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Safety of robotic right hemicolectomy: A pooled analysis of individual patient data from two international prospective datasets (EAGLE-1 and EAGLE-2)

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Abstract

Background: Anastomotic leak is the leading cause of serious morbidity after right hemicolectomy. Digital training interventions in the EAGLE programme have reduced leak rates, but the impact of robotic surgery on safety remains uncertain. This sub-analysis of the EAGLE 1 trial and EAGLE 2 prospective cohort evaluated outcomes after robotic right hemicolectomy compared with laparoscopic and open approaches.

Methods: Adults undergoing right hemicolectomy, ileocolic resection or extended right hemicolectomy with primary anastomosis were included. Operative approach was classified as open, laparoscopic or robotic. The primary outcomes were 30-day anastomotic leak and major complications, defined as Clavien-Dindo grade III-V. Secondary outcomes were reoperation, readmission, unplanned critical care admission, mortality and length of stay. Multilevel multivariable logistic regression was used, with hospital nested within study as a random effect and adjustment for age, sex, ASA grade, urgency, contamination and EAGLE intervention status.

Results: Of 6,294 eligible patients, 3,122 (49.6%) underwent laparoscopic, 2,895 (46.0%) open and 277 (4.4%) robotic surgery. Robotic procedures comprised 83 cases in EAGLE 1 and 194 in EAGLE 2; most were elective (94.2%) malignancy resections performed by consultant colorectal surgeons. Overall, anastomotic leak occurred in 4.3% of robotic cases and mortality in 0.4%. In adjusted analyses, robotic surgery was comparable to laparoscopy for major complications (odds ratio 0.88, 95% confidence interval 0.56-1.38; P = 0.571) and anastomotic leak (odds ratio 0.71, 0.38-1.30; P = 0.263). In elective procedures, outcomes for robotic surgery remained similar to laparoscopy in both EAGLE 1 and EAGLE 2.

Conclusion: Robotic right hemicolectomy appears safe in contemporary practice, with anastomotic leak, major complication and mortality rates comparable to laparoscopic surgery and more favourable than open surgery after adjustment for case mix. These findings support robotic surgery as an effective minimally invasive option for right hemicolectomy, while identifying the need for future studies that incorporate cost effectiveness and longer term oncological and patient reported outcomes.

**Collaborating authors are listed in the Appendix*

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Introduction

Anastomotic leak remains the most serious complication following right hemicolectomy, affecting approximately 8% of patients and accounting for nearly one-third of postoperative deaths[1]. Despite advances in perioperative care, variation in leak rates persists globally, reflecting differences in patient selection, technical performance, and perioperative decision-making[1-3]. Over the past decade, robotic surgery has transitioned from an experimental adjunct to an established minimally invasive option in colonic resection. Recent international data demonstrate steady growth in utilisation, with robotic colectomy rates rising from 2-30% in early multicentre

audits[4-5]. This progress has occurred alongside expanding global access, with robotic colectomies now reported from both high- and middle-income settings. Ongoing evaluation of clinical outcomes, cost-effectiveness and equity of access remains essential.

The Safe Anastomosis EAGLE was a study designed to address the challenges of variation in surgical practice in decision making around right colectomy and anastomosis through digital training interventions[6]. The online training introduced the surgeons to three pillars: risk stratification calculator, in theatre checklist and safe anastomosis techniques. The cluster-randomised EAGLE-1 trial showed that surgeon participation in Safe-anastomosis training reduced leak rates. The intervention was delivered at the surgeons' level, but the outcomes were measured at the patient level[6]. The subsequent prospective international cohort, EAGLE-2, further tested these benefits in real-world practice across 60 countries[7]. Within these cohorts, minimally invasive approaches, including robotic surgery, were increasingly used[6].

This sub-analysis aimed to evaluate the safety and effectiveness of robotic right colectomy compared with laparoscopic and open approaches from the prospective cohorts from the EAGLE-1 and EAGLE-2 studies. The focus was on anastomotic leak and major postoperative complications. This represents an analysis of high-quality, prospective, international cohorts of right-sided colectomy performed using robotic surgery compared to laparoscopic and open surgery.

Methods

Study Design and Population

This was a pre-planned sub-analysis. This study was conducted according to guidelines set by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for observational studies Supplementary Table 1[8]. Data were collected as part of the EAGLE-1 cluster randomised controlled trial (2019-2022)(6) and EAGLE-2 prospective international cohort study (2024)[7]. The methods and findings of these studies were published previously[6,7,9].

Table 1: Number of robotic cases by country from EAGLE-1 and EAGLE-2 studies

EAGLE-1			EAGLE-2		
Country (n=15)	**Hospitals (n=26)**	**Patients (n=83)**	**Country (n=19)**	**Hospitals (n=52)**	**Patients (n=194)**
Argentina	2	2 (2.4%)			
			Australia	2	2 (1.0%)
			Austria	1	1 (0.5%)
Brazil	1	2 (2.4%)			
			Bulgaria	1	2 (1.0%)
			Czechia	2	5 (2.6%)
Denmark	1	5 (6.0%)	Denmark	2	8 (4.1%)
France	1	1 (1.2%)			
Germany	1	1 (1.2%)	Germany	1	3 (1.6%)
Greece	1	4 (4.8%)	Greece	2	8 (4.1%)
Hong Kong	1	4 (4.8%)			
			Hungary	1	2 (1.0%)
India	2	2 (2.4%)	India	2	3 (1.6%)
			Ireland	2	8 (4.1%)
Italy	6	22 (26.5%)	Italy	22	95 (49.0%)
			Japan	1	1 (0.5%)
Portugal	1	2 (2.4%)	Portugal	1	5 (2.6%)
Russia	1	3 (3.6%)	Russia	1	5 (2.6%)
Singapore	1	2 (2.4%)	Singapore	1	2 (1.0%)
Spain	4	26 (31.3%)	Spain	5	21 (10.8%)
Taiwan	1	1 (1.2%)	Taiwan	1	2 (1.0%)
			Turkey	1	1 (0.5%)
UK	2	6 (7.2%)	UK	4	20 (10.3%)

Any hospital that offered elective or emergency right colectomy surgery was eligible for participation. Study approvals for participating hospitals were secured in line with local and national regulations before entry into the study. Informed patient consent was obtained if this was necessary to comply with local or national regulations. In the UK, both EAGLE-1 and EAGLE-2 were registered as a clinical audit in the central co-ordinating site and registered as either an audit or service evaluation at other recruiting institutions. This was due to no interventions being directly applied to patients, rather, the training was for surgeons. Therefore, consent was not mandated from individual patients and data collected reflected standard outcomes data from electronic records. For this analysis, only robotic cases were included, with open and laparoscopic cases serving as comparators. Data were collected online and stored on a secure server running the Research Electronic Data Capture (REDCap, Vanderbilt University, Nashville, TN, USA) web application[10], based at the University of Birmingham, UK.

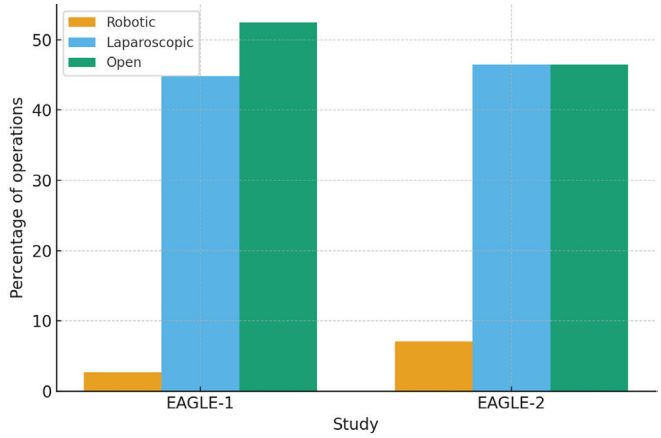

Figure 1: Distribution of surgical approaches by study

Adults undergoing right colectomy, ileocolic resection or extended right colectomy with primary anastomosis, as an emergency or elective were eligible. Exclusion criteria included patients undergoing more than one anastomosis, having additional synchronous procedures or those undergoing a second eligible operation in the data collection window. In both EAGLE-1 and EAGLE-2 the intervention was delivered at the surgeons' level, and the outcomes were collected at the patient level[6,7,9]. EAGLE-1 was a cluster randomised controlled trial where the intervention was delivered over a 4-week period where all surgeons and trainees in the hospital had access and were encouraged to complete the Safe-anastomosis digital training. Each participating hospital represented a cluster and were randomised to collect patient level outcome data either i) for 4 weeks before the intervention period, ii) for 4 weeks after the intervention period, or iii) both before and after the intervention period[6]. All consecutive eligible patients were included. National income was based on the World Bank's classification for each participating country[11]. Baseline patient characteristics included age, sex and ASA physical status. Operative variables included approach (open, laparoscopic or robotic), urgency of surgery (elective or emergency) and contamination (clean-contaminated, contaminated, dirty).

Outcomes

The primary outcomes were complications, defined as Clavien-Dindo III-V[12], and anastomotic leak, defined as radiological or clinical evidence of leakage or intra-abdominal abscess requiring drainage, or faecal fistula, within 30 days of surgery[9]. Patients missing the approach data were excluded from the analysis. Secondary outcomes were reoperation, readmission, unplanned critical care admission and mortality.

Statistical Analysis

Analyses were performed using Stata v19 (StataCorp, TX, USA)[13]. Both datasets were merged into a single pooled database. Descriptive statistics were used for country and hospital data, baseline variables, operative and outcomes data and categorised based on approach and specific study. Categorical variables are presented as frequencies and percentages, continuous variables as medians and interquartile ranges. Multilevel multivariable logistic regression assessed the association between operative approach (open, laparoscopic, robotic) and outcomes anastomotic leak and complications, adjusting for intervention effect and relevant patient and operative factors to account for covariates and reduce the risk of confounding (sex, age, ASA grade, urgency, and contamination).Hospital site was entered as a random effect nested within study to account for clustering and study effects. Results are presented as odds ratios (OR) with 95% confidence intervals (CI). A p-value <0.05

Table 2: Patient and operative factors and outcomes from robotic right hemicolectomy cases from EAGLE-1 and EAGLE-2

Variable	Levels	Robotic		Laparoscopic		Open	
		EAGLE-1 (n=83)	EAGLE-2 (n=194)	EAGLE-1 (n=1739)	EAGLE-2 (n=1383)	EAGLE-1 (n=1618)	EAGLE-2 (n=1277)
Patient factors							
Age	18-49 years	2 (2.4%)	18 (9.3%)	258 (14.8%)	239 (17.3%)	312 (19.3%)	291 (22.8%)
	50-69 years	31 (37.3%)	69 (35.6%)	613 (35.3%)	486 (35.1%)	638 (39.4%)	505 (39.5%)
	70 and over	50 (60.2%)	107 (55.2%)	868 (49.9%)	658 (47.6%)	668 (41.3%)	481 (37.7%)
Sex	Male	37 (44.6%)	102 (52.6%)	871 (50.1%)	732 (52.9%)	873 (54.0%)	721 (56.5%)
	Female	46 (55.4%)	92 (47.4%)	866 (49.9%)	651 (47.1%)	743 (46.0%)	556 (43.5%)
ASA	Grade 1-2	51 (61.4%)	123 (63.4%)	1073 (62.1%)	840 (60.7%)	861 (53.8%)	713 (55.8%)
	Grade 3-5	32 (38.6%)	71 (36.6%)	654 (37.9%)	543 (39.3%)	740 (46.2%)	564 (44.2%)
Smoker	No	60 (72.3%)	128 (66.0%)	1178 (68.2%)	926 (67.0%)	1035 (64.4%)	844 (66.1%)
	Ex smoker (stopped >6 weeks)	16 (19.3%)	34 (17.5%)	341 (19.7%)	312 (22.6%)	344 (21.4%)	248 (19.4%)
	Current smoker	7 (8.4%)	32 (16.5%)	208 (12.0%)	145 (10.5%)	229 (14.2%)	185 (14.5%)
IHD	No	65 (78.3%)	161 (83.0%)	1398 (80.5%)	1081 (78.2%)	1277 (79.0%)	996 (78.0%)
	Yes	18 (21.7%)	33 (17.0%)	339 (19.5%)	302 (21.8%)	340 (21.0%)	281 (22.0%)
Diabetes	No	67 (80.7%)	159 (82.0%)	1407 (81.0%)	1072 (77.6%)	1248 (77.2%)	957 (74.9%)
	Yes	16 (19.3%)	35 (18.0%)	331 (19.0%)	310 (22.4%)	369 (22.8%)	320 (25.1%)
BMI>30	No	69 (83.1%)	162 (83.5%)	1357 (78.7%)	1095 (79.2%)	1297 (80.5%)	1019 (79.8%)
	Yes	14 (16.9%)	32 (16.5%)	368 (21.3%)	288 (20.8%)	315 (19.5%)	258 (20.2%)
Operative factors							
Indication	Malignancy	81 (98.8%)	179 (92.3%)	1460 (84.2%)	1149 (83.1%)	1145 (71.0%)	918 (71.9%)
	Inflammatory bowel disease	1 (1.2%)	8 (4.1%)	152 (8.8%)	130 (9.4%)	126 (7.8%)	91 (7.1%)
	Other	0 (0.0%)	7 (3.6%)	121 (7.0%)	104 (7.5%)	342 (21.2%)	267 (20.9%)
Primary operating surgeon	Consultant colorectal	75 (90.4%)	161 (83.0%)	1125 (64.8%)	858 (62.0%)	590 (36.5%)	469 (36.7%)
	Trainee colorectal	1 (1.2%)	2 (1.0%)	246 (14.2%)	116 (8.4%)	160 (9.9%)	130 (10.2%)
	Consultant general	7 (8.4%)	29 (14.9%)	254 (14.6%)	325 (23.5%)	589 (36.4%)	518 (40.6%)
	Trainee general	0 (0.0%)	2 (1.0%)	111 (6.4%)	84 (6.1%)	278 (17.2%)	160 (12.5%)
Urgency	Elective	82 (98.8%)	179 (92.3%)	1454 (83.6%)	1140 (82.4%)	816 (50.5%)	718 (56.3%)
	Emergency	1 (1.2%)	15 (7.7%)	285 (16.4%)	243 (17.6%)	801 (49.5%)	558 (43.7%)
Contamination	Clean-contaminated	81 (97.6%)	192 (99.0%)	1637 (94.2%)	1304 (94.3%)	1247 (77.3%)	981 (76.8%)
	Contaminated	2 (2.4%)	2 (1.0%)	86 (5.0%)	65 (4.7%)	236 (14.6%)	194 (15.2%)
	Dirty	0 (0.0%)	0 (0.0%)	14 (0.8%)	14 (1.0%)	130 (8.1%)	102 (8.0%)
Outcomes							
Blood loss>1L	No	83 (100.0%)	194 (100.0%)	1717 (98.7%)	1373 (99.3%)	1538 (95.1%)	1238 (96.9%)
	Yes	0 (0.0%)	0 (0.0%)	22 (1.3%)	10 (0.7%)	80 (4.9%)	39 (3.1%)
Operating time >4h	No	55 (66.3%)	184 (94.8%)	1583 (91.0%)	1343 (97.1%)	1495 (92.4%)	1225 (95.9%)
	Yes	28 (33.7%)	10 (5.2%)	156 (9.0%)	40 (2.9%)	123 (7.6%)	52 (4.1%)
Ureteric/ vascular injury	No	83 (100.0%)	192 (99.0%)	1727 (99.3%)	1370 (99.1%)	1584 (97.9%)	1252 (98.0%)
	Yes	0 (0.0%)	2 (1.0%)	12 (0.7%)	13 (0.9%)	34 (2.1%)	25 (2.0%)
Length of stay (days)	Median (IQR)	5 (4 - 7)	6 (4 - 8)	6 (5 - 9)	6.0 (5 - 9)	9 (7 - 14)	8 (6 - 14)
	Range	0-53	0-60	2-30	1-30	2-30	2-30
Critical care	No	72 (86.7%)	151 (77.8%)	1355 (79.0%)	1032 (75.3%)	999 (62.4%)	774 (62.0%)
	Planned	9 (10.8%)	39 (20.1%)	324 (18.9%)	305 (22.3%)	525 (32.8%)	396 (31.7%)
	Unplanned	2 (2.4%)	4 (2.1%)	37 (2.2%)	33 (2.4%)	78 (4.9%)	79 (6.3%)
Anastomotic leak	No	78 (94.0%)	186 (95.9%)	1600 (92.9%)	1277 (93.3%)	1385 (86.1%)	1045 (83.7%)
	Yes	5 (6.0%)	8 (4.1%)	122 (7.1%)	91 (6.7%)	224 (13.9%)	204 (16.3%)
Re-operation	No	77 (92.8%)	187 (96.4%)	1617 (94.0%)	1289 (94.6%)	1465 (91.3%)	1119 (89.6%)
	Yes	6 (7.2%)	7 (3.6%)	103 (6.0%)	74 (5.4%)	140 (8.7%)	130 (10.4%)
Re-admission	No	80 (96.4%)	186 (95.9%)	1617 (94.1%)	1290 (94.6%)	1484 (92.5%)	1130 (90.5%)
	Yes	3 (3.6%)	8 (4.1%)	102 (5.9%)	73 (5.4%)	120 (7.5%)	119 (9.5%)
Mortality	No	83 (100.0%)	193 (99.5%)	1698 (98.8%)	1345 (98.7%)	1491 (93.0%)	1173 (93.9%)
	Yes	0 (0.0%)	1 (0.5%)	21 (1.2%)	18 (1.3%)	113 (7.0%)	76 (6.1%)

Table 3: Adjusted analysis of complications* and anastomotic leak following right colectomy in EAGLE-1 and EAGLE-2 combined data comparing different operative approaches (laparoscopic, open, robotic)

		Complications		Anastomotic leak	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Approach	Laparoscopic	Reference		Reference	
	Open	1.58 (1.33 – 1.88)	<0.001	1.71 (1.38 - 2.11)	<0.001
	Robotic	0.88 (0.56 - 1.38)	0.571	0.71 (0.38 - 1.30)	0.263
Sex	Female	Reference		Reference	
	Male	1.12 (0.96 - 1.30)	0.146	1.15 (0.96 - 1.38)	0.126
Age	<50 years	Reference		Reference	
	50-69 years	1.21 (0.96 - 1.53)	0.101	0.90 (0.70 - 1.16)	0.408
	>70 years	1.37 (1.08 - 1.74)	0.010	0.84 (0.64 - 1.10)	0.197
ASA grade	Grade 1-2	Reference		Reference	
	Grade 3-5	1.81 (1.54 - 2.14)	<0.001	1.43 (1.17 - 1.74)	0.001
Urgency	Elective	Reference		Reference	
	Emergency	1.78 (1.49 - 2.13)	<0.001	1.23 (0.99 - 1.53)	0.063
Contamination	Clean-contaminated	Reference		Reference	
	Contaminated	1.71 (1.35 - 2.18)	<0.001	2.47 (1.88 - 3.24)	<0.001
	Dirty	3.24 (2.36 - 4.45)	<0.001	2.58 (1.79 - 3.72)	<0.001

*Adjusted for sex, age, ASA grade, urgency, contamination and EAGLE training intervention effect. *Complications included any of the following: readmission, re-operation, unplanned admission to critical care, death (Clavien-Dindo 3-5)*

indicated statistical significance. This analysis was performed for the pooled database and separately for EAGLE-1 and EAGLE-2, and in elective patients only.

Results

Study Population

Across EAGLE-1 and EAGLE-2, 277 patients underwent robotic right hemicolectomy (83 in EAGLE-1; 194 in EAGLE-2), out of a total of 6295 patients across EAGLE-1 and EAGLE-2 and across all approaches (open, laparoscopic and robotic) with 1 patient missing data on approach. Patients were from 15 countries in EAGLE-1 and 19 in EAGLE-2, with a total of 23 different countries across both studies (Table 1). Robotic cases were spread internationally, with the highest numbers reported in Italy (49.0% of cases) and the UK (10.3%), alongside smaller contributions from 17 other countries (Table 1). Operative approaches differed between cohorts, with robotic use increasing from 2.4% in EAGLE-1 to 6.8% in EAGLE-2 (Table 2, Supplementary Table 2). In robotic surgery, most procedures were elective (94.2%) and performed by consultant colorectal surgeons (Table 2). Median age was 67 years (IQR 58–75). Malignancy was the primary indication (93.9%), and common comorbidities included diabetes (18.4%) and ischaemic heart disease (18.4%, Table 2).

Overall Outcomes

Anastomotic leak occurred in 6.0% of EAGLE-1 and 4.1% of EAGLE-2 robotic cases. Reoperation rates decreased from 7.2% in EAGLE-1 to 3.6% in EAGLE-2. Mortality was 0.5% in EAGLE-2 robotics cases with no deaths in EAGLE-1. Median length of stay was 5 days (IQR 4-7) in EAGLE-1 and 6 days (IQR 4-8) in EAGLE-2 (Table 2).

Adjusted Analysis

Outcomes were comparable between robotic and laparoscopic approaches. (Table 3-5, Supplementary Table 3-5). Compared with laparoscopic surgery, robotic surgery was comparable: overall complications (OR 0.88, 95% CI 0.56–1.38; p=0.571) and anastomotic leak (OR 0.71, 95% CI 0.38–1.30; p=0.263) Table 3. In elective-only procedures, robotic surgery showed similar outcomes when compared to laparoscopic surgery and improvement in outcomes over time with EAGLE-1 showing complications OR 1.18 for robotics (95% CI 0.56–2.54; p=0.657) and EAGLE-2 showing complications OR 0.86 (95% CI 0.51–1.45; p=0.566) Table 4. A similar trend was seen for anastomotic leak in elective only surgery: EAGLE-1 showing an OR 1.05 for anastomotic leak (95% CI 0.41–2.68; p=0.913) and EAGLE-2 showing an OR 0.70 (95% CI 0.32-1.56, p=0.386, Table 5).

Table 4: Adjusted analysis of complications* following elective right colectomy in EAGLE-1 and EAGLE-2 comparing different operative approaches (open, laparoscopic, robotic)

Complications		EAGLE-1		EAGLE-2	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Approach	Laparoscopic	Reference		Reference	
	Open	1.58 (1.22–2.04)	<0.001	1.62 (1.24–2.10)	<0.001
	Robotic	1.18 (0.56–2.54)	0.657	0.86 (0.51–1.45)	0.566
Sex	Female	Reference		Reference	
	Male	1.12 (0.86–1.47)	0.391	1.00 (0.74–1.35)	0.999
Age	<50 years	Reference		Reference	
	50-69 years	1.11 (0.71–1.73)	0.648	0.97 (0.61–1.54)	0.887
	>70 years	1.20 (0.76–1.88)	0.440	0.92 (0.57–1.49)	0.731
ASA grade	Grade 1-2	Reference		Reference	
	Grade 3-5	1.71 (1.29–2.28)	<0.001	1.57 (1.12–2.20)	0.009
Contamination	Clean-contaminated	Reference		Reference	
	Contaminated	1.30 (0.71–2.39)	0.399	1.97 (0.99–3.91)	0.054
	Dirty	2.16 (0.41–11.29)	0.363	4.48 (1.15–17.41)	0.030

*Adjusted for sex, age, ASA grade, contamination and EAGLE training intervention effect. *Complications included any of the following: readmission, re-operation, unplanned admission to critical care, death (Clavien-Dindo 3-5)*

Discussion

This analysis provides a prospective international evaluation of robotic right colectomy from two high-quality studies[6,7]. Three key findings emerge: robotic surgery is associated with safe outcomes, low anastomotic leak and low mortality rates; it is effective, reducing complications and leak compared with open surgery; and it is comparable to laparoscopic approaches as an additional minimally invasive approach. These results are likely to be driven by centralised robotics services from high volume surgeons and teams operating on well selected patients. Therefore, a degree of selection bias is present. However, excellent results can be found in the adoption and expansion of robotic right colonic surgery. Enhanced visualisation, dexterity, and ergonomics of robotic platforms may contribute towards the observed reduction in leak risk, facilitating precise vascular ligation and tension-free anastomosis. There is scope for some surgeons to convert their practice directly from open surgery to robotics surgery with good outcomes, but open surgery remains the foundation of emergency surgery and perhaps for higher risk elective patients (e.g. multiple prior operations). 92% of procedures were performed by colorectal surgeons, which may have impacted the results. Specialised colorectal procedures may well benefit from being undertaken by colorectal surgeons rather than general surgeons and only in highly specialised centres. Maintaining high volumes for

Table 5: Adjusted analysis of anastomotic leak following elective right colectomy in EAGLE-1 and EAGLE-2 comparing different operative approaches (open, laparoscopic, robotic)

Anastomotic leak		EAGLE-1		EAGLE-2	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Approach	Laparoscopic	Reference		Reference	
	Open	1.57 (1.16–2.10)	0.003	2.15 (1.53–3.01)	<0.001
	Robotic	1.05 (0.41–2.68)	0.913	0.70 (0.32–1.56)	0.386
Sex	Female	Reference		Reference	
	Male	1.40 (1.02–1.92)	0.038	1.11 (0.78–1.59)	0.549
Age	<50 years	Reference		Reference	
	50-69 years	0.69 (0.43–1.10)	0.119	0.81 (0.49–1.34)	0.409
	>70 years	0.76 (0.47–1.22)	0.258	0.73 (0.42–1.24)	0.244
ASA grade	Grade 1-2	Reference		Reference	
	Grade 3-5	1.45 (1.03–2.04)	0.031	1.10 (0.73–1.65)	0.646
Contamination	Clean-contaminated	Reference		Reference	
	Contaminated	2.60 (1.45–4.69)	0.001	2.53 (1.22–5.25)	0.012
	Dirty	1.33 (0.15–11.63)	0.796	2.33 (0.52–10.42)	0.268

Adjusted for sex, age, ASA grade, contamination and intervention effect

surgeons and centres ensures optimal surgery and peri-operative care.

Strengths of this analysis include its prospective design across two large international studies, providing contemporaneous, systematically collected data on right colectomy from a broad range of health systems. The pooled cohort is sizeable, with granular capture of patient, operative and perioperative variables, including comorbidity, urgency, contamination and surgeon seniority, which allowed detailed adjustment for case mix and key confounders. Outcomes were defined a priori using standardised criteria for anastomotic leak and Clavien–Dindo complications, and follow up to thirty days was consistent with previous EAGLE work. The inclusion of hospitals from high income and lower and middle income countries enhances generalisability and reflects real-world practice across diverse settings. The use of multilevel modelling, with hospital nested within study, further strengthens internal validity by accounting for clustering and secular differences between EAGLE-1 and EAGLE-2. Importantly, this represents one of the largest prospective cohorts specifically focused on robotic right sided colectomy, addressing a clear gap in the existing literature.

Limitations must also be acknowledged, including the small number of patients at this early evolution into practice phase. EAGLE-2 was observational, and even within the trial framework of EAGLE-1 treatment allocation to operative approach was not random, so selection bias is likely, particularly for less comorbid patients and for centres with established robotic programmes. Robotic cases were predominantly elective malignancy resections undertaken by consultant colorectal surgeons in clean contaminated fields, so residual confounding by indication and case complexity may persist despite adjustment. Surgeon and centre experience, learning curves, and case volume were not modelled explicitly, although hospital was entered as a random effect, and variation in institutional capacity for rescue, including access to interventional radiology, intensive care and timely reoperation, was not captured in detail. The two contributing studies were conducted in different time periods, during which perioperative pathways and robotic adoption evolved, and global access to robotic platforms remains restricted to better resourced hospitals, limiting applicability to centres without similar infrastructure. Finally, unmeasured perioperative factors and country level or system level variables may influence outcomes in ways that this analysis cannot fully disentangle, and longer term oncological and cost effectiveness end points were not assessed.

Future research should build on these findings through larger, prospective multicentre cohorts that are specifically designed to evaluate robotic colorectal surgery across a wider range of procedures, including left sided resections, multi visceral operations and higher risk emergency indications. These studies should move beyond short term morbidity to incorporate patient centred outcomes such as days alive and at home by day 30 (DAH30), one year health related quality of life, functional recovery and longer term oncological endpoints. Standardised collection of resource use, including readmissions, unplanned critical care, rescue interventions and post discharge support, will be essential to understand the full care pathway. Embedding detailed information on surgeon volume, learning curves, platform type and institutional capability, and recruiting from both high and lower and middle income settings, would allow more robust assessment of how robotic surgery performs across different systems and case mixes, and provide the data required for credible cost effectiveness analyses that can inform national policy and guideline development.

These findings have direct policy relevance as they indicate that, within appropriately configured services, robotic right hemicolectomy delivers safety outcomes at least comparable to laparoscopy and superior to open surgery, supporting its inclusion as a standard minimally invasive option in centres with sufficient volume, training and rescue capability. At system level, the clear gradient between open and minimally invasive approaches reinforces the need to reduce unwarranted variation in operative strategy for right sided colon cancer and to concentrate robotic programmes in units that can sustain expertise and perioperative infrastructure. The adjusted risks of leak, major complications, reoperation and the observed differences in length of stay provide key inputs for formal health economic modelling, allowing decision analytic and budget impact analyses

to examine how different mixes of open, laparoscopic and robotic surgery would affect costs, bed utilisation and downstream resource use at scale. When combined with future data on days alive and at home and one year quality of life, these parameters will enable robust cost effectiveness evaluations that can inform national guidance, procurement strategies and capital investment decisions for colorectal robotic surgery.

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