Clinical Research

Intracorporeal urinary diversion robot-assisted radical cystectomy *versus* open radical cystectomy: a systematic review

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ABSTRACT

BACKGROUND Radical cystectomy is the standard treatment for advanced bladder cancer, with open surgery associated with significant perioperative morbidity. This study aimed to compare efficacy, safety, and cost-effectiveness of robotic-assisted *versus* open radical cystectomy (ORC) with intracorporeal urinary diversion (ICUD).

METHODS A systematic review was conducted across databases (PubMed, Cochrane Library, ClinicalTrials.gov, and Google Scholar) following Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines, with the following keywords: "robotic-assisted cystectomy", "open cystectomy", "intracorporeal urinary diversion", "bladder cancer", "perioperative results", "complications", and "oncological efficacy". Only studies published in the last 10 years were included, with literature searching completed in December 2024.

RESULTS 8 studies comparing robot-assisted radical cystectomy (RARC) with ICUD to ORC were included. RARC with ICUD showed reduced blood loss, fewer transfusions, shorter hospital stays, and faster recovery with earlier bowel function, but longer operative times. Recurrence and survival, were similar between both approaches.

CONCLUSIONS RARC with ICUD is a promising alternative to open cystectomy, providing perioperative benefits and faster recovery while maintaining equivalent oncologic outcomes. However, higher initial costs and technical complexity must be considered. Further research should assess quality of life, functional recovery, and overall healthcare impact.

KEYWORDS bladder cancer, complications, cost-effectiveness, radical cystectomy, robotic-assisted surgery

Radical cystectomy, the gold-standard treatment for muscle-invasive bladder cancer, is used to remove the bladder and surrounding tissues. Traditionally performed via an effective open approach with significant morbidity due to its highly invasive nature,[1] it has evolved into minimally invasive techniques such as robot-assisted radical cystectomy (RARC), introduced in 2003, which improves surgical precision and recovery while maintaining similar cancer control. Innovations such as intracorporeal urinary diversion (ICUD) and urinary reconstruction entirely inside the abdomen further reduce complications associated with traditional methods. However, the high costs of RARC with ICUD warrant careful evaluation before widespread use.[2,3]

Several studies have shown that RARC matches open radical cystectomy (ORC) in many perioperative and long-term oncological outcomes,[4] but direct comparisons between RARC with ICUD and ORC are limited. This review conceptualizes the comparative pathway between surgical approaches—RARC with ICUD *versus* ORC—by evaluating intraoperative factors

(ischemia time, blood loss, and bowel handling), early (complications, length of stay, and opioid use) and late outcomes (functional recovery and quality of life [QoL]), oncological endpoints (margin status, recurrence, and survival), and economic impact (direct costs and readmissions), with the aim of determining whether RARC with ICUD achieves effective cancer control, improved recovery, and overall value for patients with bladder cancer.[5,6] Although previous systematic reviews have compared RARC with ORC, few have specifically focused on cases utilizing ICUD. Given the recent technical advances and emerging real-world evidence, an updated synthesis targeting the outcomes of RARC with ICUD *versus* ORC is warranted to address this knowledge gap, inform clinical practice, and provide a context for future research in bladder cancer surgery.[7]

METHODS

This systematic review compared RARC with ICUD *versus* ORC for bladder cancer treatment through a comprehensive search using predefined terms relevant to robot-assisted surgery, open cystectomy, ICUD, and bladder cancer outcomes. Studies meeting strict inclusion and exclusion criteria were selected for comparative data on perioperative outcomes, oncological efficacy, complication rates, recovery metrics, and patient-centered outcomes, such as QoL and functional recovery. Data were independently extracted by multiple reviewers, and discrepancies were resolved through discussion or third-party adjudication.

Search strategy

A comprehensive search was conducted on December 11, 2024, across PubMed, Cochrane Library, ClinicalTrials.gov, and Google Scholar. Search terms developed using Boolean operators and medical subject headings related to "robotic-assisted cystectomy", "open cystectomy", "intracorporeal urinary diversion", "bladder cancer", and associated outcomes such as "perioperative results", "complications", and "oncological efficacy" were utilized. The search considered peer-reviewed articles, randomized controlled trials (RCTs), cohort studies, and case series published in English within a specified timeframe of the past 10 years to ensure contemporary relevance. The search strategy was refined through initial trial searches and consultations with domain experts to optimize the capture of relevant publications and ensure comprehensive coverage of the topic. After removing duplicates, the titles and abstracts were independently screened by the reviewers, followed by a full-text assessment for eligibility. The search and selection process adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines.

Inclusion and exclusion criteria

The inclusion and exclusion criteria were carefully defined to ensure the selection of studies directly relevant to the comparison of RARC with ICUD *versus* ORC for bladder cancer. Studies were eligible for inclusion if they reported comparative data on perioperative outcomes, oncological efficacy, complications, recovery metrics, and patient-centered outcomes, such as QoL and functional recovery, in adult patients with bladder cancer who underwent RARC with ICUD or ORC. Eligible studies included RCTs, cohort studies, and case series (which reported the outcomes of both surgical techniques in the same study) published in English. Studies without a comparative focus on the specified surgical techniques, those involving extracorporeal urinary diversion (ECUD) alone, non-peer-reviewed publications, conference abstracts, case reports, reviews, and articles not available as full text were excluded. Additionally, studies with insufficient data or those that failed to meet the methodological quality thresholds were excluded to maintain the integrity and reliability of the review.

Study selections

The study selection process involved a comprehensive and structured approach to identify high-quality studies that compared RARC with ICUD *versus* ORC for bladder cancer. Study selection was independently performed by two reviewers at each screening and eligibility stage, and discrepancies were resolved by consensus. Of 1,128 records identified, 28 were screened for further examination after the exclusion of duplicates and ineligible records (Figure 1). Of 28 studies retrieved for full-text review, one was not retrieved because of a lack of access through institutional subscriptions and unavailability from the corresponding author. The remaining 27 studies underwent eligibility assessment, resulting in the exclusion of nine book reviews and 10 studies without a

direct comparison between RARC with ICUD and ORC. Ultimately, eight studies met all the criteria and were included in the systematic review. This rigorous and transparent process ensured the selection of relevant, robust studies essential for evaluating the comparative effectiveness of these surgical approaches.

Data extraction and methodological quality assessment

Data extraction and methodological quality assessment were independently and manually conducted by two reviewers to ensure the reliability of the findings of this systematic review, which compared RARC with ICUD *versus* ORC for bladder cancer. A study was eligible for a given synthesis if at least two studies reported comparable definitions of the outcome for RARC-ICUD *versus* ORC with sufficient statistics, including sample size and either mean (standard deviation [SD]) or event counts. Independent reviewers used a standardized form to capture key information, including study design, patient demographics, surgical techniques, and perioperative and oncological outcomes, which were assessed at the longest available follow-up. The outcomes collected included the length of surgery, 30- and 90-day readmission rates, recurrence-free survival (RFS), overall survival (OS), estimated blood loss (EBL), lymph node yield (LNY), length of stay (LOS), 90-day mortality rate, number of days alive and out of the hospital within 90 days of surgery, overall complication rates at 30 and 90 days—including Clavien Dindo classification—, and incidence of stricture. Any discrepancies were resolved through discussion or arbitration by a third reviewer. The authors of the eligible studies were contacted when clarification or additional data were required.

The methodological quality of each study was assessed using validated tools, such as the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk-of-Bias tool for randomized trials. These tools evaluate factors such as selection bias, group comparability, outcome measurement, and robustness of the reported data. Studies were categorized by quality to provide context for the synthesis of findings and ensure that the conclusions drawn were based on high-quality evidence. Two reviewers independently assessed the risk of bias and methodological quality. Disagreements were resolved by consensus or adjudication by a third reviewer.

Ethical considerations

This systematic review comparing RARC with ICUD *versus* ORC for bladder cancer relied exclusively on published data, and no new ethical approval was required. All included studies were reviewed for adherence to ethical standards, including obtaining informed consent from the participants and securing approval from relevant institutional review boards, as reported in their methodologies. Beyond clinical outcomes, this review addressed broader ethical concerns, including fair access to advanced robotic surgery, the implications of high costs in hospitals, and the importance of transparent reporting to ensure that patients receive accurate and complete information. Transparency was maintained throughout the study selection, data extraction, and analysis to maintain the integrity and credibility of the findings. This study protocol was registered in PROSPERO (CRD 1117374).

RESULTS

Study characteristics

Eight studies met the inclusion criteria and comprised both prospective and retrospective designs, with a total of 1,528 patients undergoing RARC-ICUD or ORC. The median age of the patients ranged from 63 to 69 years. Studies were conducted in Singapore, Italy, France, Australia, Turkey, the United States, and the United Kingdom (Table 1).

Follow-up durations ranged from 3 months to >5 years, enabling the assessment of both short- and mid-term perioperative and oncological outcomes. The primary outcomes were LNY, OS, RFS, EBL, LOS, and complication rates. The secondary outcomes reported were the number of days alive and out of the hospital within 90 days postoperatively, mortality rates, readmission rates, and incidence of uretero-ileal strictures. Despite methodological variations, most studies employed propensity score-matched analyses or RCTs to reduce bias.

Oncological efficacy

LNY

Five studies (Tan et al,[8] Mastroianni et al,[9] Chow et al,[10] Atmaca et al,[11] and Catto et al[12]) found a comparable LNY between RARC and ORC, indicating that the robotic approach did not compromise lymphadenectomy quality. Tan et al[8] reported a mean of 29 nodes (range: 18–32) for RARC *versus* 34 nodes (range: 24–48) for

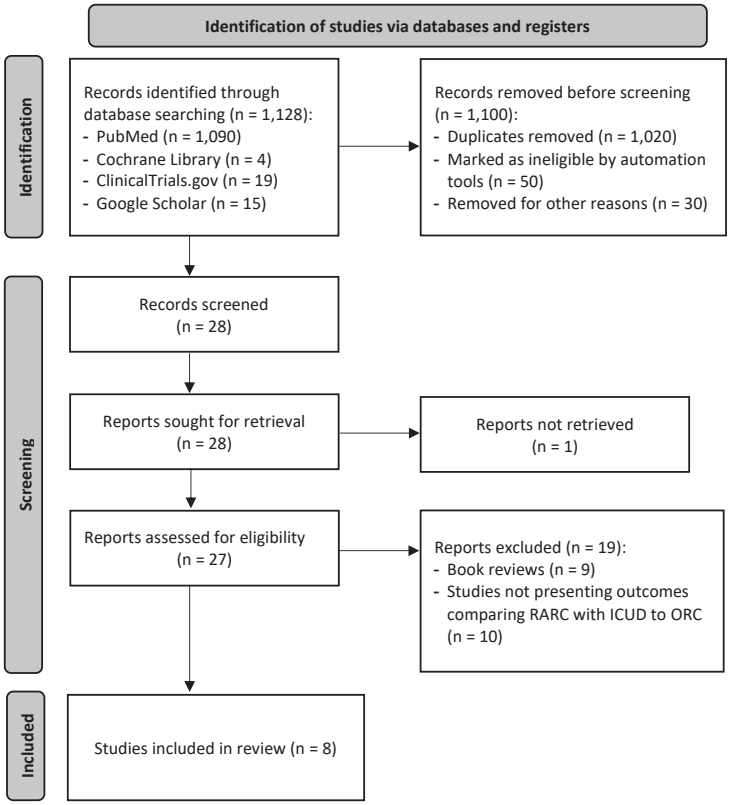

Figure 1. PRISMA 2020 flow diagram for study selection: RARC with ICUD *versus* ORC. ICUD=intracorporeal urinary diversion ; ORC=open radical cystectomy; PRISMA=Preferred Reporting Items for Systematic reviews and Meta-Analyses; RARC=robot-assisted radical cystectomy

Table 1. Characteristics of included comparative studies of RARC-ICUD *versus* ORC

First author, year	Country	Study design	Sample size	Comparison	Follow-up duration
Tan,[8] 2020	Singapore	Propensity-matched analysis	40 patients (19 RARC and 21 ORC)	RARC with ICUD vs. ORC	Mean: 33 months
Mastroianni,[9] 2022	Italy	RCT	116 patients (58 RARC and 58 ORC)	RARC with ICUD vs. ORC	6 months
Gabriel,[14] 2025	France	Single centre cohort	316 patients (228 RARC and 88 ORC)	RARC with ICUD vs. ORC	Median: 42.3 (IQR: 16.4–73.8) months
Chow,[10] 2018	Australia	Retrospective cohort	39 patients (26 RARC and 13 ORC)	RARC with ICUD vs. ORC	90 days
Atmaca,[11] 2015	Turkey	Retrospective study	74 patients (42 ORC and 32 RARC)	RARC vs. ORC	NA
Murthy,[13] 2020	USA	Retrospective cohort study	916 patients (265 ORC, 366 eRARC, and 285 iRARC)	ORC vs. eRARC vs. iRARC	Median: 52 months (ORC), 40 months (eRARC) and 37 months (iRARC)
Catto,[12] 2018	UK	Randomized clinical trial	317 participants (161 RARC and 156 ORC)	RARC vs. ORC	90 days, 6 months, 12 months
Ericson,[15] 2020	USA	Retrospective cohort study	968 patients (279 ORC, 382 eRARC, and 307 iRARC)	ORC vs. eRARC vs. iRARC	NA

eRARC=extracorporal robotic-assisted radical cystectomy; ICUD=intracorporeal urinary diversion; IQR=interquartile range; iRARC=intracorporeal robotic-assisted radical cystectomy; NA=not available; ORC=open radical cystectomy; RARC=robotic-assisted radical cystectomy; RCT=randomized controlled trial

ORC (p = 0.23). Mastroianni et al[9] reported medians of 33 (interquartile range [IQR]: 22–38) for RARC *versus* 31 (IQR: 22–38) for ORC (p = 0.7) (Table 2). Chow et al[10] and Atmaca et al[11] reported similar findings. These results suggest that RARC achieves oncological equivalence to ORC for lymph node dissection.

Table 2. Perioperative, postoperative complications, oncologic, and recovery outcomes comparing RARC-ICUD *versus* ORC

First author, year	Perioperative outcomes								Postoperative complications outcomes								Oncologic outcomes				Recovery outcomes					
	Length of surgery		EBL		LNY		LOS		30-day complication rate		90-day complication rate		90-day mortality rate		Incidence of uretero-ileal strictures*		RFS†		OS‡		30-day readmission rate		90-day readmission rate		DAOH90	
	Minutes	*p*	ml	*p*	Nodes	*p*	Days	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	Months, mean	*p*	Months, mean	*p*	n (%)	*p*	n (%)	*p*	Median (IQR)	*p*
Tan,[8] 2020	-	0.03	-	0.05	-	0.23	-	0.55	-	-	-	-	-	-	-	-	-	0.09	-	0.14	-	0.43	-	-	-	-
RARC, range	581 (450–650)§	-	397 (200–580)§	-	29 (18–32)§	-	7 (5–8)§	-	-	-	-	-	-	-	-	-	37.5	-	43.0	-	3 (15.7)¶	-	-	-	-	-
ORC, range	446 (370–470)§	-	787 (500–800)§	-	34 (24–48)§	-	8.3 (6–10)§	-	-	-	-	-	-	-	-	-	21.4	-	35.5	-	3 (14.3)¶	-	-	-	-	-
Mastroianni,[9] 2022	-	<0.001	-	-	-	0.7	-	0.8	-	>0.9	-	>0.9	-	-	-	-	-	-	-	-	-	0.8	-	0.05	-	-
RARC	313 (63)	-	-	-	33 (22–38)§	-	9 (9)	-	10 (18)	-	24 (42)¶	-	-	-	-	-	-	-	-	-	7 (12)¶	-	16 (28)¶	-	-	-
ORC	196 (40)	-	-	-	31 (22–38)§	-	10 (22)	-	5 (9)	-	25 (44)¶	-	-	-	-	-	-	-	-	-	5 (9)¶	-	12 (21)¶	-	-	-
Gabriel PE,[14] 2024	-	0.1	-	0.01	-	-	-	0.02	-	-	-	0.2	-	-	-	0.6	-	-	-	-	-	-	-	0.9	-	0.018
RARC	300 (255–350)§	-	300 (200–500)§	-	-	-	14 (9–16)§	-	-	-	126 (55.3)¶	-	-	-	40 (17.5)¶	-	-	-	-	-	-	-	77 (33.7)¶	-	75 (69–78)§	-
ORC	327 (255–386)§	-	700 (575–1,000)§	-	-	-	15 (13–20)§	-	-	-	56 (63.6)¶	-	-	-	13 (41.8)¶	-	-	-	-	-	-	-	29 (32.9)¶	-	72 (67–76)§	-
Chow K,[10] 2018	-	-	-	-	-	0.21	-	0.54	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RARC	300 (150–400)§	-	300 (150–400)§	-	18 (15–21)§	-	8 (7–11)§	-	-	-	21 (81)¶	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORC	240 (230–285)§	-	500 (250–600)§	-	25 (16–28)§	-	10 (7–12)§	-	-	-	8 (62)¶	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table continued on next page

Table 2. (Continued)

First author, year	Perioperative outcomes								Postoperative complications outcomes								Oncologic outcomes				Recovery outcomes					
	Length of surgery		EBL		LNY		LOS		30-day complication rate		90-day complication rate		90-day mortality rate		Incidence of uretero-ileal strictures*		RFS†		OS‡		30-day readmission rate		90-day readmission rate		DAOH90	
	Minutes	*p*	ml	*p*	Nodes	*p*	Days	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	Months, mean	*p*	Months, mean	*p*	n (%)	*p*	n (%)	*p*	Median (IQR)	*p*
Atmaca,[11] 2015	-	0.154	-	<0.001	-	-	-	0.548	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RARC	9.76 (1.29)¶	-	412.5 (208.3)¶	-	25.4 (9.7)¶	-	17.4 (9.8)¶	-	26 (80)¶	-	-	-	-	-	-	-	-	-	-	-	3 (9)¶	-	-	-	-	-
ORC	9.2 (1.86)¶	-	1,314.3 (987.1)¶	-	17.2 (13.5)¶	-	18.8 (10.6)¶	-	40 (95)¶	-	-	-	-	-	-	-	-	-	-	-	6 (14)¶	-	-	-	-	-
Murthy,[13] 2021	-	-	-	-	-	-	-	-	-	-	-	0.06	-	0.49	-	-	-	-	-	-	-	-	-	-	-	-
RARC	-	-	-	-	-	-	-	-	-	-	125 (45)¶	-	9 (3.2)¶	-	-	-	-	-	-	-	-	-	-	-	-	-
ORC	-	-	-	-	-	-	-	-	-	-	144 (55)¶	-	11 (4.2)¶	-	-	-	-	-	-	-	-	-	-	-	-	-
Catto,[12] 2022	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RARC	-	-	-	-	16.1 (8)¶	-	7 (6–10)§	-	-	-	-	-	2 (1.2)¶	-	-	-	-	-	-	-	-	-	-	-	82 (76–48)§	-
ORC	-	-	-	-	15.1 (9.3)¶	-	8 (6–14)§	-	-	-	-	-	4 (2.6)¶	-	-	-	-	-	-	-	-	-	-	-	80 (72–83)§	-
Ericson,[15] 2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.37	-	-	-	-	-	-	-	-	-	-
RARC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45 (14.6)¶	-	-	-	-	-	-	-	-	-	-	-
ORC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33 (11.8)¶	-	-	-	-	-	-	-	-	-	-	-

Data are presented by individual studies (randomized trials and observational cohorts) contrasting RARC-ICUD with ORC. Continuous variables are shown as mean (SD) or median [IQR] exactly as reported in the source study; proportions are n (%). *p*-values are two-sided within-study comparisons as reported by the original authors

CI=confidence interval; EBL=estimated blood loss; eRARC=extracorporeal RARC; DAOH90=days alive and out of hospital in the first 90 days; HR=hazard ratio; IQR=interquartile range; iRARC=intracorporeal RARC; LNY=lymph-node yield; LOS=length of stay; OR=odds ratio; ORC=open radical cystectomy; OS=overall survival; PSM=propensity score–matched; RARC-ICUD=robot-assisted radical cystectomy with intracorporeal urinary diversion; RCT=randomized controlled trial; RFS=recurrence-free survival; RR=risk ratio; SD=standard deviation

*Anastomotic stricture requiring endoscopic or surgical intervention within available follow-up; †time from surgery to first recurrence or death from any cause, censored at last follow-up; ‡time from surgery to death from any cause; §median (IQR); ¶mean (SD)

OS

Two studies (Tan et al[8] and Murthy et al[13]) used the mean survival time and 36-month OS rate as the primary measures. Neither study found significant differences between RARC with ICUD and ORC alone. Tan et al[8] reported a mean OS of 43.0 months for RARC and 35.5 months for ORC (p = 0.14). Murthy et al[13] observed 36-month OS rates of 73% for RARC and 65% for ORC, with a median follow-up of 52 and 37 months, respectively. These findings suggest that RARC does not compromise long-term oncological outcomes despite differences in perioperative metrics.

RFS

Two studies (Tan et al,[8] Murthy et al[13]) assessed RFS using mean RFS and 36-month RFS rates. Tan et al[8] reported a mean RFS of 37.5 months for RARC with ICUD and 21.4 months for ORC (p = 0.09), suggesting a trend toward improved oncological outcomes with robot-assisted surgery. Murthy et al[13] found comparable 36-month RFS rates between robotic and open approaches (71% *versus* 71%), with a median follow-up of 52 months (ORC), 40 months (eRARC), and 37 months (iRARC). Overall, RARC achieves similar oncological control to ORC.

Days alive and out of the hospital within 90 days of surgery

Days alive and out of the hospital within 90 days of surgery were compared between RARC and ORC in two studies (Catto et al,[12] Gabriel et al[14]). Catto et al[12] found median values of 82 days (IQR: 76–48) and 80 days (IQR: 72–83) for RARC and ORC, respectively, indicating no significant difference. Similarly, Gabriel et al[14] reported 75 days (IQR: 69–78) for RARC with ICUD *versus* 72 days (IQR: 67–76) for ORC, with a statistically significant difference (p = 0.018). These findings suggest that RARC, particularly with ICUD, may contribute to a reduced hospital stay compared with ORC.

Perioperative outcomes

Length of surgery

Three studies consistently reported longer operative times for RARC. Tan et al[8] found a median of 581 min for RARC *versus* 446 min for ORC (p = 0.03). Similarly, Mastroianni et al[9] reported 313 ± 63 min *versus* 196 ± 40 min (p<0.001). Chow et al[10] also noted 300 min (IQR 150–400) *versus* 240 min (IQR: 230–285). Despite variations in absolute times across studies, the consistent trend suggests that robot-assisted approaches are associated with prolonged surgery. However, no study has contradicted this finding.

EBL

Four studies (Tan et al,[8] Gabriel et al,[14] Chow et al,[10] Atmaca et al[11]) consistently reported significantly lower blood loss with RARC. Tan et al[8] observed a median EBL of 397 mL for RARC *versus* 787 mL for ORC (p = 0.05). Gabriel et al[14] reported 300 mL (IQR: 200–500) for RARC and 700 mL (IQR: 575–1000) for ORC. Chow et al[10] and Atmaca et al,[11] also showed similar results, noting a more than threefold higher mean EBL in ORC (1314.3 ± 987.1 mL) compared to RARC (412.5 ± 208.3 mL, p<0.001). These findings support the perioperative advantage of RARC in reducing intraoperative blood loss.

Length of stay

Six studies reported inconsistent results. Most studies, including Tan et al,[8] Catto et al,[12] Mastroianni et al,[9] Atmaca et al,[11] and Chow et al,[10] found no significant difference, with RARC stays averaging 7–9 days and ORC stays averaging 8–10 days. However, Atmaca et al[11] reported longer stays for both groups (17.4 *versus* 18.8 days), likely due to patient or institutional differences.[12] In contrast, Gabriel et al,[14] was the only study to report a significantly shorter hospital stay for RARC (14 *versus* 15 days, p = 0.02). Overall, RARC tended toward shorter hospitalizations, but most studies did not find a statistically significant advantage.

Complication rate

Two studies assessed 30-day complication rates with conflicting results. Mastroianni et al[9] found identical rates of 18% for both RARC and ORC (p>0.9), whereas Atmaca et al[12] reported a higher complication rate in ORC (95%) than in RARC (80%), indicating the possible benefit of robotic surgery in reducing early postoperative complications. However, the retrospective nature of the study by Atmaca et al,[11] and differences in patient selection may have influenced these results. Overall, the potential advantages remained dependent on patient factors, surgical expertise, and institutional protocols.[11]

Four studies reported 90-day complication rates with mixed results (Mastroianni et al,[9] Chow et al,[10]

Figure 2. Risk-of-bias (RoB 2) traffic-light plot for included randomized trials

ICD-RARP compared to Open Radical Cystectomy (standard care)

Patient or population: bladder cancer patient
Setting: clinical intervention
Intervention: ICD-RARP
Comparison: **Open Radical Cystectomy** (standard care)

Outcomes	№ of participants (studies) Follow up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with standard care	Risk difference with ICD-RARP
Proportion of Perioperatoce Transfusion	119 (7 RCTs)	⨁⨁◯◯ LOW	**RR 0.96** (0.66 to 1.39)	8 per 100	**3 fewer per 100**
Proportion of **hospital** Istay length (days)	32 (2 RCTs)	⨁⨁◯◯ LOW	**RR 1.31** (1.03 to 1.62)	9 per 100	**4 more per 100**
Proportion of Ureteroileal Stricture	13 (2 RCTs)	⨁⨁◯◯ LOW	-	The mean stricture reduction was 1	MD **2.07 higher** (0.48 higher to 3.66 higher)

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **RR:** Risk ratio; **MD:** Mean difference

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Figure 3. Summary of findings (GRADE): ICUD during RARC *versus* ORC for bladder cancer. Certainty key (GRADE): ⨁⨁⨁⨁ high: very confident the true effect lies close to the estimate; ⨁⨁⨁◯ moderate: moderately confident; true effect likely close to estimate; ⨁⨁◯◯ low: limited confidence; true effect may differ substantially; ⨁◯◯◯ very low: very little confidence; true effect likely substantially different. GRADE=grading of recommendations, assessment, development and evaluations; CI=confidence interval; RR=risk ratio; MD=mean difference; RCT=randomized controlled trial; RARC=robot-assisted radical cystectomy; ORC=open radical cystectomy; ICUD=intracorporeal urinary diversion

Gabriel et al,[14] Murthy et al[13]). Mastroianni et al[9] found similar complication rates for RARC and ORC (42% *versus* 44%, *p*>0.9), consistent with their 30-day findings.[9] Gabriel et al[14] reported slightly lower morbidity with RARC (55.3% *versus* 63.6%, *p* = 0.2). In contrast, Chow et al[10] noted a higher rate of RARC (81% *versus* 62%), highlighting potential complications linked to the ICUD learning curve and technical complexity.[11] Overall, complication rates remained high in both approaches, and result variability points to the need for standardized surgical techniques and postoperative care.

Postoperative recovery

Incidence of uretero-ileal strictures

Two studies reported mixed findings on the incidence of uretero-ileal strictures after RARC and ORC. Ericson et al[15] reported no significant differences (14.6% *versus* 11.8%, *p* = 0.37). Gabriel et al[14] observed a higher stricture rate for ORC than for RAC (41.8% *versus* 17.5%, *p* = 0.6), although the difference was not statistically significant. These trends seemed to favor RARC, but the lack of statistical significance suggests that factors other than the surgical technique contribute to stricture formation.

Mortality rate

Two studies (Catto et al[12] and Murthy et al[13]) found no significant differences in 30-day mortality rates between RARC and ORC. Catto et al[12] reported rates of 1.2% *versus* 2.6%, whereas Murthy et al[13] observed rates of 3.2% *versus* 4.2% (p = 0.49). The findings suggest that despite longer operative times, RARC does not increase the short-term mortality risk and shows a slight, non-significant survival advantage. Moreover, these studies also evaluated the 90-day mortality rates between RARC and ORC, resulting in 1.5% (2 patients) *versus* 2.6% (4 patients), suggesting a possible trend toward lower mortality in the robotic group in the study by Catto et al.[12] Similarly, Murthy et al[13] reported rates of 3.2% (9 patients) for RARC and 4.2% (11 patients) for ORC, with no statistically significant difference (p = 0.49). These findings indicate that RARC may offer comparable and potentially slightly improved short-term survival outcomes compared to ORC.

Readmission rate

Thirty-day readmission rates were reported in two studies (Tan et al,[8] Mastroianni et al[9]). Tan et al[8] found similar rates between the RARC (15.7%) and ORC (14.3%) groups with no significant difference (p = 0.43). However, Mastroianni et al[9] reported slightly higher readmission rates for RARC (12%) than for ORC (9%), although the difference was not statistically significant (p = 0.8). These findings suggest that RARC does not significantly reduce 30-day readmission rates compared to ORC.

Ninety-day readmission rates were evaluated by Mastroianni et al[9] and Gabriel et al.[14] Mastroianni et al[9] (prospective randomized trial, 116 patients) reported higher RARC readmissions (28% *versus* 21%, p = 0.05), indicating a slightly higher readmission rate in the robotic cohort. In contrast, Gabriel et al[14] (316 patients, real-world cohort) found comparable rates between RARC (33.7%) and ORC (32.9%) (p = 0.9).

Comparing surgical techniques for perioperative outcomes

Perioperative outcomes from multiple studies consistently favor comparing RARC with ICUD to ORC. Multiple studies, including Mazzone et al[7] and Tan et al,[8] reported markedly reduced intraoperative blood loss (≈ 200 mL to >50% less than ORC). RARC also showed shorter hospital stays and faster recovery times, which are attributed to less invasive techniques and reduced complications, considering the studies by Perri et al[16] and Cochetti et al.[18] Both prospective and retrospective analyses confirmed lower rates of perioperative morbidity, even for patients with comorbidities or advanced disease stages, as shown by Murthy et al[13] and Gul et al.[18] Despite occasional reports of slightly longer operative times in some cases, overall evidence supports RARC with ICUD as a less invasive and effective alternative to ORC, particularly in terms of perioperative parameters, such as blood loss, recovery, and complication rates, without compromising oncological outcomes.[13]

Comparison of complications and cost-effectiveness

A comparison of complications and cost-effectiveness between RARC with ICUD *versus* ORC revealed significant findings. RARC was associated with reduced intraoperative blood loss, fewer transfusions, and lower rates of high-grade perioperative complications, as demonstrated in studies by Mazzone et al,[9] Perri et al,[16] and Cochetti et al.[17] Additionally, RARC often resulted in shorter hospital stays and faster recovery, thereby minimizing postoperative morbidity. However, the cost-effectiveness of RARC remains controversial because of the higher initial costs of robotic equipment and training requirements. Studies such as those by Murthy et al,[13] indicate that improved outcomes and decreased complication rates may offset these costs over time, particularly as surgical expertise increases and hospital resources are optimized. Although ORC generally has lower upfront costs, the reduced morbidity and quicker recovery associated with RARC suggest that it may offer a favorable cost-benefit ratio in specific patient populations. This balance between reduced complications and economic considerations makes RARC a competitive alternative to ORC in modern surgical practice.[13]

The risk-of-bias assessment for the included randomized controlled trials is summarized in Figure 2. Most studies demonstrated a low risk of bias across the assessed domains, although some concerns were raised particularly in the randomization process and selection of the reported results. Certainty of the evidence for the main outcomes, evaluated using GRADE approach, is depicted in Figure 3. The evidence was rated as low for all reported outcomes.

DISCUSSION

Our findings indicate that RARC-ICUD offers perioperative advantages, most notably lower EBL and quicker recovery, while sustaining oncological efficacy comparable to that of ORC. These advantages, demonstrated broadly across varying institutional settings, were tempered by substantial between-study variability, including differences in patient populations, surgeon experience, and diversion techniques, which limited the strength of inferences. As RARC-ICUD requires higher initial costs and specialized training, its overall value may become more apparent over time, with fewer complications and shorter hospital stays. Evidence supports a continued shift toward intracorporeal diversion techniques; however, standardized protocols and further investigations are needed to clarify their impact on QoL and long-term functional recovery.[4]

Perioperative outcomes

Studies have consistently reported that RARC has a longer operative duration than ORC owing to its technical complexity and steep learning curve. However, the trade-off is a significant reduction in intraoperative blood loss, as shown by Mazzone et al[7] and Tan et al.[8] This reduction lowers the need for perioperative transfusions, which carry risks such as infection, immunosuppression, and prolonged recovery.[6] Additionally, Simone et al[19] observed reduced intraoperative blood loss (397 *versus* 787 mL, p = 0.05, HR 2.11, 85% CI: 1.26–3.52), along with reduced postoperative pain and ileus. These benefits are attributed to smaller incisions, reduced abdominal wall retraction, minimal bowel manipulation, enhanced three-dimensional vision, improved magnification, and pneumoperitoneum effects of robotic platforms, which facilitate meticulous dissection and decreased blood loss.[8]

Moreover, minimally invasive techniques in RARC contribute to shorter hospital stays and faster postoperative recovery. Studies by Cochetti et al[16] and Perri et al,[17] revealed acceptable complication rates in robotic procedures, despite the complexity of ICUD. These findings are particularly important for patients with comorbidities or advanced disease, for whom traditional open surgery may pose a higher risk. By reducing perioperative stress, RARC enables better postoperative recovery and enhances the overall surgical experience.[2,18]

Oncological efficacy

The oncological outcomes of RARC are critical for determining its role in bladder cancer management. Long-term data from studies by Mastroianni et al and Gabriel et al suggested that RARC is comparable to ORC in terms of cancer-specific survival, RFS, and OS.[5,14] These results indicate that the adoption of robotic techniques does not compromise oncological efficacy, even in patients with high-risk or advanced tumors.[5]

LNY is a crucial measure of oncological adequacy in radical cystectomy. Findings from multiple studies indicate that RARC achieves an LNY comparable to that of ORC, with no significant differences in the number of retrieved lymph nodes. Although earlier concerns suggested that the robotic approach might compromise the quality of lymphadenectomy, recent studies (Tan et al,[8] Mastroianni et al[9]) have demonstrated that meticulous templated dissection remains the primary determinant of optimal LNY. Although ORC has historically yielded a higher number of nodes, the packaging technique in RARC, in which lymph nodes are often removed in a single, larger specimen, may contribute to this discrepancy without necessarily affecting oncological outcomes.

OS and RFS are long-term oncological outcomes of RARC and are both influenced by a range of tumor-related factors, including pathological stage, lymph node involvement, and histological variants. Two major studies (Tan et al,[8] Murthy et al[13]) demonstrated no significant differences in OS or RFS between RARC and ORC. Interestingly, Tan et al[8] reported a trend toward an improved mean RFS in the RARC group, although the difference was not statistically significant. This suggests a potential benefit of robotic surgery, possibly linked to decreased perioperative morbidity, reduced inflammation, and faster recovery, allowing for the timely administration of adjuvant therapy. However, the lack of consistent survival advantages implies that oncological outcomes are more heavily dictated by tumor biology and adjuvant treatments than by the surgical approach itself.[8]

Long-term complications and QoL

Stricture formation is a significant long-term complication of radical cystectomy that affects both renal function and QoL. Findings from two studies (Ericson et al,[15] Gabriel et al[14]) revealed inconsistent uretero-ileal stricture rates between robot-assisted and open surgical approaches, indicating that

stricture development is multifactorial and includes both surgical technique and individual patient characteristics. Recent systematic reviews have reported similar risks of uretero-ileal stricture across these methods, with rates of 15% for RARC with ICUD, 12.4% for ECUD, and 9.6% for ORC. However, no single study has shown a statistically significant difference among these techniques.[14,15] Although postoperative complications, such as uretero-ileal strictures, are more common in RARC with ICUD than in RARC with ECUD or ORC, this number remains statistically non-significant. The benefits of RARC with ICUD are still considered to outweigh potential long-term complications.

Patient selection is a critical factor in determining surgical outcomes. Research, including studies by Abreu et al,[20] highlights the need to tailor surgical approaches to individual characteristics such as age, comorbidities, and tumor stage.[20] Older patients or those with comorbidities may particularly benefit from RARC owing to its reduced morbidity and faster recovery, although careful assessment remains essential. RARC also enhances QoL by reducing perioperative complications (less blood loss and shorter hospital stay) and supporting quicker recovery and return to daily activities. Functional recovery and psychological well-being are now central to evaluating surgical success, with Catto et al[12] emphasizing the positive effects of RARC on postoperative QoL.[21] Therefore, RARC is preferred and recommended, as it offers better perioperative outcomes without a significant increase in long-term complications.

Cost-effectiveness

A major challenge of RARC is its cost-effectiveness, given the high investment in equipment, training, and maintenance, which can limit its adoption. Some studies, such as that by Murthy et al,[13] suggest that reduced perioperative complications and quicker recovery may help balance these higher upfront costs, particularly in high-volume centers. Additionally, the learning curve for RARC and ICUD is steep, with outcomes tied to surgeon expertise.[3,22] Continuous training and advancements in robotic technology are gradually narrowing this gap.[23] In experienced hands, RARC offers a high degree of precision, particularly in lymph node dissection and intracorporeal urinary reconstruction.[14,24] In summary, RARC should be encouraged over ORC, as it can reduce postoperative costs through quicker recovery and fewer perioperative complications. However, these benefits may require time to offset the high initial investment required for RARC.

Limitations and further directions for RARC

Despite its benefits, RARC has some limitations. Longer operative times, as reported by Gul et al,[18] remain a concern, particularly during early adoption.[23] However, these times tend to decrease with experience and advancements.[13] Potential surgeon fatigue in prolonged procedures highlights the need for adequate support systems and team-based approaches.[19] The comparison between ICUD and ECUD also adds depth to the discussion. Studies such as those by Martin and Corcoran[25] reveal that ICUD reduces complications related to urinary reconstruction.[25] By performing all reconstruction steps within the abdominal cavity, ICUD minimizes the risks associated with bowel exposure and external handling, leading to better outcomes.[26]

The discussion of RARC also extends to broader implications for surgical innovation and healthcare delivery. As robotic surgery has become more integrated into clinical practice, it sets new benchmarks for minimally invasive techniques.[11] By combining technological precision with improved patient outcomes, RARC exemplifies the future of surgery in oncology.[4,27] Over time, its adoption can reduce morbidity, enhance recovery, and maintain oncological safety, aligning with the goals of modern medicine.[28] As more institutions adopt robotic surgery and refine its protocols, RARC with ICUD is likely to become a standard of care in bladder cancer treatment, offering a blend of innovation and effectiveness.[24,25]

Limitations

Owing to the clinical and analytical heterogeneity among the included studies, we did not perform a meta-analysis, which precluded formal heterogeneity metrics and may have reduced the statistical precision. Instead, we used a structured narrative synthesis to evaluate outcomes across studies. Our English language restriction for the included studies raised the possibility of language bias. Another key limitation of this systematic review was the variability in the study design and overall quality of evidence. Many of the included studies were retrospective, which may have introduced bias in patient selection and outcome reporting. This study might also be

biased from the original studies because patients who underwent RARC could be privileged compared to their counterparts. Additionally, because RARC is a relatively new technology, patient selection for this procedure may be significantly limited to those with more favorable safety profiles. Additionally, the sample sizes of some studies were relatively small, limiting the generalizability of the findings. Although RARC with ICUD appears to offer advantages in terms of perioperative outcomes, its long-term oncological efficacy and survival benefits remain inconclusive, with several studies having limited follow-up durations. Moreover, the learning curve associated with robot-assisted techniques can influence surgical outcomes, and the lack of standardized protocols for robotic surgery further complicates comparisons between studies. Economic evaluations are hindered by the high initial costs of robotic systems and the variability in healthcare resource availability, making it difficult to universally assess the true cost-effectiveness of RARC. Therefore, further high-quality, multicenter, long-term, RCTs are needed to provide more robust evidence and address these limitations.

RARC with ICUD demonstrates promising benefits in terms of reduced blood loss, faster recovery, and fewer perioperative complications. Its long-term oncological efficacy remains comparable to that of ORC. It also provides surgeons with enhanced precision and ergonomic benefits. However, it also presents challenges, particularly those related to the learning curve and technical complexities associated with ICUD. The economic implications of robotic surgery, including its high upfront costs and the need for specialized training, must also be considered when evaluating its broader applicability. Despite these challenges, RARC with ICUD is increasingly being performed by experienced surgeons in high-volume centers. However, further research, including large-scale RCTs with extended follow-up periods, is still needed to confirm its oncological outcomes and cost-effectiveness and to guide clinical practice in bladder cancer treatment.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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