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European Association of Urology

Bladder Cancer

10-yr Outcomes of Senior Clinical Fellowship in Robot-assisted Radical Cystectomy (RARC) with focus on Intracorporeal Ileal Conduit Urinary Diversion: Aggregated Learning Curve Assessment and Achievement of the EAU-Robotic Urology Section (ERUS) RARC Curriculum

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Abstract

Objective: (1) To examine 10-yr outcomes of Robot-assisted Radical Cystectomy (RARC) with Intracorporeal Ileal Conduit (ICIC) performed by international clinical fellows within a 1-yr RCS-Eng Urothelial Senior Fellowship Programme. (2) To explore fellows' learning curve (LC) trajectories and perceived European Association of Urology Robotic Urology Section (ERUS) RARC/ICIC curriculum competency achievement.

Methods: RARC/ICIC with curative intent for bladder cancer performed by supervised fellows (2015–2025) were reviewed. Perioperative outcomes and Kaplan-Meier survival trajectories served as surrogates of training competency and safety. Cumulative sum (CUSUM) model by operative time (OT) was applied for RARC/ICIC LC. Time to perceived proficiency across the 12 ERUS RARC/ICIC clinical modules was explored.

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Results: A total of 423 procedures (median follow-up 39 mo, interquartile range 16–70) were included. Proficiency by CUSUM was identified at 30th case, with significant reduction in total OT thereafter (350 vs 300 min, p = 0.017). Outcomes within learning and proficiency phases were comparable, including postoperative complications (36.6% vs 46.0%, p = 0.07), readmissions (16.9% vs 18.7%, p = 0.68), and cancer-specific survival (p = 0.97). ERUS curriculum acquisition was progressive: early modules in 0–1 mo by 88.9% of fellows and advanced modules in 4–6 mo by 100%. Skin-to-skin RARC/ICIC was achieved within ≤3, 4–6, and >6 mo in 11.1%, 33.3% and 55.6% of fellows, respectively. Previous robotic exposure was the only predictor for shorter time to independence (odds ratio, 2.34; 95% confidence interval 1.17–13.29). Post-fellowship, 88.9% of fellows continued independent RARC/ICIC practice.

Conclusions: Structured Senior Robotic Fellowship training achieves safe and efficient acquisition of RARC/ICIC skills. The observed LC corroborates the educational value of the ERUS modular curriculum in the setting of a tertiary referral center.

ADVANCING PRACTICE

What does this study add?

This study analyzes the outcomes of 10 yr of Robot-Assisted Radical Cystectomies (RARCs) with intracorporeal ileal conduit (ICIC) performed by international fellows within the setting of a RCS-Eng certified clinical fellowship, to analyze the surgical learning curve and impact of surgical training on patients outcomes. Under supervision and in the setting of a structured fellowship in a tertiary referral center, surgical training can be attempted safely even for complex procedures such as RARC. Finally, results of a survey circulated among former fellows on time to perceived proficiency of different RARC operative steps corroborates the modular progression proposed by the European Association of Urology Robotic Urology Section RARC + ICIC curriculum.

Clinical Relevance

This study demonstrates that structured high-volume robotic fellowship training enables safe acquisition of robot-assisted radical cystectomy with intracorporeal ileal conduit skills without compromising perioperative or oncologic outcomes. The findings support the real-world educational value of modular ERUS-based training pathways and highlight the importance of expert supervision and progressive autonomy for complex robotic bladder cancer surgery. Associate Editor: M. Carmen Mir.

Patient Summary

Robot-assisted radical cystectomy with intracorporeal ileal conduit is a demanding and technically challenging procedure. Our results from 10 yr of robotic fellowship programme at a tertiary referral center suggest that radical cystectomy training and surgical independence can be safely achieved under experienced supervision and with a stepwise complexity-based progression, without compromising patient outcomes. The survey conducted among former fellows corroborates the modular progression proposed by the ERUS curriculum.

1. Introduction

Robot-assisted surgery (RAS) is increasingly utilized for most major urologic oncologic procedures, providing enhanced dexterity and three-dimensional visualization for the surgeon. These advantages translate into reduced perioperative morbidity, lower estimated blood loss, improved recovery, and oncologic outcomes comparable or superior to open and laparoscopic approaches [1–3].

Radical cystectomy (RC) represents the standard treatment for cT2–T4 N0 M0 muscle-invasive bladder cancer (MIBC) and selected non–muscle-invasive bladder cancer (NMIBC) [4,5]. Over the past two decades, the adoption of robot-assisted radical cystectomy (RARC) has steadily increased due to significantly reduced intra- and postoperative morbidity and comparable oncologic outcomes to open surgery [6,7]. In addition, intracorporeal urinary diversions are associated with improved perioperative outcomes while maintaining equivalent long-term oncologic and complication profiles [8]. Nevertheless, RARC with intracorporeal ileal conduit (RARC/ICIC) remains technically demanding and time-consuming, with complex and long learning curves often requiring dedicated and structured training pathways to achieve surgical maturity [9].

More recently, RAS has reshaped surgical education, shifting training paradigms from the traditional "see-one, do-one, teach-one" Halstedian model toward structured, stepwise learning programs [10–13]. In this context, the European Association of Urology (EAU) Robotic Urology Section (ERUS) developed a Delphi consensus for structured training curriculum dedicated to RARC/ICIC [14]. The curriculum defines prerequisite surgical competencies, followed by theoretical, video-based training and a stepwise stratified progression of operative clinical modules during mentored RARC cases. The RARC/ICIC procedure is deconstructed into standardized steps, subsequently clustered into five modules of increasing technical complexity, allowing trainees to progressively achieve full procedural independence over a 6–12-mo training period.

The aim of our study was to report the results of RARC/ICIC performed over a decade of Royal College of Surgeons England (RCS-Eng) and British Association of Urological Surgeons (BAUS)-approved Senior Clinical Fellowship program in urothelial carcinoma, with comparisons across fellowship years and subanalyses by training trimester. Learning curve dynamics were explored using objective, volume-based measures of surgical expertise gained over the 1-yr program. Finally, a survey was circulated among former fellows to explore perceived competency across the ERUS modular curriculum and to evaluate postfellowship surgical practice and career trajectories.

2. Materials and methods

2.1. The Guy's and St Thomas' (GSTT) Urothelial Senior Robotic Fellowship Program

The GSTT Urothelial Fellowship is a UK-based, RCS-Eng and BAUS approved 1-yr Senior Robotic Fellowship (SRF) at Guy's and St Thomas' NHS Foundation Trust, London, UK.

The fellowship position is awarded through a competitive selection process. Selected fellows (1 per year) enter the programme with heterogeneous prior surgical backgrounds and undergo progressive responsibility acquisition under structured mentorship. Step-by-step familiarization with RARC/ICIC operative phases and technical review before hands-on surgical exposure (ie, "Preclinical Training") is required for all fellows.

All robotic procedures are performed using a dual-console Da Vinci (Intuitive surgical Inc., Sunnyvale, CA, USA) robotic system, allowing the mentor and fellow to operate simultaneously and enabling real-time supervision with graded transfer of autonomy. For each case, the fellow is actively involved from patient positioning and trocar placement onward, progressing to console participation according to individual competency and case complexity. Console time is granted following demonstrated familiarity with procedural steps and critical phases, under continuous supervision by one of three senior consultant urologists (MSK, RT, RN) with extensive experience in robotic BC surgery (>500 RARC procedures each).

The RCS-Eng fellowship programme provides continuous, high-volume clinical and surgical exposure throughout the entire 12-mo period. Surgical training is centered on dedicated BC operating lists, with 2 weekly robotic operating room sessions. On these days, fellows are primarily involved in RARC/ICIC when scheduled, typically accounting for one procedure per operating day. Multidisciplinary engagement represents a core component of the programme. In addition, fellows contribute to the on-call rotation with regular out-of-hours duties.

2.2. The 10-yr study cohort from the prospective GSTT radical cystectomy Registry

All patients undergoing RC at GSTT have been prospectively recorded within a dedicated institutional BC database since 2004. For the purpose of the present study, only patients with either high-risk or very high-risk non–muscle-invasive bladder cancer (NMIBC) or cT2-T4a N0M0 MIBC who underwent RARC/ICIC with curative intent between 2015 and 2025 were identified. Baseline demographic, anthropometric, and clinical/pathologic variables, including age, sex, body mass index, Charlson Comorbidity Index, and American Society of Anesthesiologists score, were recorded. All patients underwent standard preoperative counseling and multidisciplinary urothelial meetings regarding available management options. All participants provided written informed consent for the surgical procedure and the use of de-identified clinical data for research purposes.

Inclusion criteria were: (1) histologically confirmed urothelial carcinoma or mixed urothelial variant histology; (2) primary or recurrent bladder cancer; (3) absence of distant metastases at preoperative clinical staging; and (4) RARC/ICIC plus pelvic lymphadenectomy with either a standard (internal iliac, obturator fossa, and external iliac) or an extended (standard + aortic bifurcation, common iliac and presacral) template, performed as primary treatment with curative intent. Only procedures performed partially or completely by the BC Robotic Fellow under direct supervision of the senior BC consultant were considered eligible.

Exclusion criteria comprised: (1) radiologically suspected or histologically confirmed distant metastatic disease; (2) previous external beam pelvic radiotherapy; and (3) RC performed for indications other than BC, including functional, salvage, palliative, or radiation-induced conditions.

2.3. Survey-based assessment of perceived ERUS RARC/ICIC module competency

A comprehensive survey was developed and circulated among all fellows who completed the GSTT SRF programme between 2015 and 2025. The questionnaire sought to capture a range of information related to fellows' background, training exposure, clinical and robotic practice, and postfellowship career trajectories. The original draft was developed by senior faculty members involved in fellowship training and distribution and data collection were conducted using a secure online platform (Google Docs).

Fellows were asked to report time to achievement of operative independence across clinical components of RARC/ICIC, including progression to skin-to-skin autonomy.

The ERUS RARC/ICIC modular framework was used as the reference structure for organizing and analyzing fellows' self-reported competency progression.

Survey results were explored to describe perceived learning progression and to assess factors associated with operative independence, providing a subjective competency complement to the objective learning curve and perioperative outcome analyses. The complete survey template is reported as Supplementary File 1.

2.4. Statistical analysis and objective learning curve assessment

Statistical analyses were performed using R statistical software (R Foundation for Statistical Computing, Vienna, Austria; version 4.3.0). Baseline demographic, clinical, perioperative, pathological, and oncologic variables were summarized using descriptive statistics. Categorical variables were reported as counts and percentages, while continuous variables were expressed as mean ± standard deviation or median with interquartile range (IQR), as appropriate.

To account for the training-based structure of the fellowship programme, analyses were organized according to three complementary dimensions: fellowship year (corresponding to individual fellows), training trimester (four consecutive 3-mo periods within each fellowship year), and training phase (learning vs proficiency). This was adopted to explore temporal changes in operative performance and safety metrics in relation to trainee autonomy.

Perioperative outcomes were compared as continuous events using the Mann–Whitney U test or one-way analysis of variance, and categorical variables using the $\chi2$ test or Fisher's exact test, as appropriate. Cancer-specific survival (CSS) and overall survival (OS) were depicted by Kaplan-Meier curves and compared across the different complementary dimensions using the log-rank test. Breslow (generalized Wilcoxon) and Tarone–Ware tests were additionally applied to account for differences in early and late event distributions.

Objective assessment of surgical skill acquisition was performed using an aggregated cumulative sum (CUSUM) methodology based on OT, selected as a surrogate marker of technical efficiency [15]. For each procedure performed by each fellow, deviations from the overall mean OT were cumulatively summed to generate individual CUSUM curves, which were subsequently aggregated across fellows to describe the learning trajectory. Aggregated CUSUM values were plotted against sequential case number, and polynomial regression modeling was applied to characterize non-linear learning patterns and identify inflection points corresponding to transitions between learning and proficiency phases. The proficiency threshold derived from this analysis was subsequently used to stratify perioperative and survival outcome comparisons. A detailed CUSUM methodology paragraph has been attached as Supplementary File 2.

Survey variables were analyzed descriptively. In addition, an univariable logistic regression model was implemented to explore predictors associated with earlier achievement of operative independence, with results reported as odds ratios (ORs) and 95% confidence intervals (CIs). All statistical tests were two-sided, and a p value <0.05 was considered statistically significant.

3. Results

3.1. Surgical trends and operative outcomes

3.1.1. Study cohort

A total of 423 consecutive patients undergoing RARC/ICIC with curative intent at GSTT were included. The cohort comprised 321 males (75.9%) and 102 females (24.1%), with a median age of 70 yr (IQR, 63–76) at the time of surgery. Overall, 227 patients (53.7%) were treated for MIBC, and 196 (46.3%) for high- or very high-risk NMIBC. A substantial proportion of patients had received prior intravesical or systemic therapy, with 142 (33.6%) previously exposed to Bacillus Calmette-Guérin (BCG) and 88 (20.8%) undergoing neoadjuvant chemotherapy (NAC). Pelvic lymph node dissection (PLND) was performed using a standard template in 295 patients (69.7%) and an extended template in 96 (22.7%). Overall perioperative outcomes were consistent with contemporary high-volume RARC series, including a median total OT of 330 min (IQR, 290–390) and an overall postoperative complication rate of 39.7%, predominantly low- to intermediate-grade events. A comprehensive description of baseline demographic, pathological, and perioperative characteristics is provided in Supplementary Table 1.

3.1.2. Fellowship year distribution of patient characteristics and operative metrics

When stratified by fellowship year (Table 1, Supplementary Fig. 1), the proportion of procedures performed for NMIBC varied across fellows, ranging from 48.0% in earlier fellowship years to 34.3% in later years (p = 0.04), with a parallel reduction in prior intravesical BCG exposure (40.0% vs 22.9%; p = 0.008). Conversely, the use of NAC increased across fellowship years, from 12.0% to 25.7% (p = 0.05), indicating a progressively higher prevalence of MIBC cases managed within the programme. Intraoperative complication rates differed between fellowship training years (p = 0.007), peaking during the earliest training cycle (24.0%) and remaining ≤6.4% thereafter. In contrast, postoperative complication rates (range 34.7–42.6%; p = 0.37) and 90-d readmission rates (range, 8.6–24.4%; p = 0.21) did not differ significantly between fellows.

Operative efficiency varied across fellowship training years, with median total OT ranging from 400 min (IQR, 325–457) to 285 min (IQR, 257–328) (p < 0.001). No significant inter-fellow differences were observed in positive soft-tissue surgical margin rates, or length of hospital stay. A standard PLND template remained the most performed across fellowship years (range, 55.6–97.1%, p < 0.001).

3.2. Temporal evolution of RARC/ICIC outcomes across fellowship training

3.2.1. Perioperative outcomes by training trimester

Perioperative outcomes stratified by fellowship trimester are summarized in Table 2. Across the four training periods,

Table 1 – Patient demographic and pathological characteristics stratified per academic year and senior robotic fellow in RARC/ICIC at Guy's and St Thomas' NHS Foundation Trust, London, UK

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	*p* value
Sample, *n* (%)	25	49	45	38	27	45	59	53	47	35	
Gender, *n* (%)											
Male	21 (84)	41 (83.7)	38 (84.4)	28 (73.7)	20 (74.1)	28 (62.2)	45 (76.3)	41 (77.4)	29 (61.7)	30 (85.7)	0.96
Female	4 (16)	8 (16.3)	7 (15.6)	10 (26.3)	7 (25.9)	17 (37.8)	14 (23.7)	12 (22.6)	18 (38.3)	5 (14.3)	
Age, median (IQR)	71 (62.5–74.5)	69 (63–77.5)	71 (65.5–75.5)	71.5 (61.25–75)	73 (69–77)	68 (64.5–74)	70 (64.5–77)	70 (60–77)	69 (59–77)	72 (65–76)	0.88
Ethnicity, *n* (%)											
White/Caucasian	22 (88)	46 (93.9)	44 (97.8)	35 (92.1)	24 (88.9)	43 (95.6)	57 (96.6)	45 (84.9)	45 (95.7)	34 (97.1)	0.30
Other	3 (12)	3 (6.1)	1 (2.2)	3 (7.9)	3 (11.1)	2 (4.4)	2 (3.4)	8 (15.1)	2 (4.2)	1 (2.9)	
BMI, median (IQR)	27.4 (25.5–29.5)	26.8 (23.8–30.7)	26.7 (24.0–30.7)	27.0 (22.4–29.8)	26 (23.0–27.4)	27.0 (23.8–32)	29.1 (25.1–32.2)	27.8 (24.8–31.0)	28.1 (24.5–32.4)	27 (25.5–28.0)	0.48
Concomitant CIS, *n* (%)											
No	19 (76)	36 (73.5)	31 (68.9)	27 (71.1)	16 (59.3)	31 (68.9)	35 (59.3)	34 (64.2)	32 (68.1)	28 (80)	0.60
Yes	6 (24)	13 (26.5)	14 (31.1)	11 (28.9)	11 (40.7)	14 (31.1)	24 (40.7)	19 (35.8)	15 (31.9)	7 (20)	
Prev. BCG exposure, *n* (%)											
No	15 (60)	24 (49)	20 (44.4)	26 (68.4)	22 (81.5)	32 (71.1)	44 (74.6)	36 (67.9)	35 (74.5)	27 (77.1)	0.008
Yes	10 (40)	25 (51)	25 (55.6)	12 (31.6)	5 (18.5)	13 (28.9)	15 (25.4)	17 (32.1)	12 (25.5)	8 (22.9)	
cT stage, *n* (%)											0.08
cTa	4 (16)	6 (12.2)	4 (8.9)	5 (13.2)	2 (7.4)	3 (6.7)	8 (13.6)	7 (13.2)	5 (10.6)	1 (2.9)	
cTis	1 (4)	2 (4.1)	4 (8.9)	2 (5.2)	1 (3.7)	3 (6.7)	1 (1.7)	2 (3.8)	1 (2.1)	0	
cT1	7 (28)	14 (28.6)	17 (37.8)	13 (34.2)	11 (40.7)	13 (28.9)	22 (37.3)	14 (26.4)	12 (25.5)	11 (31.4)	
cT2	12 (48)	24 (49)	16 (35.6)	15 (39.5)	10 (37)	23 (51.1)	17 (28.8)	21 (39.6)	20 (42.6)	18 (51.4)	
cT3	0	3 (6.1)	3 (6.7)	3 (7.9)	3 (11.1)	3 (6.7)	10 (16.9)	5 (9.4)	8 (17)	4 (11.4)	
cT4	1 (4)	0	1 (2.2)	0	0	0	1 (1.7)	4 (7.5)	1 (2.1)	1 (2.9)	
Stage Category, *n* (%)											
NMIBC	12 (48)	22 (44.9)	25 (55.6)	20 (52.6)	14 (51.9)	19 (42.2)	31 (52.5)	23 (43.4)	18 (38.3)	12 (34.3)	0.04
MIBC	13 (52)	27 (55.1)	20 (44.4)	18 (47.4)	13 (48.1)	26 (57.8)	28 (47.5)	30 (56.6)	29 (61.7)	23 (65.7)	
NAC, *n* (%)											
No	22 (88)	39 (79.6)	38 (84.4)	28 (73.7)	22 (81.5)	35 (77.8)	45 (76.3)	43 (81.1)	37 (78.7)	26 (74.3)	0.05
Yes	3 (12)	10 (20.4)	7 (15.6)	10 (26.3)	5 (18.5)	10 (22.2)	14 (23.7)	10 (18.9)	10 (21.3)	9 (25.7)	
Intraoperative complications, *n* (%)											
No	19 (76)	47 (95.9)	43 (95.6)	37 (97.4)	27 (100)	43 (95.6)	57 (96.6)	51 (96.2)	44 (93.6)	33 (94.3	0.007
Yes	6 (24)	2 (4.1)	2 (4.4)	1 (2.6)	0	2 (4.4)	2 (3.4)	2 (3.8)	3 (6.4)	2 (5.7)	
EBL (ml), median (IQR)	500 (450–500)	350 (212–400)	300 (200–462.5)	300 (200–500)	200 (125–300)	275 (200–325)	300 (200–400)	300 (200–400)	300 (200–475)	300 (250–325)	0.005
LOS (d), median (IQR)	7.5 (7.0–8.75)	7 (6–9)	8 (7–13)	7 (6–9.5)	8.5 (7.25–12.25)	8 (7–11.8)	8.5 (7–13.2)	8 (7–14)	7 (6.5–9)	9 (7–10)	0.14
Operative time (min), median (IQR)	400 (325–457)	360 (305–390)	285 (257–327.5)	305 (270–337)	300 (270–360)	330 (277–365)	360 (330–420)	360 (300–375)	360 (330–390)	360 (270–390)	<0.001
Postoperative complications *n* (%)											
No	15 (60.0)	32 (65.3)	28 (62.2)	23 (60.5)	17 (63.0)	26 (57.8)	35 (59.3)	31 (58.5)	27 (57.4)	21 (60.0)	0.37
Yes	10 (40.0)	17 (34.7)	17 (37.8)	15(39.5)	10 (37.0)	19 (42.2)	24 (40.7)	22 (41.5)	20 (42.6)	14 (40.0)	
90-d readmissions, *n* (%)											
No	20 (80)	42 (85.7)	37 (82.2)	33 (86.8)	24 (88.9)	34 (75.6)	46 (78.0)	44 (83.0)	37 (78.7)	32 (91.4)	0.21

Table 1 (*continued*)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	*p* value
Yes	5 (20)	7 (14.3)	8 (17.8)	5 (13.2)	3 (11.1)	11 (24.4)	13 (22.0)	9 (17.0)	10 (21.3)	3 (8.6)	
PLND, *n* (%)											
Not performed	1 (4)	0	1 (2.2)	4 (10.5)	1 (3.7)	2 (4.4)	8 (13.6)	7 (13.2)	7 (14.9)	1 (2.9)	<0.001
Standard	24 (96)	43 (87.8)	42 (93.3)	18 (47.4)	15 (55.6)	29 (64.4)	36 (61)	19 (35.8)	35 (74.5)	34 (97.1)	
Extended	0	6 (12.2)	2 (4.4)	16 (42.1)	11 (40.7)	14 (31.1)	15 (25.4)	27 (50.9)	5 (10.6)	0	
pT stage, *n* (%)											
pT0	6 (24)	13 (26.5)	0	4 (10.5)	3 (11.1)	11 (24.4)	5 (8.5)	4 (7.5)	5 (10.6)	4 (11.4)	
pTa	1 (4)	5 (10.2)	3 (6.7)	4 (10.5)	2 (7.4)	4 (8.9)	6 (10.2)	4 (7.5)	4 (8.5)	0	
pTis	1 (4)	5 (10.2)	3 (6.7)	4 (10.5)	2 (7.4)	6 (13.3)	12 (20.3)	8 (15.1)	6 (12.8)	2 (5.7)	
pT1	6 (24)	5 (10.2)	13 (28.9)	5 (13.2)	5 (18.5)	5 (11.1)	9 (15.3)	9 (17)	9 (19.1)	9 (25.7)	
pT2	6 (24)	6 (12.2)	7 (15.6)	11 (28.9)	5 (18.5)	10 (22.2)	10 (16.9)	10 (18.9)	6 (12.8)	11 (31.4)	
pT3	2 (8)	14 (28.6)	16 (35.6)	9 (23.7)	8 (29.6)	7 (15.6)	11 (18.6)	15 (28.3)	16 (34)	7 (20)	
pT4	3 (12)	1 (2)	3 (6.7)	1 (2.6)	2 (7.4)	2 (4.4)	6 (10.2)	3 (5.7)	1 (2.1)	2 (5.7)	
Soft-tissue surgical margin, *n* (%)											
Negative	23 (92)	47 (95.9)	41 (91.1)	36 (94.7)	27 (100)	45 (100)	57 (96.6)	52 (98.1)	45 (95.7)	35 (100)	0.092
Positive	2 (8)	2 (4.1)	4 (8.9)	2 (5.3)	0	0	2 (3.4)	1 (1.9)	2 (4.3)	0	

IQR = interquartile range; CIS = Carcinoma in Situ; BCG = Bacillus Calmette-Guérin; NMIBC = non-muscle invasive bladder cancer; MIBC = muscle invasive bladder cancer; NAC = neoadjuvant chemotherapy; EBL = estimated blood loss; LOS = length of stay; PLND = pelvic lymph node dissection.

operative complexity and postoperative safety metrics remained largely stable, despite progressive trainee autonomy.

Intraoperative complications occurred in 6 (5.7%), 6 (4.6%), 7 (6.6%), and 3 (3.7%) cases during the first, second, third, and fourth trimesters, respectively (p = 0.82). Similarly, postoperative complications and readmission rates did not significantly differ between consecutive trimesters (p = 0.21 and p = 0.84). Median length of stay remained constant at 8 d across all trimesters (p = 0.23). Surgical margin status was consistent throughout training, with positive soft-tissue margins observed in 4.7%, 3.8%, 1.9%, and 3.7% of cases from the first to fourth trimester, respectively (p = 0.62). In contrast, operative efficiency improved progressively over the fellowship year. Median total OT decreased from 355 min (IQR, 300–393) in the first trimester to 300 min (IQR, 270–360) in the fourth trimester (p = 0.008). A similar reduction was observed for RARC-specific OT, which decreased from a median of 180 min (IQR, 142.5–240) in the first trimester to 120 min (IQR, 120–180) in the final trimester (p = 0.021).

3.2.2. *Survival analysis by training trimesters*

CSS and OS were analyzed to assess oncologic outcomes across progressive phases of fellowship training. Across the entire cohort, mean CSS and OS were, respectively, 87.8 mo (SE, 2.1; 95% CI, 83.7–91.8) and 79.9 mo (SE, 2.1; 95% CI, 75.8–83.9). When stratified by fellowship trimester, no statistically significant differences in CSS (log-rank χ^2 = 1.15, p = 0.67) and OS distributions (log-rank χ^2 = 4.08, p = 0.25) were observed (Fig. 1A and B).

3.3. *learning curve Proficiency by Clinical Outcomes*

3.3.1. *Learning curve assessment and perioperative outcomes during the proficiency phase*

The aggregated CUSUM analysis based on overall RARC/ICIC OT and RARC-only console time is shown in Fig. 2. Polynomial regression modeling identified a cubic function as the best fit for the aggregated CUSUM curve both for total OT (R^2 = 0.78) and for RARC time (R^2 = 0.81). The inflection point of the fitted OT learning curve corresponded to the 30^{th} RARC/ICIC procedure, which was used to define the transition between learning and proficiency phases.

Based on this threshold, n = 284 procedures (≤30th case per fellow) were classified as the learning phase and n = 139 as the proficiency phase (Table 3). Median total OT was significantly longer during the learning phase compared with the proficiency phase (350 min [IQR, 300–390] vs 300 min [IQR, 260–330], p = 0.017). Similarly, median console RARC time was longer in the learning phase (180 min [IQR, 135–210] vs 140 min [IQR, 120–200], p = 0.024).

Rates of intraoperative complications were comparable between learning and proficiency phases (n = 14, 4.9% vs n = 8, 5.8%; p = 0.72), as were postoperative complications (n = 104, 36.6% vs n = 64, 46.0%; p = 0.07). 90-d readmission rates did not differ between phases (16.9% vs 18.7%, p = 0.68). Finally, positive soft-tissue margin rates were similarly distributed between the learning and proficiency phases (4.2% vs 2.2%, p = 0.28).

Table 2 – Perioperative outcomes stratified by cumulative training trimesters of senior robotic fellowship in RARC/ICIC at Guy's and St Thomas' NHS Foundation Trust, London, UK

	1st trimester	2nd trimester	3rd trimester	4th trimester	*p* value
Sample, *n* (%)	106	130	106	81	
EBL (ml), median (IQR)	300 (200–400)	300 (200–400)	350 (200–450)	300 (200–400)	0.09
LOS (d), median (IQR)	8 (6–10)	8 (7–11)	8 (7–11)	8 (7–14)	0.23
RARC time (min), median (IQR)	180 (142.5–240)	180 (150–210)	180 (139–203)	120 (120–180)	0.021
Operative time (min), median (IQR)	355 (300–392.5)	360 (300–400)	335 (290–600)	300 (270–360)	0.008
Intraoperative complications, *n* (%)					
No	100 (94.3)	124 (95.4)	99 (93.4)	78 (96.3)	0.82
Yes	6 (5.7)	6 (4.6)	7(6.6)	3 (3.7)	
Postoperative complications *n* (%)					
No	67 (63.2)	84 (64.6)	55 (51.9)	49 (60.5)	0.21
Yes	39 (36.8)	46 (35.4)	51 (48.1)	32 (39.5)	
90-d readmissions, *n* (%)					
No	88 (83.0)	108 (83.1)	89 (84.0)	64 (79.0)	0.84
Yes	18 (17.0)	22 (16.9)	17 (16.0)	17 (21.0)	
Soft-tissue surgical margin, *n* (%)					
Negative	101 (95.3)	125 (96.2)	104 (98.1)	78 (96.3)	0.62
Positive	5 (4.7)	5 (3.8)	2 (1.9)	3 (3.7)	
Ureteral margin, *n* (%)					
Negative	102	119	101	73	0.15
Positive	4	11	5	8	
Urethral margin, *n* (%)					
Negative	94	115	94	70	0.85
Positive	12	15	12	11	
Number of LNs yielded, median (IQR)	14 (11.5–21)	15 (11–18)	17 (13–22)	15 (10–19)	0.185

EBL = estimated blood loss; IQR = interquartile range; LOS = length of stay; RARC = robot-assisted radical cystectomy; LNs = lymph nodes.

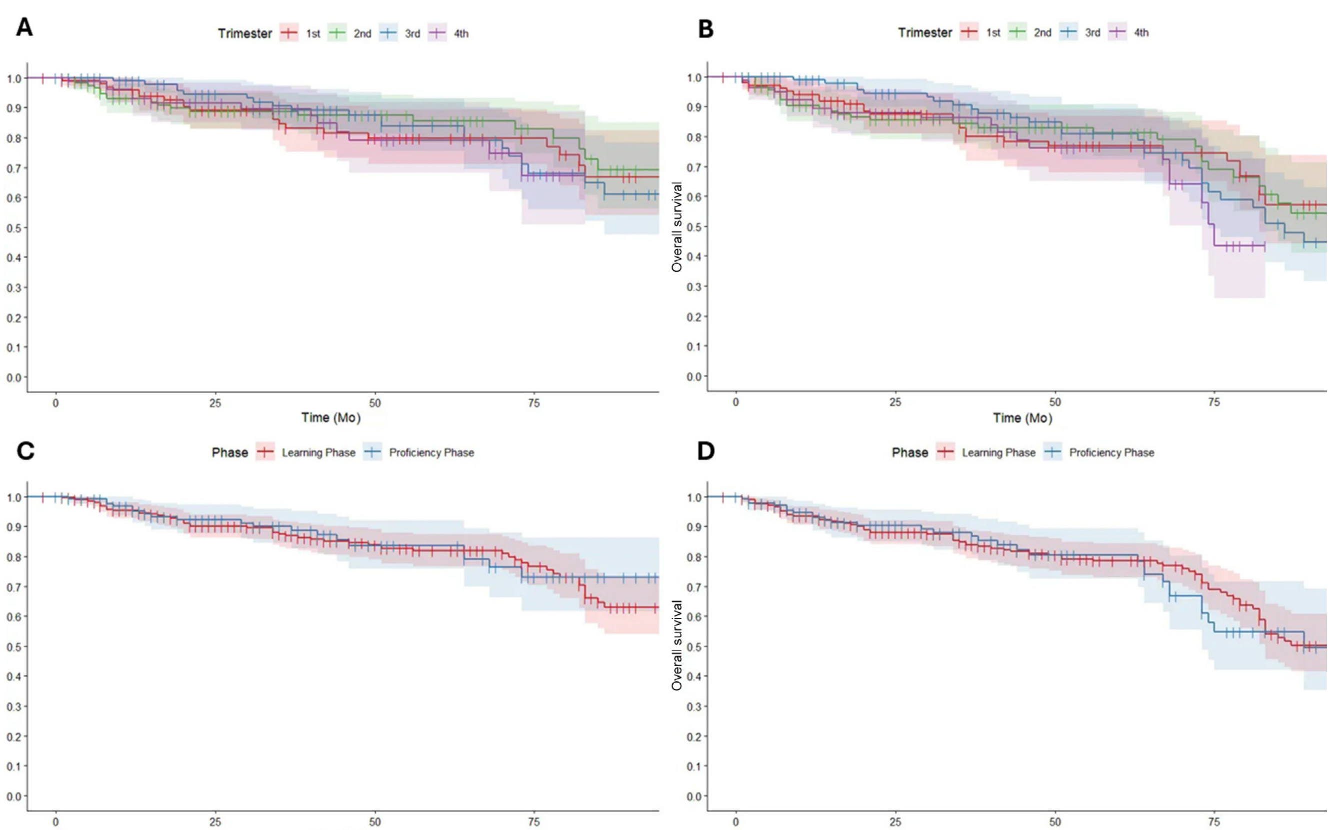

Fig. 1 – Kaplan-Meier survival analysis for cancer-specific survival and overall survival, by trimester of fellowship (A and B) and by learning versus proficiency phase (C and D), for RARC/ICIC performed by senior robotic fellows at Guy's and St Thomas' NHS Foundation Trust, London, UK.

3.3.2. Survival outcomes by learning and proficiency phases

Kaplan-Meier survival analyses were adopted to assess CSS and OS across the progressive learning and proficiency phases.

Mean CSS estimates were 87.6 mo (SE, 2.5; 95% CI, 82.8–92.5) for procedures performed during the learning phase and 82.3 mo (SE, 3.1; 95% CI, 76.2–88.2) for procedures per-

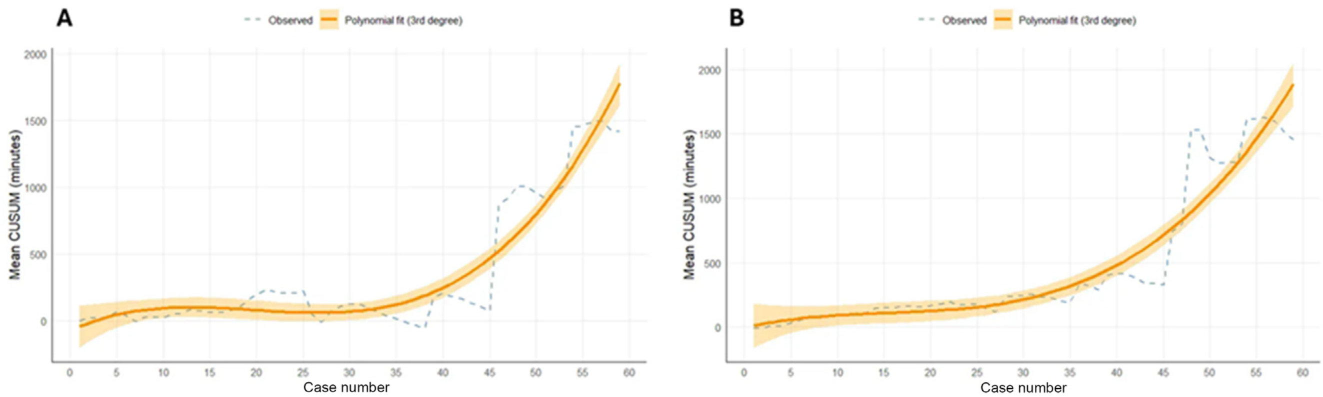

Fig. 2 – Aggregated CUSUM learning curve for total RARC/ICIC operative time (A) and RARC-only time (B) for senior robotic fellows at Guy's and St Thomas' NHS Foundation Trust, London, UK.

Table 3 – Perioperative outcomes stratified according to senior robotic fellow learning versus proficiency phases among the overall population who underwent RARC/ICIC between 2015 and 2025 at Guy's and St Thomas NHS Foundation Trust, London, UK

	Learning phase	Proficiency phase	*p* value
Sample, *n* (%)	284	139	
EBL (ml), median (IQR)	300 (200–400)	300 (200–400)	0.09
LOS (d), median (IQR)	8 (7–10)	8 (7–11)	0.15
RARC time (min), median (IQR)	180 (135–210)	140 (120–200)	0.024
Operative time (min), median (IQR)	350 (300–390)	300 (260–330)	0.017
Intraoperative complications, *n* (%)			
No	270 (95.1)	131 (94.2)	0.72
Yes	14 (4.9)	8 (5.8)	
Postoperative complications, *n* (%)			
No	180 (63.4)	75 (54)	0.07
Yes	104 (36.6)	64 (46)	
90-d readmissions, *n* (%)			
No	236 (83.1)	113 (81.3)	0.68
Yes	48 (16.9)	26 (18.7)	
Soft-tissue surgical margin, *n* (%)			
Negative	272 (95.8)	136 (97.8)	0.28
positive	8 (4.2)	3 (2.2)	

EBL = estimated blood loss; IQR = interquartile range; LOS = length of stay; RARC = robot-assisted radical cystectomy; LNs = lymph nodes.

formed during the proficiency phase (Fig. 1C). No significant differences in CSS distributions were observed between the two phases of the learning curve (log-rank χ^2 = 0.001, p = 0.97). This finding was consistently confirmed by Breslow (χ^2 = 0.107, p = 0.74) and Tarone–Ware tests (χ^2 = 0.052, p = 0.82).

For OS (Fig. 1D), mean survival estimates were 80.5 mo (SE, 2.5; 95% CI, 75.7–85.3) for learning phase cases and 75.3 mo (SE, 3.3; 95% CI, 68.9–81.7) for proficiency phase cases. OS distributions did not differ significantly between learning and proficiency phases (log-rank χ^2 = 0.55, p = 0.45), with concordant results obtained using Breslow (χ^2 = 0.000, p = 0.998) and Tarone–Ware tests (χ^2 = 0.072, p = 0.79).

3.4. *Survey results: training exposure, perceived ERUS competency, and postfellowship RARC practice*

Among the 10 fellows who completed the GSTT Senior Robotic Fellowship during the study period, nine responded to the survey and were included in the analysis (response rate 90%). Survey results on pre-fellowship robotic experience are summarized in Supplementary Table 2.

All respondents reported prior exposure to robotic surgery before the start of the fellowship (n = 9, 100%). Pre-fellowship robotic console experience was most commonly limited to 1–2 yr (5/9, 55.6%), while two of nine fellows (22.2%) reported <1 yr and >2 yr. Most respondents had not completed a prior dedicated robotic fellowship before joining the programme (n = 7, 77.8%). Regarding pre-fellowship exposure, robotic prostatectomy was reported as the most representative procedure by eight fellows (88.9%); nevertheless, six fellows (66.7%) did not consider themselves independent robotic surgeons prior to fellowship initiation.

Perceived competency acquisition across the ERUS RARC/ICIC curriculum showed a stepwise temporal gradient, with earlier modules reached sooner than advanced ICIC-related components (Supplementary Table 3). Module 1 competency was most frequently reported within 0–1 mo (n = 8, 88.9%). Module 2 was most commonly achieved within 2–3 mo (n = 5, 55.6%). For Modules 3 and 4, the modal timeframe remained 2–3 mo (Module 3: n = 7, 77.8%; Module 4: n = 6, 66.7%), whereas Module 5 was consistently reported within 4–6 mo by all respondents (n = 9, 100.0%). When considering the global "skin-to-skin" milestone, independent completion of RARC/ICIC was achieved within ≤3 mo by one fellow (11.1%), within 4–6 mo by 3 (33.3%), and after >6 mo by 5 (55.6%), highlighting residual inter-individual variability despite a shared modular training pathway. At univariable logistic regression, longer baseline robotic exposure (>1 yr) was found as the only predictor associated with earlier achievement of skin-to-skin independence (OR, 2.341; 95% CI, 1.176–13.293; Supplementary Table 4).

Postfellowship professional trajectories are summarized in Supplementary Table 5. Following completion of the GSTT Senior Robotic Fellowship, five fellows (55.6%) held an academic appointment, while the remaining respondents were employed in high-volume non-academic or mixed clinical settings. In terms of surgical activity, five fellows (55.6%) reported performing >100 robotic procedures/year, with RARC accounting for a substantial proportion of their robotic case mix.

With regard to urinary diversion techniques, all fellows performing RARC postfellowship reported preferential adoption of an ICIC (100%). A perceived increase in annual RARC volume compared with the pre-fellowship period was reported by five fellows (62.5%). Large majority (66.7%) of respondents self-identified their current clinical practice as primarily focused on BC surgery.

4. Discussion

The rate of RARC performed worldwide as an alternative to open RC for the management of BC is steadily increasing. The perioperative and oncologic safety of this approach has been confirmed by the iROC study with superior perioperative morbidity and mortality outcomes with comparable oncologic results when compared with open RC [16]. Nonetheless, RC remains the most demanding oncologic procedure in urology, still associated with the highest perioperative morbidity and postoperative complication rates [6].

In the first part of the present study, we evaluated surgical trends, perioperative outcomes, and long-term follow-up data of RARC performed within our SRF programme at a UK tertiary referral center. Within this setting, both intraoperative and postoperative complication rates were comparable to the lower range reported in contemporary high-volume RARC series [17,18]. Similarly, oncologic outcomes, including positive surgical margin rates and long-term survival, were consistent with those reported in recent literature from experienced referral centers [19]. Over time, a shift in case mix was observed, with fewer NMIBC and more MIBC patients undergoing RARC, likely reflecting evolving bladder-preserving strategies and real-world patterns of NAC use [20–24].

RARC/ICIC, due to its clinical complexity and steep learning curve, provides a model to investigate whether surgical training for highly demanding oncologic procedures can be delivered safely within a structured, high-volume, and supervised training environment. In this context, ERUS has played a leading role in promoting structured robotic education, with previously validated modular training curricula for robot-assisted radical prostatectomy and robot-assisted radical nephrectomy (RAPN) [25,26].

More recently, ERUS proposed a Delphi-developed, training curriculum for RARC, structured on defined pre-training requirements, combined with theoretical instruction, preclinical lectures, and clinical modular exposure [14]. Similarly, our institution has implemented a structured robotic fellowship programme dedicated to RARC within a high-volume referral center. Unlike the ERUS curriculum, pre-fellowship robotic console experience and formal tableside assistance were not considered mandatory prerequisites for enrolment. Access to the programme was instead based on competitive selection. Nevertheless, the fellowship is grounded on the same modular training principles described within the ERUS curricula, with progressive responsibility acquisition under close mentorship and theoretical and console simulation training integration.

When assuming OT as continuous variable to characterize surgical learning curve, a threshold of 30 cases emerged as the point at which RARC fellows shifted to surgical proficiency. In contrast, a recent series evaluating learning curves in RARC have reported that a plateau in 90-d major complication rates was reached at approximately 137 procedures [27]. However, our findings are consistent with those reported in a recent validation study of the ERUS RARC curriculum. In that analysis, the learning trajectory of a single trainee who completed the curriculum under expert supervision was evaluated, demonstrating that surgical performance metrics approached those of the mentor after approximately n = 20 procedures [28]. In the present study, we captured learning trajectories across multiple trainees rather than a single operator, providing a wider representation of skill acquisition. Taken together with the findings of the pilot validation study of the ERUS RARC curriculum, our results suggest that fellowship programmes may mitigate the intrinsic complexity of the learning curve associated with highly demanding procedures such as RARC. With respect to operative efficiency, previous studies have shown that longer operative times do not necessarily translate into increased perioperative morbidity, particularly when they reflect deliberate intraoperative communication, teaching, and structured feedback between the trainee and the supervising surgeon [26,29]. In our analysis, perioperative safety indicators, including intra- and postoperative complication rates, readmissions, and oncologic outcomes, remained comparable to those reported in contemporary high-volume series, supporting the appropriateness of OT as a marker of learning progression within a protected training environment.

The clinical component of the ERUS training curriculum for RARC is structured into five distinct modules organized according to increasing technical complexity. Although the ERUS structured RARC/ICIC curriculum was formally introduced in 2023, the present BC fellowship had long adopted a comparable stepwise training philosophy, with graded exposure to procedural complexity over the course of the year. In the present study, a dedicated questionnaire was circulated with the aim of assessing the time to perceived proficiency for each ERUS module and to evaluate the validity of the ERUS segmentation proposal. Overall, our findings are consistent with the modular progression proposed by ERUS curriculum, indicating that skill acquisition in RARC evolves according to increasing technical and cognitive demands rather than following the chronological order of the procedure. In this context, modular training appears particularly efficient to address the non-linear nature of the learning process. Importantly, following completion of the RARC fellowship, majority of respondents reported continued independent practice of RC (88.9%), using a robotic approach (100%) and preferentially adopting an intracorporeal urinary diversion (100%), supporting the real-world transferability of the training model.

Several limitations must be acknowledged. Our study is a retrospective analysis, with the intrinsic limits of nonrandomized observational data. The specific selection and mentorship modalities limit generalizability to settings where prerequisites, case volume, dual-console availability, and mentorship differ from those of a tertiary referral center. In addition, our cohort included both male and female patients, whereas the published ERUS curriculum was developed in a male population. Nonetheless, anatomical differences are largely confined to specific extirpative steps and are therefore unlikely to have substantially influenced the overall learning trajectory. Moreover, while ICIC was by far the most commonly performed diversion at our center, fellows had limited exposure to RARCs with alternative diversion types (ie, neobladder or cutaneous ureterostomy), which may have partially influenced the learning curve. Finally, we acknowledge that the present work should not be interpreted as a formal validation of the ERUS RARC curriculum because our fellowship experience spans 2015–2025, whereas the ERUS curriculum was published in 2023. Rather, our data support the real-world applicability of the underlying modular principles in a structured fellowship setting. Methodologically, OT was used as a surrogate of technical efficiency and procedural reproducibility. However, while it is appropriate for modeling learning trajectories, it is not a direct measure of surgical quality. Similarly, the survey captures perceived proficiency and is subject to recall and desirability biases, and the aggregated CUSUM approach, although strengthening programme-level inference, necessarily smooths inter-individual variability.

5. Conclusions

This study reports a 10-yr experience of RARC/ICIC performed within a structured SRF at a high-volume referral center. Within this setting, RARC/ICIC achieved perioperative and oncologic outcomes comparable to those reported by international high-volume bladder cancer centers, while being delivered within an intensive, fellowship-based training programme.

Learning curve analyses demonstrate that surgical proficiency can be achieved without compromising patient safety when training is delivered within a standardized programme and under continuous expert supervision. Of note, our GSTT urothelial fellowship experience closely mirrors the modular principles underpinning the ERUS-RARC curriculum, with survey findings providing real-world support for its educational structure. These results apply to structured, high-volume training environments and should not be extrapolated to unstructured settings.

Our results reflect the value of sustained clinical leadership, team continuity, and a shared educational vision within a dedicated BC service.

Author contributions: Francesco Del Giudice had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Appendix A. Supplementary material

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