (NS) CD III 3.8% vs 1.5% (NS)

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

Study	Design / cohort	Intervention / comparator	Main findings
Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL			
			No vascular injuries or leaks Median LN 34.5 vs 34 No positive margins Median follow-up 2.6 years 3-y RFS 89.1% vs 86.7%, OS 100% vs 95.6% (NS)
Hill *et al.*, 2026 [30]	Retrospective (prospective databases); single centre, two surgeons; 2014–2024; n = 631	Robotic CME + D3 (da Vinci Xi)	Conversion 0% Operative time 165 minutes Complications 16.0% (CD ≥ III 2.4%) Leak 1.1% 30-day mortality 0.3% No vascular injuries Median LN 30.5 (536 adenocarcinomas) Median follow-up 42.8 months 5-y DFS 98.5/89.9/68.6% (stage I/II/III) LR 0.4%

ASA, American Society of Anesthesiologists physical status; Benz type 0, complete mesocolic excision on pathological grading; BMI, body mass index (kg/m²); CCI, Comprehensive Complication Index; CD, Clavien–Dindo grade; CI, confidence interval; CME, complete mesocolic excision; CUSUM, cumulative sum; CVL, central vascular ligation; D2/D3, D2/D3 lymphadenectomy; DFS, disease-free survival; DSS, disease-specific survival; ICA, intracorporeal anastomosis; ICG, indocyanine green; LN, lymph nodes; LOS, length of stay; LR, local recurrence; mCME, modified complete mesocolic excision; mo, months; NR, not reported; NS, not significant; OR, odds ratio; OS, overall survival; PSM, propensity score matching; R0, microscopically negative resection margin; RAS, robotic-assisted surgery; RFS, recurrence-free survival; RH, right hemicolectomy; RMB, renminbi; R-RHC, robotic right hemicolectomy.

The evidence was predominantly retrospective, comprising 22 retrospective studies, 16 of which used prospectively maintained databases, two prospective studies, and one randomised study. Eighteen studies were single-centre (including seven single-surgeon series) and seven were multicentre. All

studies reporting the robotic platform used da Vinci systems, ranging from earlier three-arm models to the Xi platform. Two studies evaluated alternative systems, Dexter [24] and Huge [33].

Potential overlap in patient cohorts was identified across studies from the same institutions: Spinoglio et al. [10, 11], Larach et al. [17, 21], Siddiqi et al. and Khan et al. [18, 20], Bianchi et al. and Ferraro et al. [19, 26], and Madarasz et al. and Nowakowski et al. [28, 32, 34]. Furthermore, the multicentre study by Van Eetvelde et al. [27] included a centre contributing patients to the cohorts reported by Siddiqi et al. and Khan et al. Consequently, potentially overlapping studies were not regarded as independent sources of evidence.

Results

Early evidence for technical feasibility and oncological adequacy of robotic CME/CVL

Early studies established the feasibility of robotic CME/CVL, with favourable perioperative and oncological outcomes. In 100 robotic right colectomies with modified CME, Spinoglio et al. reported low major morbidity (Clavien-Dindo grades III-IV, 4%), a mean lymph-node yield of 28.2, and 4-year disease-free and overall survival of 91.4% and 90.3%, respectively, for stage I-III disease [10]. Their subsequent non-matched comparison with laparoscopy, whose robotic arm overlapped with this cohort, demonstrated fewer conversions with robotics (0% vs 6.9%) but longer operating times (279 vs 236 minutes), with comparable lymph-node yields and 5-year survival [11]. In 43 patients undergoing totally robotic modified CME, Bae et al. reported a median lymph-node yield of 29 and, at a median follow-up of 55 months, 5-year overall and disease-free survival of 93.6% and 81.1%, respectively [12]. However, as neither of these series included a comparator, the specific benefits of robotics cannot be established [10, 12].

Early comparisons with conventional, non-CME laparoscopic surgery suggested greater pathological radicality with robotic CME. In a two-centre retrospective study, Yozgatli et al. reported higher lymph-node yields with robotic CME than with conventional laparoscopic hemicolectomy (mean 41 vs 33; p = 0.04), and longer distance between the vascular tie and the colonic wall (13 vs 11 cm), but substantially longer operating times (286 vs 132 minutes), similar complication rates, and two SMV injuries in the robotic group, both repaired robotically [13]. As the groups differed in surgical platform, extent of lymphadenectomy and operating team, the independent contribution of robotics remains uncertain.

Technical refinements were explored in parallel. In a single-surgeon series, Schulte am Esch et al. found higher lymph-node yields with a standardised suprapubic bottom-to-up approach than with a medial-to-lateral approach in robotic CME (40.2 vs 16.3), suggesting that operative technique may also influence pathological outcomes [14]. In 20 patients, Spinoglio et al. showed that indocyanine green (ICG) lymphatic mapping identified additional nodes outside the expected drainage basin in seven (35%),

demonstrating the potential of intraoperative fluorescence guidance; its effect on oncological outcomes, however, was not assessed [15].

Subsequent case series supported the reproducibility of robotic CME/CVL, reporting low conversion and anastomotic leak rates, high rates of R0 resection, and lymph-node yields of 28–36 [16–18]. In 77 selected patients, Siddiqi et al. reported 3-year disease-free and an overall survival of 94% [18]. In the largest of these series, Bianchi et al. reported R0 resection in all 161 patients, with conversion and major morbidity rates of 3.7% each and anastomotic leakage of 0.6% [19]. However, these uncontrolled, predominantly specialist-centre experiences establish feasibility and oncological adequacy rather than superiority. Taken together, these early studies show that robotic CME/CVL can achieve adequate oncological quality with acceptable morbidity, although the respective contributions of the robotic platform, extent of lymphadenectomy, and operative technique cannot yet be separated.

Comparative evidence and oncological precision

Comparative evidence suggests that the apparent oncological advantages of robotic CME largely reflect the extent of lymphadenectomy rather than the surgical platform itself. Khan et al. compared 40 robotic CME/CVL procedures with 80 laparoscopic D2 right colectomies from a non-inferior cohort, reporting greater lymph-node yields (29 vs 18) and longer specimens (322 vs 260 mm) with robotic surgery, but longer operating times (180 vs 130 minutes) [20]. Distant recurrence was less frequent (8% vs 24%), and 3-year overall survival was higher (99% vs 90%; $p = 0.045$), whereas disease-free survival did not differ significantly. These findings are difficult to attribute to robotics alone because of to differences in surgical platform, extent of lymphadenectomy, and treatment period. Consistent with this interpretation, Larach et al. found that robotic CME yielded more lymph nodes than conventional robotic right colectomy (mean 37·7 vs 21·8; $p < 0.001$), despite comparable specimen lengths and perioperative outcomes [21].

Studies comparing robotic and laparoscopic CME with standardised oncological resection have not consistently demonstrated superior pathological outcomes with robotics. Tian et al. and Nonaka et al. reported comparable lymph-node yields and pathological outcomes, with no significant differences in postoperative complications [22, 23] or survival [22]. Although robotic surgery was associated with fewer conversions and improved postoperative recovery, these were associated with longer operating times and greater hospital expenditure. Furthermore, differential use of intracorporeal anastomosis (95% vs 20%) may have confounded recovery outcomes [22, 23]. In contrast, Magarini et al. reported higher total and central lymph-node yields, fewer reinterventions and shorter hospitalisation with robotics [31], however, baseline differences, differential anastomotic technique and missing oncological outcomes limit interpretation. Overall, robotic CME may offer selected perioperative advantages, but superiority in oncological adequacy or long-term outcomes has not been consistently demonstrated when the extent of resection is equivalent.

Two small studies reported comparable outcomes across robotic platforms. Pochhammer et al. found similar pathological and perioperative outcomes with Dexter, da Vinci Xi and laparoscopy, although operating times were longest with da Vinci Xi [24]. Hiramatsu et al. similarly reported comparable outcomes with Hugo RAS and da Vinci Xi, but a longer total operating time with Hugo (286 vs 246 minutes), despite similar console time, attributed to set-up and docking during early implementation [33].

The only randomised evidence is from RoLaCaRT-1, an international, multicentre, phase II pilot trial [25]. Of 29 patients randomised to robotic or laparoscopic right hemicolectomy, 18 and nine, respectively, underwent surgery before the trial was terminated early because of funding constraints. R0 resection was achieved in all patients, with no significant between-group differences in mesocolic specimen quality, lymph-node yield (mean 25.2 vs 19.1), or quality of life. Robotic surgery required longer theatre time (226 vs 187 minutes) but was associated with a lower 90-day Comprehensive Complication Index (median 0 vs 20.9; p = 0.008), fewer anastomotic leaks (0% vs 22%), and shorter hospital stay (median 4 vs 6 days). Surgeon workload measures also tended to favour robotics. These findings should be interpreted cautiously given the small sample, early trial termination, median follow-up of six months, and differential use of intracorporeal anastomosis (100% vs 22%). The trial therefore provided preliminary randomised evidence of comparable pathological quality of robotic CME, but did not establish its superiority over laparoscopic CME.

Learning curve, training and implementation

The wider adoption of robotics depends on whether complex CME/CVL can be taught and implemented safely beyond expert settings. Ferraro et al. compared outcomes between a senior surgeon and junior surgeon without prior colorectal operative experience who had completed a structured robotic training programme [26]. Among 31 case-matched patients per surgeon, no significant outcome differences were observed, suggesting that structured training may enable less experienced surgeons to achieve results comparable to those of experts. However, this study overlaps with the Bianchi cohort and represents a training analysis of the same broader clinical experience rather than independent validation in a separate population [19].

Van Eetvelde et al. evaluated implementation across five European tertiary centres, analysing 551 consecutive robotic right colectomies classified as standard robotic right colectomy, implementation-phase CME, or established robotic CME [27]. Greater procedural complexity prolonged operating time but did not adversely affect vascular events, conversion, anastomotic leakage, postoperative recovery, or length of stay. No SMV injuries were reported, while established CME was associated with higher lymph-node retrieval. Overall and severe 30-day morbidity remained comparable after propensity score matching [27]. These findings support the stepwise implementation of robotic CME in experienced centres without an apparent increase in perioperative risk.

Madarasz et al. performed a cumulative sum (CUSUM)-based learning-curve analysis of operating time in 71 robotic right colectomies involving CME, CVL, and hand-sewn intracorporeal anastomosis,

excluding two converted cases [28]. Across three surgeons, operating time stabilised after approximately 16 cases. The mean lymph-node yield was 29.6 and an R0 resection rate 98.6%. Complications occurred in 25.4% of patients, with all anastomotic leaks occurring within each surgeon's first 10 cases. However, these findings may not be generalisable beyond surgeons with prior robotic and minimally invasive experience. An extended analysis from the same centre including 95 robotic right colectomies demonstrated inter-surgeon variation in the learning curve, with operating time stabilising after eight cases for one surgeon and 18 for the other two [34]. CME was achieved in 91.6% cases. These findings suggest that proficiency is surgeon-specific and should not be defined by a fixed case threshold.

Generalisability and outcomes in high-risk patients:

The clinical value of robotic CME depends on whether favourable outcomes are maintained in technically challenging patients and contemporary high-volume practice. Miyakawa et al. evaluated 211 SMV-first robotic CME procedures performed by nine surgeons at a single centre, including 80 patients with obesity (body mass index ≥ 30 kg/m²) [29]. Obesity was associated with longer operating times (290 vs 247 minutes), greater blood loss, and a borderline higher conversion rate (5.0% vs 0.8%; p = 0.05), but did not significantly affect postoperative complications (18.8% vs 12.2%), lymph-node yield (median 34.5 vs 34), margin status, or survival. Three-year recurrence-free survival was 89.1% versus 86.7%, and overall survival was 100% versus 95.6%, over a median follow-up of 2.6 years. No vascular injuries or anastomotic leaks occurred in either group. These findings suggest that robotic CME can achieve oncological adequacy despite greater technical complexity. However, in the absence of a laparoscopic comparator in patients with obesity, the specific benefits of the robotic approach remain uncertain.

Hill et al. reported a contemporary series of 631 robotic right hemicolectomies incorporating CME and D3 lymphadenectomy, performed by two surgeons at a comprehensive cancer centre between 2014 and 2024 [30]. No conversions or vascular injuries were reported. Major complications (Clavien–Dindo grade III or higher) occurred in 2.4% of patients, anastomotic leakage in 1.1%, and 30-day mortality in 0.3%, with a median hospital stay of four days. Among 536 patients with colon adenocarcinoma, the median lymph-node yield was 30.5. At a median follow-up of 42.8 months, five-year disease-free survival was 98.5%, 89.9%, and 68.6% for stages I, II, and III, respectively, while the local recurrence rate was 0.4%. These findings indicate favourable perioperative safety and long-term oncological outcomes in a specialist setting. However, the lack of a concurrent comparator and the concentration of procedures among two high-volume surgeons prevent attribution of these outcomes specifically to robotics.

Discussion

This review indicates that robotic CME/CVL is technically feasible, reproducible in experienced programmes and capable of achieving high-quality oncological resection. Across early and contemporary series, R0 resection rates were high, lymph-node yields were largely adequate, with generally low conversion and major morbidity [10, 12, 16–19, 28–30]. The central question, however, is

not whether robotic CME can produce good outcomes, but whether those outcomes are attributable to the robotic platform and whether they exceed those achievable with expert laparoscopic CME.

Comparative studies have frequently confounded surgical platform with oncological extent. Yozgatli et al. [13] and Khan et al. [20] reported higher lymph-node yields with robotic CME than with non-CME laparoscopic colectomy, but the cohorts also differed in operating team [13] or treatment period [20]. When Larach et al. held the platform constant, adding CME to robotic right colectomy increased mean nodal yield from 21.8 to 37.7 without significantly altering specimen length [21], indicating that the extent of resection is a determinant of nodal yield. Conversely, when oncological technique was standardised, nodal yields were generally similar after robotic and laparoscopic CME [11, 22–24], and pathological specimen quality did not differ between two robotic platforms and laparoscopy [24]. The randomised RoLaCaRT-1 pilot trial found comparable R0 resection, complete mesocolic excision and mesocolic integrity [25]. Accordingly, robotic CME has not consistently demonstrated oncological superiority over high-quality laparoscopic CME, and apparent advantages diminish when the extent and quality of surgery are comparable.

Lymph-node yield should be interpreted cautiously. Reported yields in robotic CME series ranged from approximately 20 [22, 26] to more than 40 nodes [13, 14], likely reflecting differences in the extent of lymphadenectomy, pathological processing, institutional protocols, patient anatomy and tumour biology. Moreover, Schulte am Esch et al. reported higher yields with a standardised bottom-to-up than a medial-to-lateral approach using the same robotic platform, suggesting that operative technique may also influence nodal retrieval [14]. Similarly, ICG-guided robotic CME may facilitate more individualised lymphadenectomy by identifying lymphatic drainage beyond expected anatomical basins [15]. Importantly, nodal yield is a surrogate measure and does not independently demonstrate therapeutic benefit. RELARC found greater radicality with CME/D3 without a significant improvement in 3-year disease-free survival [6], while CoME-in demonstrated improved pathological quality without establishing a survival benefit [7]. Higher nodal yields should therefore be interpreted as evidence of technical and pathological adequacy rather than as proof of improved cancer survival.

Long-term outcomes support the oncological safety of robotic CME. Disease-free survival was 81–91% at 4–5 years [10–12] and 94% at 3 years [18]. In the largest contemporary cohort, 5-year disease-free survival was 98.5%, 89.9% and 68.6% for stages I, II and III, respectively [30]. However, these findings derive predominantly from uncontrolled specialist-centre cohorts. Khan et al. reported higher 3-year overall survival after robotic CME (99% vs 90%; $p = 0.045$), but disease-free survival did not differ, and the comparator was non-concurrent non-CME surgery [20]. Direct comparisons of robotic and laparoscopic CME found no significant survival differences [11, 22, 24], although follow-up was limited in two studies [22, 24]. Thus, current evidence suggests comparable oncological outcomes between robotic and laparoscopic CME, but does not establish a survival advantage specific to robotics.

Robotic assistance may facilitate dissection around the central vascular axis. Conversion rates were low across robotic series [10, 12, 17, 18, 30] and were lower than those reported with laparoscopic surgery in

six comparative studies [11, 20, 22, 24, 31, 32]. Central dissection is associated with a recognised risk of vascular injury, which was more frequent with laparoscopic CME/D3 than with D2 dissection in the RELARC trial [6]. In the robotic literature, no SMV injuries occurred during stepwise implementation across five centres [27], and no vascular injuries were reported in two large single-centre cohorts [29, 30]. Nevertheless, Yozgatli et al. reported two SMV injuries during robotic dissection [13]0, and anastomotic leakage occurred in 6.7% of robotic and no laparoscopic patients in one small series [32], highlighting that, although robotic assistance may facilitate technical execution, its effect on procedural safety remains uncertain.

In patients with obesity, robotic CME required longer operating times and was associated with greater blood loss and a borderline higher conversion rate, yet lymph-node yield, margin status, morbidity and survival were similar to those in non-obese patients [29]. However, because the comparator comprised non-obese robotic patients rather than patients with obesity undergoing laparoscopic CME, the study cannot establish a specific advantage of robotics in overcoming the technical challenges associated with obesity.

Training and implementation provide another plausible area of robotic value. Ferraro *et al*. demonstrated comparable outcomes between a senior and junior surgeon without previous colorectal operative experience following structured training [26], Van Eetvelde *et al*. showed that CME could be introduced stepwise across five centres without increasing major morbidity [27], and Madarasz *et al*. identified an operative learning plateau after approximately 15–20 cases [28], although an extended analysis from the same centre found this varied between surgeons, from eight to approximately 18 cases [34]. Collectively, these findings suggest that robotic surgery may facilitate the standardisation and wider adoption of CME. However, they do not establish that proficiency in CME can be achieved de novo after a fixed number of procedures. Although the studies varied in design and surgical experience, the learning-curve analyses involved surgeons with prior minimally invasive and robotic experience and relied primarily on operating time to define proficiency [28, 34], and all anastomotic leaks in one series occurred within each surgeon's first 10 cases [28]. Assessment of oncological proficiency should extend beyond operative efficiency to include mesocolic integrity, vascular safety, completeness of central lymphadenectomy, margin status and, ultimately, recurrence.

The economic case for robotic CME remains unresolved. Longer operating times were among the most consistent disadvantages of robotic surgery [11, 13, 20, 22, 24, 25],31, and Tian et al. reported approximately 46% higher hospital expenditure without improvements in nodal yield, complications or survival [22]. Efficiency also varied by platform, with da Vinci procedures taking longer than both Dexter and laparoscopic surgery despite comparable oncological outcomes [24], and Hugo procedures taking longer than da Vinci procedures during early implementation [33], suggesting that robotic systems should not be considered a homogeneous intervention. Conversely, RoLaCaRT-1 reported a lower cumulative complication burden, fewer anastomotic leaks, shorter hospital stay and a trend towards lower surgeon workload with robotic surgery [25]. However, intracorporeal anastomosis was performed in all robotic cases but only 22% of laparoscopic cases in RoLaCaRT-1 [25], potentially confounding

differences in recovery. Future cost-effectiveness analyses should therefore account for capital and consumable costs, theatre utilisation, conversion, length of stay, complications, training, surgeon ergonomics, platform availability and case complexity.

Limitations

The evidence base consisted predominantly of retrospective, single-centre studies from specialist units with established robotic programmes, and included only one small randomised pilot trial [25], which limits generalisability. Short follow-up and heterogeneous outcome reporting further limited comparisons and precluded meta-analysis. Moreover, overlapping institutional cohorts may reduce the independence of findings and artificially inflate the evidence base [10, 11, 17–21, 26–28, 32, 34], while variation in the definition and implementation of CME complicates comparisons. Several studies reported financial relationships with robotic manufacturers [10, 11, 18, 19, 24, 25, 27, 30, 32], and RoLaCaRT-1 received industry funding from Intuitive Surgical, although the influence of these relationships on the findings remains uncertain. The evidence was also largely restricted to da Vinci platforms, with only two studies evaluating alternative systems [24, 33], limiting its applicability to newer modular platforms. Collectively, these limitations warrant caution in interpreting the findings and prevent definitive conclusions about the comparative effectiveness of robotic and laparoscopic CME.

Future research should prioritise adequately powered randomised comparisons of robotic and standardised laparoscopic CME, using the same anastomotic technique in both arms. Specimen quality should be assessed objectively, through central pathological review of mesocolic integrity, standardised vascular landmarks and operative video, rather than relying solely on the surgeon's designation of the procedure as CME. Long-term recurrence and survival should remain essential endpoints, alongside conversion, vascular injury, recovery, surgeon ergonomics, learning curves, platform-specific performance and formal health-economic evaluation. Prespecified subgroup analyses of obesity, complex vascular anatomy, locally advanced disease and other technically demanding scenarios may help identify the patients most likely to benefit from robotic assistance.

Conclusions

Robotic CME/CVL has evolved from an experimental technique into a reproducible approach capable of delivering high-quality oncological resection, with generally low conversion rates, acceptable morbidity and favourable long-term oncological outcomes. However, current evidence does not demonstrate that the robotic platform itself improves cancer control. The value of robotics may instead lie in improving the technical reproducibility of an already-defined oncological operation, through greater control during central vascular dissection, lower conversion, structured implementation and preservation of quality in difficult patients. These potential benefits must be weighed against longer operating times, higher costs and the predominance of specialist-centre data. At present, robotic CME/CVL should be regarded as an alternative to laparoscopic CME, rather than a proven superior standard. Its future role will depend on

demonstrating clinically meaningful and cost-effective benefits, particularly in complex patients and in the wider implementation of CME beyond expert centres.

Declarations

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript and have no financial or non-financial interests to disclose.

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Amelia Simenacz, Christos Damaskos and Nikolaos Garmpis The first draft of the manuscript was written by Amelia Simenacz and Christos Damaskos and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

References

1. Hohenberger W, Weber K, Matzel K, Papadopoulos T, Merkel S (2009) Standardized surgery for colonic cancer: complete mesocolic excision and central ligation–technical notes and outcome. Colorectal Dis 11(4):354–364 discussion 364-5. 10.1111/j.1463-1318.2008.01735.x
2. Seow-En I, Chen WT (2022) Complete mesocolic excision with central venous ligation/D3 lymphadenectomy for colon cancer - A comprehensive review of the evidence. Surg Oncol 42:101755. 10.1016/j.suronc.2022.101755
3. Sica GS, Vinci D, Siragusa L, Sensi B, Guida AM, Bellato V, García-Granero Á, Pellino G (2023) Definition and reporting of lymphadenectomy and complete mesocolic excision for radical right colectomy: a systematic review. Surg Endosc 37(2):846–861. 10.1007/s00464-022-09548-5
4. Brown KGM, Ng KS, Solomon MJ, Chapuis PH, Koh CE, Ahmadi N, Austin KKS (2024) Complete mesocolic excision for colon cancer: current status and controversies. ANZ J Surg 94(3):309–319. 10.1111/ans.18741
5. Siani LM, Garulli G (2016) Laparoscopic complete mesocolic excision with central vascular ligation in right colon cancer: A comprehensive review. World J Gastrointest Surg 8(2):106–114. 10.4240/wjgs.v8.i2.106
6. Lu J, Xing J, Zang L, Zhang C, Xu L, Zhang G, He Z, Sun Y, Feng Y, Du X, Hu S, Chi P, Huang Y, Wang Z, Zhong M, Wu A, Zhu A, Li F, Xu J, Kang L, Suo J, Deng H, Ye Y, Ding K, Xu T, Zhang Y, Zhang Z, Zheng M, Su X, Xiao Y (2024) RELARC study group. Extent of Lymphadenectomy for Surgical Management of Right-Sided Colon Cancer: The Randomized Phase III RELARC Trial. J Clin Oncol 42(33):3957–3966. 10.1200/JCO.24.00393
7. Degiuli M, Aguilar AHR, Solej M, Azzolina D, Marchiori G, Corcione F, Bracale U, Peltrini R, Di Nuzzo MM, Baldazzi G, Cassini D, Sica GS, Pirozzi B, Muratore A, Calabrò M, Jovine E, Lombardi R, Anania G, Chiozza M, Petz W, Pizzini P, Persiani R, Biondi A, Reddavid R (2024) A Randomized Phase III Trial of Complete Mesocolic Excision Compared with Conventional Surgery for Right Colon Cancer: Interim Analysis of a Nationwide Multicenter Study of the Italian Society of Surgical Oncology

Colorectal Cancer Network (CoME-in trial). Ann Surg Oncol 31(3):1671–1680. 10.1245/s10434-023-14664-0

8. Piozzi GN, Subramaniam S, Duhoky R, Hohenberger W, Khan JS (2024) Robotic Complete Mesocolic Excision for Right Colon Cancer: Learning Curve, Training, Techniques, Approach, Platforms, and Future Perspectives. Laparosc Endosc Robot Surg 753–59. 10.1016/j.lers.2024.04.001
9. Tejedor P, Francis N, Jayne D, Hohenberger W, Khan J, CME Project Working Group (2022) Consensus statements on complete mesocolic excision for right-sided colon cancer-technical steps and training implications. Surg Endosc 36(8):5595–5601. 10.1007/s00464-021-08395-0
10. Spinoglio G, Marano A, Bianchi PP, Priora F, Lenti LM, Ravazzoni F, Formisano G (2016) Robotic Right Colectomy with Modified Complete Mesocolic Excision: Long-Term Oncologic Outcomes. Ann Surg Oncol 23(Suppl 5):684–691. 10.1245/s10434-016-5580-x
11. Spinoglio G, Bianchi PP, Marano A, Priora F, Lenti LM, Ravazzoni F, Petz W, Borin S, Ribero D, Formisano G, Bertani E (2018) Robotic Versus Laparoscopic Right Colectomy with Complete Mesocolic Excision for the Treatment of Colon Cancer: Perioperative Outcomes and 5-Year Survival in a Consecutive Series of 202 Patients. Ann Surg Oncol. ;25(12):3580–3586. 10.1245/s10434-018-6752-7. Epub 2018 Sep 14. Erratum in: Ann Surg Oncol. 2019;26(Suppl 3):884. doi: 10.1245/s10434-019-07267-1
12. Bae SU, Yang SY, Min BS (2019) Totally robotic modified complete mesocolic excision and central vascular ligation for right-sided colon cancer: technical feasibility and mid-term oncologic outcomes. Int J Colorectal Dis 34(3):471–479. 10.1007/s00384-018-3208-2
13. Yozgatli TK, Aytac E, Ozben V, Bayram O, Gurbuz B, Baca B, Balik E, Hamzaoglu I, Karahasanoglu T, Bugra D (2019) Robotic Complete Mesocolic Excision Versus Conventional Laparoscopic Hemicolectomy for Right-Sided Colon Cancer. J Laparoendosc Adv Surg Tech A 29(5):671–676. 10.1089/lap.2018.0348
14. Schulte Am Esch J, Iosivan SI, Steinfurth F, Mahdi A, Förster C, Wilkens L, Nasser A, Sarikaya H, Benhidjeb T, Krüger M (2019) A standardized suprapubic bottom-to-up approach in robotic right colectomy: technical and oncological advances for complete mesocolic excision (CME). BMC Surg 19(1):72. 10.1186/s12893-019-0544-2
15. Spinoglio G, Petz W, Borin S, Piccioli AN, Bertani E (2019) Robotic right colectomy with complete mesocolic excision and indocyanine green guidance. Minerva Chir 74(2):165–169. 10.23736/S0026-4733.18.07831-8
16. Ramachandra C, Sugoor P, Karjol U, Arjunan R, Altaf S, Patil V, Kumar H, Beesanna G, Abhishek M (2020) Robotic Complete Mesocolic Excision with Central Vascular Ligation for Right Colon Cancer: Surgical Technique and Short-term Outcomes. Indian J Surg Oncol 11(4):674–683. 10.1007/s13193-020-01181-9
17. Larach JT, Rajkomar AKS, Narasimhan V, Kong J, Smart PJ, Heriot AG, Warrier SK (2021) Robotic complete mesocolic excision and central vascular ligation for right-sided colon cancer: short-term outcomes from a case series. ANZ J Surg 91(1–2):117–123. 10.1111/ans.16224

18. Siddiqi N, Stefan S, Jootun R, Mykoniatis I, Flashman K, Beable R, David G, Khan J (2021) Robotic Complete Mesocolic Excision (CME) is a safe and feasible option for right colonic cancers: short and midterm results from a single-centre experience. Surg Endosc 35(12):6873–6881. 10.1007/s00464-020-08194-z
19. Bianchi PP, Salaj A, Giuliani G, Ferraro L, Formisano G (2021) Feasibility of robotic right colectomy with complete mesocolic excision and intracorporeal anastomosis: short-term outcomes of 161 consecutive patients. Updates Surg 73(3):1065–1072. 10.1007/s13304-021-01001-x
20. Khan JS, Ahmad A, Odermatt M, Jayne DG, Ahmad NZ, Kandala N, West NP (2021) Robotic complete mesocolic excision with central vascular ligation for right colonic tumours - a propensity score-matching study comparing with standard laparoscopy. BJS Open 5(2):zrab016. 10.1093/bjsopen/zrab016
21. Larach JT, Flynn J, Wright T, Rajkomar AKS, McCormick JJ, Kong J, Smart PJ, Heriot AG, Warrier SK (2022) Robotic complete mesocolic excision versus conventional robotic right colectomy for right-sided colon cancer: a comparative study of perioperative outcomes. Surg Endosc 36(3):2113–2120. 10.1007/s00464-021-08498-8
22. Tian Y, Xiong D, Xu M, Fan Q, Zheng H, Shen H, Huang B, Wang L, Li C, Zhang A, Liu B, Li F, Gao F, Tong W (2023) Robotic versus laparoscopic right hemicolectomy with complete mesocolic excision: a retrospective multicenter study with propensity score matching. Front Oncol 13:1187476. 10.3389/fonc.2023.1187476
23. Nonaka T, Tominaga T, Takamura Y, Kaido O, Noda K, Sawai T, Matsumoto K (2025) Robotic versus laparoscopic right hemicolectomy with complete mesocolic excision using a cranial approach: a propensity score-matched retrospective cohort study. Tech Coloproctol 29(1):181. 10.1007/s10151-025-03223-2
24. Pochhammer J, Franke F, Martin M, Beckmann JH, Osmonov D, Alkatout I, Becker T (2025) Right Colectomy with Complete Mesocolic Excision and Intracorporeal Anastomosis: A Monocentric, Single-Surgeon Comparison of Dexter, DaVinci and Laparoscopic Approaches. Life (Basel) 15(7):1122. 10.3390/life15071122
25. Stevenson ARL, Khan JS, Wilson K, O'Connell RL, Pillinger S, Lynch C, Francis NK, Curtis NJ, Miskovic D, Clouston AD, Miller GC, Chow CFK, Warrier S, Heriot AG, Tonkin D, Bell S, Muhlmann MD, Austin KKS, Gillespie CJ, Larson DW, Temple L, Pigazzi A, Mercieca-Bebber R, Simes J (2026) RoLaCaRT-1: pilot randomised phase II study of robotic vs laparoscopic hemicolectomy for right colon cancer. Surg Endosc 40(3):2062–2077. 10.1007/s00464-025-12400-1
26. Ferraro L, Formisano G, Salaj A, Giuratrabocchetta S, Giuliani G, Salvischiani L, Bianchi PP (2022) Robotic right colectomy with complete mesocolic excision: Senior versus junior surgeon, a case-matched retrospective analysis. Int J Med Robot 18(3):e2383. 10.1002/rcs.2383
27. Van Eetvelde E, Duhoky R, Piozzi GN, Perez D, Jacobs-Tulleneers-Thevissen D, Khan J, Bianchi PP, Ruiz MG (2025) European multicentre analysis of the implementation of robotic complete mesocolic excision for right-sided colon tumours. Colorectal Dis 27(1):e17287. 10.1111/codi.17287

28. Madarasz Z, Nowakowski K, Leitz M, Sturzu BC, Baltamar A, Baginski K, Hoyer A, Hoeppner J, Nimczewski F, Vladimirov M (2026) Robotic right colectomy with complete mesocolic excision, central vascular ligation and hand-sewn intracorporeal anastomosis: feasibility, safety, and learning curve analysis. Front Surg 12:1740276. 10.3389/fsurg.2025.1740276
29. Miyakawa T, Ochiai K, Guraieb-Trueba M, Ramamurthy J, Behman R, Messick CA, Nguyen S, Konishi T, Chang GJ (2026) Comparison of surgical outcomes of robotic complete mesocolic excision for right-sided colon cancer in obese versus non-obese patients. Surg Endosc 40(5):3873–3883. 10.1007/s00464-026-12650-7
30. Hill MB, Tawantanakorn T, Gonen M, Garcia-Aguilar J, Weiser MR (2026) Robotic Right Hemicolectomy with Complete Mesocolic Excision and D3 Lymphadenectomy: Perioperative Complications and Oncologic Outcomes. Surg Oncol Insight 3(1):100213. 10.1016/j.soi.2025.100213
31. Magarini R, Achilli P, Carnevali P, Origi M, Talamo G, Frattaruolo C, Larson DW, Ferrari G (2026) Robotic versus laparoscopic surgery for right-sided colon cancer: is it better for central lymph nodes harvesting in right colectomy with complete mesocolic excision? Surg Endosc. 19. 10.1007/s00464-026-13275-6
32. Nowakowski K, Wesselmann L, Leitz M, Nimczewski F, Hoyer A, Baginski K, Hiller W, Hoeppner J, Madarasz Z (2026) Comparative Outcomes of Open, Laparoscopic, and Robotic Right Colectomy for Colon Cancer: Postoperative Recovery, Surgical Quality, and 3-Year Survival-A Monocentric Retrospective Study. Cancers (Basel) 18(17):2769. 10.3390/cancers18172769
33. Hiramatsu K, Toda S, Matoba S, Maeda Y, Okazaki N, Fukui Y, Hanaoka Y, Ueno M, Kuroyanagi H (2026) Early implementation and feasibility of Hugo RAS system-assisted right colectomy for right-sided colon cancer: an exploratory propensity score-matched comparison with the da Vinci surgical system. Surg Endosc 17. 10.1007/s00464-026-13344-w
34. Madarasz Z, Baginski K, Hoyer A, Michel J, Nowakowski K, Leitz M, Nimczewski F, Hoeppner J (2026) Surgeon- and procedure-specific variability in operative-time learning curves during parallel implementation of robotic colorectal surgery. Front Oncol 16:1905964. 10.3389/fonc.2026.1905964

Figures

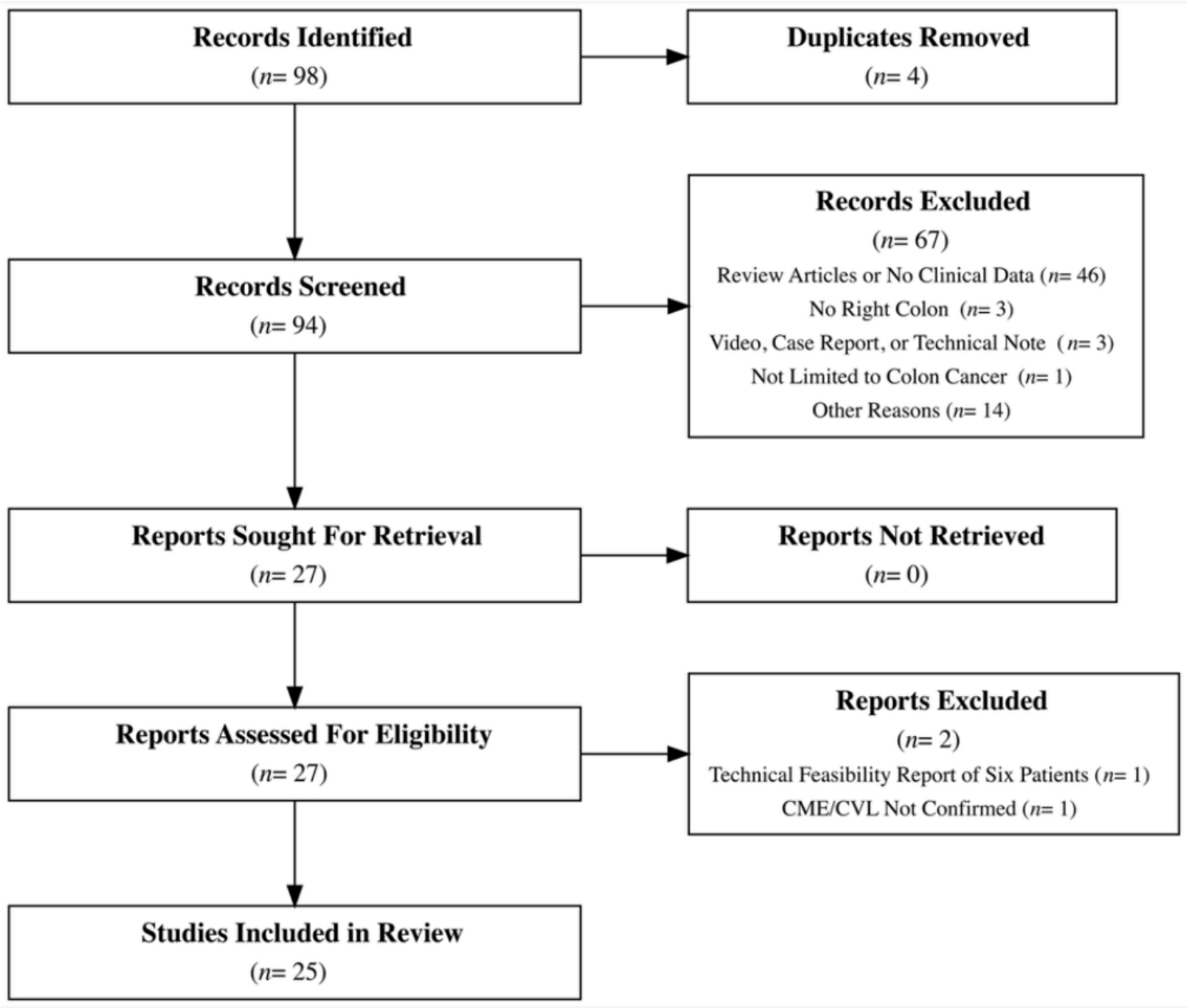


Figure 1

PRISM Flow Diagram