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Feasibility, clinical outcomes, and learning curves of robotic-assisted colorectal cancer surgery in a high-volume district general hospital: a cohort study

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Introduction: Robotic-assisted surgery (RAS) is one of the most influential surgical advances with widespread clinical and health-economic benefits. West Hertfordshire Teaching Hospital NHS Trust was the first in the UK to simultaneously integrate two CMR Surgical Versius robots. This study aims to investigate clinical outcomes of RAS, explore surgeon learning curves and assess the feasibility of implementation within a district general hospital (DGH).

Methods: A prospective cohort study of 100 consecutive patient data were collected between July 2022 and August 2023, including demographics, operative and clinical variables, and compared with laparoscopic surgery (LS) data from the National Bowel Cancer Audit. Surgeon learning curves were analysed using sequential surgical and console times.

Results: In the RAS cohort, the median age was 70 (IQR 57–78 years) and 60% were male. Retrieval of a minimum of 12 lymph nodes significantly increased in RAS compared to LS (95% vs. 88%, $P=0.05$). The negative mesorectal margin rate was similar between RAS and LS (97% vs. 91%, $P=0.10$), as well as length of stay greater than 5 days (42% vs. 39%, $P=0.27$). For anterior resections performed by the highest volume surgeon ($n=16$), surgical time was reduced over 1 year by 35% (304.9–196.9 min), whilst console time increased by 111% (63.0–132.8 min).

Conclusions: Key quality performance indicators were either unchanged or improved with RAS. There is potential for improved theatre utilisation and cost-savings with increased RAS. This study demonstrates the feasibility and easy integration of robotic platforms into DGHs, offering wider training opportunities for the next generation of surgeons.

Keywords: colorectal surgery, learning curves, robotic assisted surgery, training

Introduction

Robotic-assisted surgery (RAS) is one of the most influential surgical advances in recent years. Although it was originally introduced in the 1980s, it has only gained clinical momentum in the last 20 years across multiple surgical specialties. RAS offers a three-dimensional, high-definition visualisation with increased dexterity for instrument manipulation in confined spaces. Multispeciality robotic surgery provides many benefits to clinicians, patients, and global health economics. The Commission on the Future of Surgery has predicted significant developments in robotic surgery to have one of the greatest impacts on transforming surgical care over the next 20 years[1]. Further improvements in robotic autonomy and machine learning are likely to contribute to major advances in future clinical applications.

Robotic technology has been embraced worldwide with growing evidence that clinical outcomes improve in the intraoperative and postoperative setting compared to the conventional laparoscopic or open approach. The advancement of novel platforms, including the next-generation surgical robotic system, uses versatile, lightweight, and portable units, allowing easy integration within the theatre setting. Initial uptake was focused on tertiary centres, but these advancements are finding popularity within district general hospitals facilitated by its evolving ergonomic design and with augmented training and mentorship that is inclusive and multispecialty[2–6].

HIGHLIGHTS

- Robotic-assisted surgery provides consistent or improved clinical outcomes.
- Robotic-assisted surgery demonstrates the potential for improved theatre utilisation and cost-savings.
- Robotic-assisted surgery can be safely integrated within district general hospitals.
- A strategic phased programme for robotic implementation within a unit is essential to allow early training opportunities for the surgical trainees.

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A recent study demonstrated an 8.4-fold increase in RAS for common surgical procedures between 2012 and 2018[7]. Current evidence demonstrates reduced conversion to open rates, improved functional outcomes and decreased length of hospital stay[8–10]. Oncological outcomes are comparable to the current standards[4,11]. Literature suggests a reduced need for rehabilitation and a quicker return to work and normal activities. There is a demonstrable benefit in improved clinical outcomes and medium to long-term costs[12]. Evaluation of the interdisciplinary collaboration that RAS offers has the potential to demonstrate a reduced burden on rehabilitation services related to invasive surgery, shorter operative times, and hospital stays, leading to the enrichment of surgical innovation and quality accessible to all. RAS systems are expensive to procure, but implementing multi-speciality RAS can offset the costs in the medium to long-term (i.e. greater than 7 years).

Robotic applications have been used for the surgical treatment of bowel cancer for over 20 years, demonstrating its safety and efficacy, particularly for total mesorectal excision (TME). A 2015 meta-analysis of eight studies found that robotic TME was associated with a lower conversion rate, reduced positive margin rate and lesser occurrence of erectile dysfunction than laparoscopic TME[13]. Other studies have also found an improved specimen quality with robotic TME, using the parameters of lymph node yield and circumferential resection margin[14,15]. There is conflicting data in the literature comparing the learning curves of RAS and conventional laparoscopic surgery, with some studies suggesting a clear robotic benefit for novice surgeons[16], and others demonstrating a steeper curve with RAS in those with prior laparoscopic experience[3,5,17].

This study was designed to (i) assess functional patient outcomes in RAS colorectal resections compared to conventional laparoscopic surgery, (ii) explore the learning curves in consultants who have fully transformed to RAS, and (iii) illustrate the feasibility of rapid implementation of robotic technology in a district general hospital.

Methods

West Hertfordshire Teaching Hospitals NHS Trust (WHTH) is a high-volume surgical centre that introduced a phased rollout programme of the CMR Versius robotic system across multiple specialties, including colorectal, upper gastrointestinal, urology, and gynaecology in 2022. All consultant colorectal surgeons completed the robotic training programme comprising interactive modules on the console and in-person training sessions.

Ethics approval

This project was not considered 'research' by the Health Research Authority (HRA). Therefore, HRA research ethics approval was not required to proceed. The service evaluation was reviewed and approved by the information governance team, and clinical lead for surgery at WHTH prior to its commencement.

Patient recruitment and data collection

A cohort study was conducted with 100 consecutive patients who underwent elective RAS colorectal cancer resections at WHTH between July 2022 and August 2023 by six colorectal surgeons. Clinical data was collected from electronic patient records and real-time data recorded during the surgery by CMR Surgical. Clinical data points included patient demographics, preoperative diagnosis and staging, operation type, and various perioperative, intraoperative, and postoperative outcomes (operation time, conversion to open rates, length of stay, analgesia usage, complications, and histology). Robotic data points included setup times, console times, and volumetric hand motion for two surgeons with the highest operative caseload. Key surgical quality indicators were compared with conventional data provided by NBOCA[18].

Primary and secondary outcomes

The primary outcome of the study was the assessment of clinical outcomes of RAS colorectal resectional surgery compared to the conventional laparoscopic outcomes recorded by NBOCA. Secondary outcomes included exploring the learning curves of robotic surgery across various resections, and review of the feasibility of implementation of the robotic platform in a district general hospital.

Statistical analysis

The statistical analysis was carried out using IBM SPSS Statistics, version 29 (IBM Corp.). To accommodate the non-normal distribution of some of our data, nonparametric tests were employed. Specifically, the Mann–Whitney U test was used to compare continuous variables such as age, BMI, operation time, length of stay, and lymph node yield between the two groups. For categorical data, such as sex distribution, incidence of complications, and conversion rates, the χ^2 test or Fisher's exact test was applied as appropriate, depending on the expected counts in each cell of the contingency tables. To analyse surgeon learning curves, we employed a descriptive analysis approach, tracking changes in operative times, setup times, and volumetric hand motions across sequential cases. This allowed for the visualisation of improvements in efficiency and technique as experience with the robotic system increased. Linear regression models were considered to quantitatively assess the relationship between case sequence number and operative metrics, providing a statistical measure of learning rate. The significance level for all tests was set at $P < 0.05$. Adjustments for multiple comparisons were not made, as this exploratory analysis aimed to generate hypotheses rather than confirm definitive outcomes. CIs were calculated to quantify the precision of the estimated effects, with a 95% confidence level employed.

Results

Patient clinical data

One hundred consecutive patients were analysed with a median age of 70 (IQR 57–78 years) and 60% were male ($n = 60$). The majority of the demographic was white British (77%, $n = 77$) followed by white other (9%, $n = 9$), Asian (4%, $n = 4$), and white Irish (4%, $n = 4$). The median BMI was 28.7 (SD = 5.5), the American Society of Anesthesiologists (ASA) grade was 2.2 (SD = 0.6), and the mean Colorectal Physiologic and Operative Severity Score for the Enumeration of Mortality and Morbidity (CR-POSSUM) was 16.8 (SD = 3.1), equating to a 2% estimated mortality. A total of 36% ($n = 36$) were diagnosed with rectal adenocarcinoma, 24% ($n = 24$) sigmoid adenocarcinoma, and 24% ($n = 24$) caecal adenocarcinoma. Synchronous tumours were identified in 4% ($n = 4$) on colonoscopy. The most common operation was a right hemicolectomy 33% ($n = 33$) followed by anterior resection 19% ($n = 19$) and abdominoperineal resection 16% ($n = 16$). Patient characteristics and clinical data are presented in Table 1.

Six of the 36 patients (16.7%) with rectal cancer received neoadjuvant chemoradiotherapy. The remaining 64 patients with alternative sites of malignancy did not undergo neoadjuvant treatment.

Clinical outcomes

The conversion to open rate was 8% ($n = 8$), of which the mean BMI was 30.7 (SD = 7.4). Four out of 14 (28%) patients with a BMI > 40 were converted to open. Indications for conversion were dense adhesions, inability to identify key structures, intraperitoneal fat and postradiotherapy changes.

Five out of 78 (6.4%) patients had an anastomotic leak, of which three returned to theatre and the remaining two were managed conservatively. Forty-seven percent of participants had no documented complications from their procedure at a mean follow-up of 149 days (SD = 113 days). The mean LOS was 6.6 days (SD = 5.1), and the risk-adjusted percentage of patients with LOS greater than 5 days was 42% ($n = 42$). The mean lymph node yield for all resections was 23 (SD = 8.5). The proportion of surgical specimens with at least 12 lymph nodes was 95.3% (95% CI: 87.7–98.7%) for colonic resections and 94.9% (95% CI: 82.8–99.3%) for rectal resections. The percentage of rectal resections with negative margins was 97.4%. Table 2 compares the key quality performance indicators of robotic-assisted surgery compared to conventional laparoscopic surgery within the unit.

Table 1

Patient characteristics ($n = 100$) undergoing elective RAS colorectal cancer resections

	Number, *n* (%)		Number, *n* (%)
Age	Median 67 (SD 13.3)	Cancer diagnosis	
Sex (M)	60 (60%)	Rectal adenocarcinoma	36 (36%)
Ethnicity		Sigmoid colon adenocarcinoma	26 (26%)
White British	77 (77%)	Caecal adenocarcinoma	15 (15%)
White, Other	9 (9%)	Ascending colon adenocarcinoma	11 (11%)
Asian	4 (4%)	Transverse colon adenocarcinoma	9 (9%)
White, Irish	4 (4%)	Hepatic flexure adenocarcinoma	5 (5%)
ASA		Splenic flexure adenocarcinoma	1 (1%)
Grade 1	9 (9%)	Neoadjuvant therapy	
Grade 2	59 (60%)	Rectal cancer ($n = 36$)	6 (16.7%)
Grade 3	31 (31%)	Colon cancer ($n = 64$)	0 (0%)
BMI		Chemotherapy and radiotherapy	4 (4%)
$18 \leq x < 25$	26 (27%)	Chemotherapy alone	0 (0%)
$25 \leq x < 30$	41 (42%)	Radiotherapy alone	2 (2%)
$30 \leq x < 35$	20 (20%)	Procedure name	
$35 \leq x < 40$	6 (6%)	Right hemicolectomy	33 (33%)
40+	5 (5%)	Anterior resection	19 (19%)
CR-POSSUM		Abdominoperineal resection	16 (16%)
$13 \leq x \leq 15$	41 (41%)	Sigmoid colectomy	13 (13%)
$16 \leq x \leq 18$	39 (39%)	Low anterior resection	12 (12%)
$19 \leq x \leq 21$	10 (10%)	Extended right hemicolectomy	8 (8%)
22+	10 (10%)	Left hemicolectomy	1 (1%)

Surgeon learning curve

Learning curves were assessed from two colorectal surgeons (S1, S2) with the highest patient caseload, for right hemicolectomies and anterior resections, displayed in Figures 1–2. The docking times of the robotic system significantly reduced by 3.6 min (37% reduction), from 10.2 min to 6.6 min over 51 cases.

Surgeon 1: Operative times decreased for right hemicolectomies by 64.7 min (33% reduction), from 194.6 min to 129.8 min over 28 cases. Anterior resections were also reduced by 108 min (35% reduction), from 304.9 min to 196.9 min over 16 cases. For right hemicolectomies, console times decreased by 3.8 min (6% reduction), from 68.9 min to 65.1 min and volumetric hand motion decreased by 4.2 cm^3 (7% reduction), from 60.1 cm^3 to 55.9 cm^3 over 28 cases. For anterior resections, the console time increased by 69.8 min (111% increase), from 63.0 min to 132.8 min and volumetric hand motion stayed the same at 56.5 cm^3 over 16 cases.

Surgeon 2: For right hemicolectomies, operative times were reduced by 3.5 min (2% reduction), from 168.4 min to 164.9 min over 13 cases. Whereas with anterior resections, there was an increase of 12 min in operative time (4% increase), from 288.0 min to 300.0 min over 10 cases. For right hemicolectomies, console times increased by 2.1 min (3% increase), from 75.5 min to 77.6 min and volumetric hand motion increased by 20.9 cm^3 (45% increase), from 46.6 cm^3 to 67.5 cm^3 over 13 cases. For anterior resections, console times decreased by 78.8 min (62% reduction), from 127.1 min to 48.4 min and volumetric hand motion increased by 12.3 cm^3 (22% increase), from 55.5 cm^3 to 67.8 cm^3 over 10 cases.

Discussion

The primary findings demonstrate the feasibility of rapid robotic implementation within a district general hospital with comparable or improved clinical outcomes. At WHTH, the total procedure volume with CMR Versius was more than double the UK average 8 months following its implementation. A transformation to robotic-assisted surgery is a national vision with the potential to offer improved clinical outcomes, ergonomic benefits to the surgeon, and an increase in valuable hospital capacity with maximised utility and cost-savings in the long-term.

The proportion of colonic resections with a lymph node yield of at least 12 and the negative margin rate of rectal cases showed improvement by 7 and 6%, respectively after transitioning to RAS, with the lymph node yield demonstrating statistical significance ($P = 0.05$). In comparison to the national rates, robotic colorectal resections showed a higher lymph node yield and negative mesorectal margin rates (national rates: 85 and 83%, respectively). A 2018 study of 463 patients suggested RAS was associated with an increased lymph node yield and improved lymph node to length of surgical specimen ratio[19], suggesting significance may be seen with a higher patient caseload.

The length of hospital stay greater than 5 days increased by 3% but remains 14% lower than the national average of 56% reported by NBOCA 2019–2022[18]. Bhama *et al.*[9] demonstrated a reduced length of stay with robotic-assisted colorectal resections when compared to CLS, of 4.3 days vs 5.3 days ($P < 0.001$). Shorter length of stay was observed in elderly populations (age > 65) for left-sided colorectal resections by 1.6 days, 5.8 days vs 4.2 days

Table 2

Outcomes from the key quality performance indicators of 100 patients undergoing robotic-assisted surgery compared to conventional laparoscopic surgery (NBOCA, $n = 442$)

	LS 2019–2022 (Trust) Proportion (%) Total $n = 442$ Rectal $n = 130$	LS 2019–2022 (National) Proportion (%) Total $n = 53\,984$ Rectal $n = 11\,869$	RAS 2022–2023 Proportion (%) Total $n = 100$ Rectal $n = 36$
Lymph node yield ≥ 12 (colon)	88%	85%	95% ($P = 0.05$)
Negative margin rate (rectal)	91%	83%	97% ($P = 0.10$)
Risk-adjusted length of stay > 5 days (all cases)	39%	56%	42% ($P = 0.27$)

Stated *P*-values compare data between LS 2019–2022 (Trust) and RAS 2022–2023 outcomes.

($P = 0.004$)[20]. Conversely, an American Nationwide analysis including 128 288 patients (2.78% underwent RAS) found similar length of stay between the robotic and laparoscopic groups. It is feasible that the already low length of stay with laparoscopic surgery may be difficult to improve further[21]. This is evidenced in our cohort, where the length of stay greater than 5 days has remained consistently below the national average.

Previous studies have shown the conversion to open rate is reduced with RAS compared to laparoscopic surgery[22–24]. In a large meta-analysis of RCTs and observational studies, Ng *et al.*[22] showed the odds ratio of conversion to open in RAS vs CLS cases to be 0.4 ($P < 0.001$). These benefits have also been demonstrated in the narrow pelvis with a large mesorectum and obesity owing to a greater range of movement within a confined space[25]. The expenditure associated with reduced conversions to open surgery can translate to increased cost-savings in the medium to long-term[26]. In our cohort, 100% of patients with class III obesity or higher ($n = 14$), had negative margins, > 12 lymph nodes resected, and none had serious complications (Clavien–Dindo Grade > 2). This supports the notion that RAS is a safe treatment modality for technically difficult cases.

The learning curve for robotic surgery has been shown to be more rapid, building on the fundamental skills of laparoscopy. As the caseload increased, docking times of the instruments effectively reduced, enhancing theatre utilisation. These findings are paralleled by other studies using the Da Vinci surgical robot demonstrating no additional time added to the case[27,28]. Different surgeon learning curves were observed with reduced operating times for right hemicolectomies and anterior resections for S1 compared to minimal change for S2. The vast difference can be attributed to S1 performing 115% more right hemicolectomies and 60% more anterior resections than S2 in the duration of this study, meaning that S1 had more opportunity for improvement. S1's trend for anterior resections showed a decreasing operating time, and an increasing console time, implying that operations were quicker when more of the operation was completed robotically. Guend *et al.*[29] analysed 418 colorectal resections performed by 5 surgeons to find that the learning curve for the first surgeon was 74 cases, with those joining later in the programme being 25–30 cases. This suggests a more rapid learning profile for surgeons within a unit who have

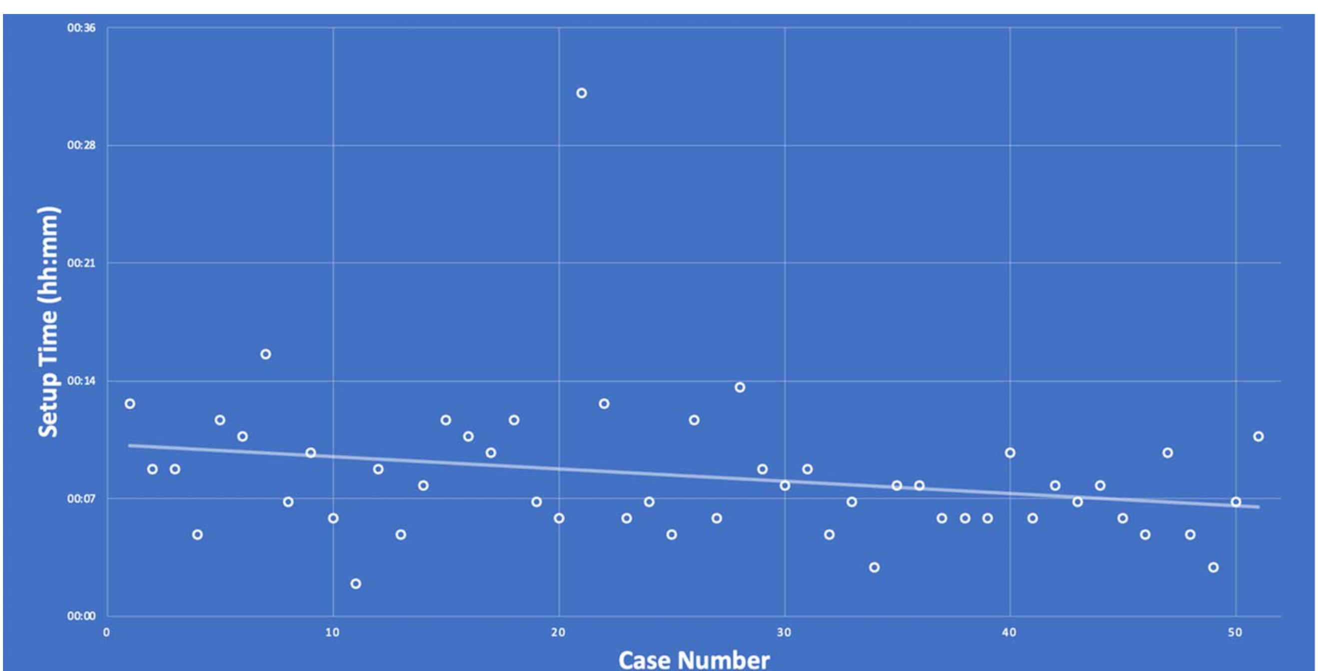

Figure 1. Consecutive robotic setup times for both right hemicolectomies and anterior resections performed by two colorectal surgeons.

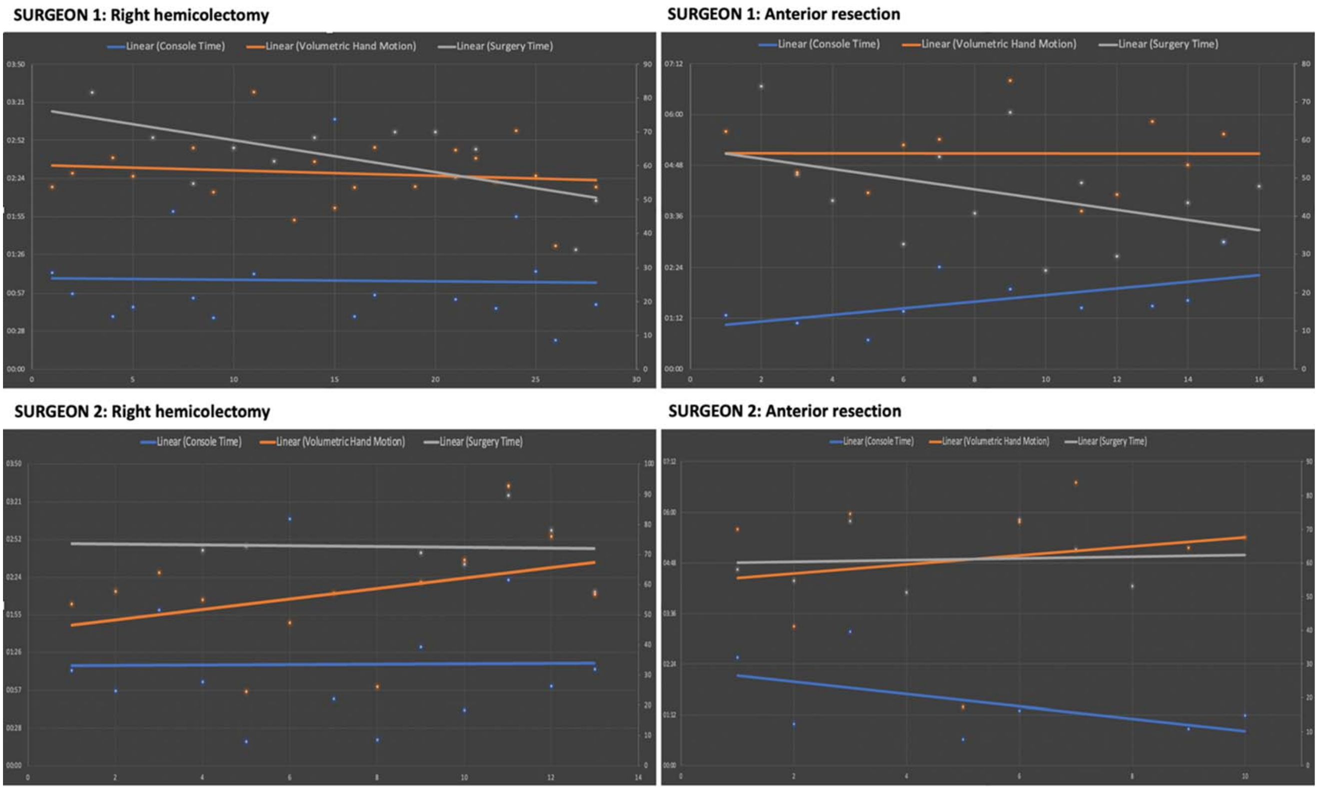

Figure 2. Graphs showing the progression of console times (operative times) and volumetric hand motions for right hemicolectomies and anterior resections for Surgeon 1 (S1) and Surgeon 2 (S2). Primary vertical axis = Time (hh:mm). Secondary vertical axis = Volume (cm^3). Horizontal axis = Case number.

an established robotic practice. On a broader note, this has the potential to translate to surgical trainees training within a robotic unit which currently does not form part of their curriculum. Robotic surgery in district general hospitals will present a wider opportunity for all trainees and may be the catalyst to embedding robot training within the current training programme.

Limitations of this study include its retrospective nature and relatively small comparative cohort of 100 patients. However, this study has demonstrated the feasibility of rapid robotic implementation within a DGH in a short timeframe. A randomised control trial comparing RAS with laparoscopic surgery would provide a higher level of evidence to show the benefits of RAS.

Conclusions

RAS is being adopted nationwide at a more rapid rate with easier integration into district general hospitals. This study has demonstrated multidimensional benefits, including the feasibility, safety, and achievement of key performance indicators. Clinical outcomes were seen to be maintained or improved overall with lymph node yield and negative mesorectal margins. There was minimal margin for improvement with length of stay with already below averages rates compared to the national average. Overall, robotic platforms have the potential to capture and audit surgical data precisely, and this scrutiny will enhance and enrich surgical technique and training in the wider district general hospital setting.

Ethical approval

This project was not considered 'research' by the Health Research Authority (HRA). Therefore, HRA research ethics approval was not required to proceed. The service evaluation was reviewed and approved by the information governance team, and clinical lead for surgery at WHTH prior to its commencement.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

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Author contribution

S.M.: data collection and writing the paper; B.V.: data interpretation and writing the paper; A.A.R.: data and statistical analysis; J.H.: data interpretation and critical edits; V.P.: study design and concept, critical edits, and final review.

Conflicts of interest disclosure

The authors declare no conflicts of interest.

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Not applicable.

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Presentation

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