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Robot-assisted radical cystectomy: Where we are in 2023

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Open radical cystectomy (ORC) is associated with high rates of perioperative morbidity and mortality, owing to its extensive surgical nature and the high frequency of multiple co-morbidities among patients. As an alternative, robot-assisted radical cystectomy (RARC) has been increasingly adopted worldwide, being a reliable treatment option that utilizes minimally invasive surgery. Seventeen years have passed since the advent of the RARC, and comprehensive long-term follow-up data are now becoming available. The present review focuses on the current knowledge of RARC in 2023, and analyzes various aspects, including oncological outcomes, peri/post-operative complications, post-operative quality of life (QoL) change, and cost-effectiveness. Oncologically, RARC showed comparable oncological outcomes to ORC. With regard to complications, RARC was associated with lower estimated blood loss, lower intraoperative transfusion rates, shorter length of stay, lower risk of Clavien–Dindo grade III–V complications, and lower 90-day rehospitalization rates than ORC. In particular, RARC with intracorporeal urinary diversion (ICUD) performed by high-volume centers significantly reduced the risk of post-operative major complications. In terms of post-operative QoL, RARC with extracorporeal urinary diversion (ECUD) showed comparable results to ORC, while RARC with ICUD was superior in some respects. As the RARC implementation rate increases and the learning curve is overcome, more prospective studies and randomized controlled trials with large-scale patients are expected to be conducted in the future. Accordingly, sub-group analysis in various groups such as ECUD, ICUD, continent and non-continent urinary diversion, etc. is considered to be possible.

Keywords: Cystectomy; Postoperative complications; Quality of life; Robotics; Treatment outcome

INTRODUCTION

Bladder cancer is a serious health risk, both functionally and oncologically, and is a continuously increasing socioeconomic burden [1,2]. It is now the sixth most common type of cancer in the US [3] and the tenth most common cancer in the world, with its incidence steadily rising worldwide each year [4]. Regarding surgical treatments, radical cystectomy (RC) with pelvic lymph node dissection is considered the gold standard for muscle-invasive bladder cancer and selected patients with high-risk non-muscle invasive bladder cancer [5,6]. However, owing to its unavoidably extensive surgical nature and the high frequency of multiple co-morbidities among patients, it is associated with high rates of perioperative morbidity and mortality [7].

Minimally invasive strategies have gained popularity in various fields because of their potential to reduce surgical morbidity and shorten hospital length of stay (LOS). In particular, robot-assisted laparoscopic RC (RARC), since its introduction in 2003, has gradually become adopted as a surgi-

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cal option with the goal of improving perioperative outcomes and survival [8]. From 2004 to 2012, the number of RARCs increased 30-fold, from 0.6% to 18.5% [9,10]. In the early days of RARC, extracorporeal urinary diversion (ECUD) was most commonly implemented; however, most RARCs are now performed using the intracorporeal urinary diversion (ICUD) method in the high-volume centers [11].

In analyzing the outcomes of previous studies, one important issue to consider is the shallow learning curve for RARC, arising from its complex surgical nature. Without careful examination, confusing and counter intuitive conclusions could be drawn. For instance, in terms of complication rates, Clavien–Dindo grade 3–5 (major) complications in RARC with ICUD decreased significantly, from 25% in 2005 to 6% in 2015, as the learning curve was gradually overcome [12].

In this review, we discuss the current knowledge of RARC as of 2023. We compared not only the conventional robotic and open approaches but also the ECUD and ICUD diversion methods within the robotic approach. Furthermore, by organizing oncological outcomes, peri/post-operative complications, post-operative quality of life (QoL) changes, and conducting a cost-effectiveness analysis of RARC, we assessed its advantages and disadvantages in each aspect compared to open RC (ORC).

ONCOLOGICAL OUTCOMES

1. Robotic approach vs. laparoscopic approach vs. open approach

Sathianathen et al. [13] performed a systematic review and meta-analysis including five randomized controlled trials (RCTs) (one multicenter and four single-center), and compared RARC with ORC [14-19]; they concluded that surgical technique does not have a considerable impact on oncological outcomes. More recently, the randomized open vs. robotic cystectomy (RAZOR) trial showed comparable recurrence-free survival (RFS), progression-free survival, and overall survival (OS) rates for up to 3 years [20]. Data from the International Robotic Cystectomy Consortium (IRCC) suggested that oncologic outcomes are comparable for up to 10 years after RARC [21]. Ip et al. [22] also compared the 10-year oncological outcomes of ORC and RARC. The results showed no difference between RARC and ORC patients with respect to OS and RFS, despite the fact that RARC patients were older and had more co-morbidities.

Murthy et al. conducted a retrospective review of all patients undergoing curative-intent RC with urinary diversion for urothelial bladder cancer at a single institution from 2010–2018 [23]. Higher positive surgical margin rates were observed in the ORC cohort (7.2%, p=0.041). These findings from a single, large institution, in conjunction with RCT data, suggest that RARC does not compromise in terms of perioperative or long-term oncologic outcomes when compared to ORC. Additionally, a retrospective review of the IRCC found that RARC was not associated with different relapse patterns or higher relapse rates compared to ORC [24]. Meanwhile, Mortezavi et al. [6] recently reported the largest comparative analysis of RARC with ICUD and ORC, using a nationwide population-based cohort from the Swedish National Register of Urinary Bladder Cancer. They demonstrated that, compared with ORC, RARC with ICUD was associated with a higher lymph node yield (median [IQR], 20 [15–27] lymph nodes vs. 14 [8–24] lymph nodes; p<0.001) and lower all-cause mortality (hazard ratio, 0.71; 95% CI, 0.56–0.89; p=0.004).

Feng et al. [25] conducted a systematic review comparing robot-assisted and laparoscopic RCs (LRCs), including 10 studies (two RCTs, four prospective studies, and four retrospective studies). They demonstrated that the relative risk of positive surgical margins was not significantly different between the RARC group and LRC group. There was a significantly higher lymph node yield and longer OS (HR, 0.26; 95% CI, 0.17–0.37; p<0.00001) in the RARC group than in the LRC group.

In the meanwhile, Elsayed et al. [24] investigated the rates and patterns of recurrences after RARC. Result showed that RARC was not associated with different patterns or higher relapse rates compared to historic ORC data. According to Zennami et al. [26], this trend was also shown in locally advanced (≥cT3) disease.

2. Robotic ECUD vs. ICUD

So far, no RCTs have been conducted on this topic. Katayama et al. [27] performed a systematic review and meta-analysis comparing ECUD and ICUD RARC. Twelve studies including a total of 3,067 patients were analyzed. With regard to oncological outcomes, patients receiving an ICUD had a significantly higher lymph node (LN) yield than those who received an ECUD (mean difference [MD], 3.68; 95% CI, 0.80–6.56; p=0.01), while PSM of positive LN was not significantly different between ICUD and ECUD. Cai et al. [28] also performed a pooled analysis of 13 retrospective studies that included a total of 4,755 patients. The average follow-up time was 21.3 months in the ICUD group and 23.3 months in ECUD group, respectively. In the three studies that assessed recurrence rates in 2,613 patients, the ICUD group showed a lower recurrence rate than the ECUD group (OR, 0.74; 95%

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CI, 0.61–0.91; p=0.004). In the two studies that assessed the mortality rates in 2,251 patients, no significant difference was observed between the two groups (OR, 1.00; 95% CI, 0.79–1.26; p=0.98). Additionally, Ham et al. [29] recently reported the results of 11 multicenter studies. They showed that although the overall recurrence (36.5% vs. 25.5%, p=0.013) and pelvic recurrence (12.1% vs. 5.9%, p=0.031) rates were higher in the ECUD group, there was no significant difference in the 5-year RFS (43.2% vs. 58.4%, p=0.516), cancer-specific survival (79.3% vs. 89.7%, p=0.392) and OS (74.3% vs. 81.4%, p=0.411) between the ICUD and ECUD groups. This is supported by the two institution prospective study by Bertolo et al. [30], that there were comparable RFS (log-rank p=0.08) and metastasis-free survival (log-rank p=0.02) between two groups at a mean follow-up of 18 months.

PERI- AND POST-OPERATIVE OUTCOMES

Metabolic, infectious, genitourinary, and gastrointestinal complications were identified as the primary causes of readmission after RARC in 39.5%, 23.5%, 22.3%, and 17% of patients, respectively [31]. Fifty percent of readmissions occurred in the first two weeks after hospital discharge. Male sex (OR, 3.5; p=0.02) and in-hospital infections (OR, 4.35; p=0.002) were independent predictors for multiple readmissions [31]. The shallow learning curve of RARC (10 to 75 cases) is one of the important issues to consider because it may affect various peri- and post-operative outcomes, including LOS, complication rates, etc [32].

1. Robotic approach vs. open approach

Catto et al. [33] reported a recent RCT comparing RARC with ICUD to ORC at 9 sites in the UK. Results showed that RARC with ICUD group showed a significant increase in days out of the hospital over the postoperative 90 days. Thromboembolic complications (1.9% vs. 8.3%; difference, –6.5%; 95% CI, –11.4% to –1.4%) and wound complications (5.6% vs. 16.0%; difference, –11.7%; 95% CI, –18.6% to –4.6%) were less common with robotic surgery than open surgery. Mortezavi et al. [6] reported the results of a nationwide population-based cohort study from the Swedish National Register of Urinary Bladder Cancer. Compared with ORC, RARC with ICUD was associated with a lower estimated blood loss (median [IQR], 150 [100–300] mL vs. 700 [400–1300] mL; p<0.001), intraoperative transfusion rate (OR, 0.05; 95% CI, 0.03–0.08; p<0.001), shorter LOS (median [IQR], 9 [6–13] days vs. 13 [10–17] days; p<0.001), and 90-day rehospitalization rate (reason not analyzed) (OR, 1.28; 95% CI, 1.02–1.60; p=0.03). In comparison to the ORC group, the RARC group had a lower risk of Clavien–Dindo grade III or higher complications (OR, 0.62; 95% CI, 0.43–0.87; p=0.009). Another analysis of 28 Italian multicenter prospective cohort studies compared ORC, LRC, and RARC [34]. They found that RARCs was feasible and had similar perioperative complication rates as those of the other approaches. RARC has several advantages, especially in elderly patients. According to Xie et al. [35], elderly patients (≥80 years) who received RARC had a similar risk of perioperative complications and RFS as younger patients. Thus, RARC could be an alternative treatment for selected octogenarians. Zhou et al. [36] recently conducted a systematic review and meta-analysis comparing intracorporeal RARC and ORC. They found that compared with ORC, RARC with ICUD demonstrated lower estimated blood loss (weighted MD, −449.25; 95% CI, -566.47 to -332.03; p<0.01), lower blood transfusion rates (OR, 0.31; 95% CI, 0.22–0.46; p<0.01), and rates of lower post-operative complications with Clavien–Dindo grades III–IV (30 days: OR, 0.65; 95% CI, 0.47–0.90; p=0.01; 90 days: OR, 0.72; 95% CI, 0.53–0.98; p=0.04), but a longer operative time (weighted MD, 78.82; 95% CI, 52.77–104.87; p<0.01). Furthermore, there was no significant difference between RARC with ICUD and ORC in terms of rates of post-operative complication with Clavien–Dindo grades I–II (30 days: OR, 0.71; 95% CI, 0.36–1.40; p=0.32; 90 days: OR, 0.98; 95% CI, 0.74–1.30; p=0.89).

2. Robotic ECUD vs. ICUD

Randomized data comparing the outcomes of ICUD vs. ECUD are lacking. RARC with ICUD, as a completely minimally invasive procedure, may provide benefits in terms of smaller incisions, reduced pain, accelerated bowel recovery, and reduced risk of fluid imbalance [37,38]. The use of ICUD has increased over the past decade, especially in high-volume institutions, showing improved perioperative outcomes over time [12]. A large cohort study from the IRCC compared ICUD and ECUD after RARC, and showed that ICUD was associated with a shorter operative time and less blood loss [39]. However, ICUD was associated with more overall (but not high-grade) complications. Nevertheless, the complication rates significantly decreased over time [12,39]. There is one prospective study by Bertolo et al. [30] comparing two robotic approaches performed by two institutional surgeons. They showed that no differences were found in postoperative complications either overall (ICUD: 26.7% vs. ECUD: 34.8%, p=0.3) or major (ICUD: 10 [16.7%] vs. ECUD: 14 [21.2%], p=0.6). There was no difference in 30 days and 90 days postoperative complication rates also.

It is also noteworthy that ICUD patients with a high

age-adjusted Charlson Comorbidity Index had a lower risk of complications than ECUD patients [40]. This may be due to reduced surgical stress, including less blood loss, lower transfusion rates, or avoidance of excessive bowel manipulation, and less time exposed to external air. ICUD neobladder level increased significantly over time. Patients who underwent RARC with ICUD neobladders had shorter hospital stays and fewer 30-day reoperations, but were readmitted more frequently than those who received ECUD neobladder [41]. Teoh et al. [42] reported the results of 9 multicenter Asian RARC registries. RARC with ICUD was safe and technically feasible with similar post-operative complication rates to ECUD, with the additional benefits of reduced blood loss and shorter hospitalization. A meta-analysis and systemic review by Tanneru et al. [43] reported that the overall complication rates at 30 and 90 days were comparable between ICUD and ECUD. More experienced centers and those with higher volumes had decreased operative times for ICUD compared to ECUD. According to Katayama et al. [27], complications of RARC with ICUD in the short- and mid-term periods were equivalent to those of ECUD, with a trend toward faster bowel recovery. This study also showed that ICUD performed at high-volume centers significantly reduced the risk of post-operative major complications. The fast recovery, evidenced by time to flatus passage, oral intake, and length of hospital stay was also observed in Korean multicenter study by Shim et al. [44]. In terms of functional outcome, Khan et al. [45] compared the functional outcome between RARC with ICUD and ECUD of the Studer method. The result showed that there was no significant difference between the groups as regards urodynamic parameters. However, continence was attained a little earlier in the ICUD group.

HEALTH-RELATED QOL AND FUNCTIONAL CAPACITY

Patients with bladder cancer are usually elderly, have lower functional capacity, and have multiple co-morbidities [46]. Furthermore, RC is one of the most common operations performed in urology. Thus, recovery of QoL after RC is a critical issue in the field of urology. RARC undoubtedly offers the benefits of less morbidity, shorter hospital stays, faster recovery, and fewer narcotic analgesic requirements, which all contribute to increasing the patient's QoL [47]. Health-related QoL (HROoL) improved and returned to baseline within 6 months after RARC with ICUD, and the development of early and late complications after surgery were the primary factors impacting global HRQoL after RARC with ICUD [48]. However, there is still little evidence regarding whether RARC is superior to ORC in improving HRQoL outcomes.

Seven prospective RCTs were performed to compare HRQoL between extracorporeal ORC and RARC (Table 1). The first study, which was reported by Messer et al. [49], used the Functional Assessment of Cancer Therapy-Vanderbilt Cystectomy Index (FACT-VCI) to compare patients. There was no significant difference in scores between ORC and RARC at 3, 6, 9, and 12 months post-operatively. However, a significantly lower physical well-being score at six months was reported in the ORC group (mean difference, -2.5; p=0.04).

The second trial, conducted by Bochner et al. [18], analyzed HRQoL between extracorporeal ORC and RARC by comparing the European Organization for the Research and Treatment of Cancer Quality of Life 30-item core questionnaire (EORTC QLQ-C30) at 3 and 6 months post-operatively. There were no significant differences at 3 or 6 months post-operatively between the two groups in any domain.

The third RCT study by Khan et al. [17] compared extracorporeal ORC, LRC, and RARC with QoL assessed using the FACT-Bladder Cancer and FACT-General questionnaires. Most patients underwent an ileal conduit. Similar to prior studies, this study did not find any significant differences among the three approaches. However, they did not report preoperative baseline QoL or subdomain scores. Furthermore, the period over which post-operative QoL was measured differed for each patient, which was a limitation.

The fourth trial, the RAZOR trial, included the largest number of patients [50]. The FACT-VCI and Short-Form 8 Health Survey (SF-8) were used to compare extracorporeal ORC and RARC cohorts at 3 and 6 months post-operatively (n=178). There were no significant differences between cohorts at any time point for any of the FACT-VCI or SF-8 composite scores. Using data from the RAZOR trial, Venkatramani et al. [51] recently reported that patients require 3 to 6 months to recover baseline levels after RC, irrespective of the surgical approach. Hand grip strength and activities of daily living (ADL) tended to recover to baseline earlier after RARC; however, there was no difference in the percentage of patients who recovered compared with that of ORC. To summarize the results of trials conducted up to 2020, there was generally no difference in QoL between RARC and ORC, while RARC was shown to be superior in terms of early recovery of ADL and physical well-being. However, these studies were limited by an extracorporeal to urinary diversion, jeopardizing the benefits expected of a minimally invasive procedure [52].

The fifth RCT by Mastroianni et al. [5] compared HRQoL

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Table 1. Comparison of health-related quality of life and functional capacity outcomes between ORC, LRC and RARC from prospective randomized clinical trials

Reference	Year	Surgical approach	No. of patients	Questionnaire	Summary of findings
Messer et al. [49]	2014	ORC vs. RARC	25	FACT-VCI	No significant differences at 3, 6, 9, or 12 mo. Lower physical well-being score at 6 mo (ORC).
Bochner et al. [18]	2015	ORC vs. RARC	53	EORTC QLQ-C30	No significant differences at 3 or 6 mo.
Khan et al. [17]	2016	ORC vs. LRC vs. RARC	46	FACT-BL, FACT-G	No significant differences at mean follow-up of 8 mo.
Becerra et al. [50]	2020	ORC vs. RARC	178	FACT-VCI, SF-8	No significant differences at 6 mo.
Venkatramani et al. [51]	2022	ORC vs. RARC	206	Participant reported ADL questionnaire	Hand grip strength and ADL tended to recover to baseline earlier after RARC. However, there was no difference in the percentage of patients who had recovered compared with ORC.
Mastroianni et al. [5]	2022	ORC vs. RARC with ICUD	51	EORTC QLQ-C30, QLQ-BLM30	ORC patients more likely to report 1-y impairment of role functioning, and bowel symptoms. RARC patients more likely to report 1-y urinary symptom impairment (interim report).
Vejlgaard et al. [53]	2022	ORC vs. RARC with ICUD	50	EORTC QLQ-C30, QLQ-BLM30	No significant differences at 3 mo.
Catto et al. [33]	2022	ORC vs. RARC with ICUD	317	EQ-5D-5L, EORTC QLQ-C30, WHODAS 2.0 score	ORC patients reported worse EQ-5D-5L score and grester disability at 5 wk. No significant differences at 3 mo.

ORC, open radical cystectomy; RARC, robot-assisted radical cystectomy; LRC, laparoscopic radical cystectomy; ADL, activities of daily living; ICUD, intracorporeal urinary diversion; FACT-VCI, Functional Assessment of Cancer Therapy-Vanderbilt Cystectomy Index; EORTC QLQ-C30, European Organization for the Research and Treatment of Cancer Quality of Life 30-item core questionnaire; FACT-BL, Functional Assessment of Cancer Therapy – Bladder; FACT-G, Functional Assessment of Cancer Therapy - General; SF-8, Short-Form 8 Health Survey; QLQ-BLM30, Quality of Life Questionnaire for Muscle-Invasive Bladder Cancer; EQ-5D-5L, European Quality of Life 5-Dimension, 5-Level instrument; WHODAS 2.0, World Health Organization Disability Assessment Schedule 2.0.

between ORC and RARC with ICUD. In their interim analysis, 1-year HRQoL outcomes were compared between ORC and RARC with ICUD [5]. EORTC QLQ-C30 and QLQ-BLM30 were collected at baseline and at 1 year. Overall, both groups reported significant worsening of body image and physical and sexual function (all p=0.012). Patients receiving ORC were more likely to report significant 1-year impairments in role functioning, symptom scales, and bowel symptoms (all p=0.048). On generalized linear mixed-effect regression, patients undergoing ORC experienced a significant increase in insomnia (p=0.047) and abdominal bloating and flatulence (p=0.035) compared to the RARC cohort. Patients receiving RARC reported significant urinary symptoms and problems (p=0.018).

Sixth is a single center, double-blinded RCT, named the BORARC trial. Similar to the fifth trial, they also compared HRQoL between ORC and RARC with ICUD. They used the EORTC QLQ-C30 and QLQ-BLM30 QoL questionnaires, and demonstrated that 90 day post-operative QoL did not differ between ORC and RARC [53].

Seventh is a multicenter study RCT from the UK [33]. They additionally analyzed early period HRQoL at 5 weeks. Results showed that RARC with ICUD showed superior results at 5 weeks compared to ORC (both European Quality of Life 5-Dimension, 5-Level instrument scores, and World Health Organization Disability Assessment Schedule 2.0 scores). But as in the previous studies, the differences were not significant after 12 weeks.

Recently, Wijburg et al. [54] reported the results of a prospective comparative effectiveness study conducted in 19 Dutch centers. There was no statistically significant difference in HRQoL between ORC and RARC. Although this study was not an RCT, it has the advantage of being a large population multicenter study, and 88% of patients underwent intracorporeal reconstruction.

Collectively, most RCTs demonstrated that there is no significant difference in QoL between extracorporeal RARC and ORC. However, the actual impact of the RARC learning curve on clinical outcomes is unknown, although both the learning curve [55,56] and hospital volume [57] are likely to influence the outcomes of RARC. In addition, there is a current surgical trend of utilizing intracorporeal RARC, encompassing 95% of all RARCs [39], which may have greater benefits [58]. Thus, more RCTs are needed to reflect real-world clinical practice, to provide concrete and practical evidence.

Still, the above RCT study results have a limitation in that they have a heterogeneous urinary diversion type and a biased distribution towards ileal conduit in most of the studies. Although the ileal conduit has the advantages of

faster and easier surgery and low complications, orthotopic neobladder generally offers significantly better QoL by maintaining body image and normal voiding function in suitable patients [59,60]. They have a better physical function and a more active lifestyle [61], including better sexual function [60]. Further RCTs are needed to perform subgroup analysis of different urinary diversion types in comparing the HRQoL of RARC and ORC.

Meanwhile, there is strong evidence that functional prehabilitation, including aerobic physical activity, psychosocial counseling, and nutrition programs, have a positive impact on health, survival, and QoL [46,62]. Optimization of functional capacity before and after RC is considered an important factor in achieving better post-operative QoL [63]. The CanMoRe RCT is currently in progress and seeks to provide new knowledge on rehabilitation after RARC [62].

COST-EFFECTIVENESS

The need to set priorities in health care is becoming increasingly apparent, and thus, cost-effectiveness analysis, which defines cost-effectiveness quantitatively through objective measurements of net costs and health effects, is widely used to assess the relative value of different treatment option [64].

Before examining cost effectiveness, several studies conducted cost analyses for RARC (Table 2). Smith et al. [65] performed a comparative cost analysis between RARC and ORC, which included variability in operation time, transfusion requirements, and hospital stay, and concluded that RARC is associated with a higher financial cost (+$1,640) than ORC. Several other studies have also noted that RARC itself incurs approximately 16%–19% higher costs than ORC [1,66]. However, one point to consider is that several extra costs arise from readmission, and these are known to occur more frequently in ORC than in RARC. Those who underwent readmission had direct costs 1.42 times higher than those who did not require readmission [67].

Some authors have conducted detailed analyses of the cost items in RARC and the best ways to reduce costs. According to the European Association of Urology-Young Academic Urologists, patients who underwent RARC with ICUD were recruited from 11 European centers in four European countries (Belgium, France, the Netherlands, and the UK) from 2015 to 2020 [68]. Eighty-four percent of the costs of RARC were due to hospital stay (42%), ICU stay (3%), and operative time (39%), while 16% of the costs were due to robotic (8%) and stapling (8%) instruments. They suggested that decreasing the LOS and reducing operative time could help decrease the cost of RARC and make it more widely accessible. Another group suggested scenarios potentially resulting in significant cost savings for RARC, specifically an operating time ≤175 minutes, LOS ≤4 days, and RARC equipment ≤€281 [69].

Cost-effectiveness analysis has recently been performed by several study groups (Table 2). Bansal et al. developed a cost-decision tree model by considering data on LOS, operation times, transfusion rates, volume, and complication rates [1]. They revealed that although RARC is 18.9% more expensive than ORC, only minimal improvements in the QoL (quality-adjusted life years [QALYs] of 0.0988) are required for RARC to be considered a cost-effective alternative to ORC. In another study by Kukreja et al. [70], a cost-decision tree model using complications, readmissions, and/or transfusions, and QALYs were included in a 90-day time horizon model. They found that RARC costs $2,969 less per QALY than ORC. RARC may be the preferred strategy if complications can be prevented 74% of the time or transfusion can be avoided 70% of the time. As long as RARC can prevent complications and transfusions, it is more cost-effective than ORC. Recently, Machleid et al. [71] reported a similar result using a cost-decision tree model and incremental cost-effectiveness ratio (ICER). The model considered readmission or transfusion, short-term complications, and QALYs converted into net monetary benefits. They concluded that the intervention costs of RARC or ORC and the probabilities of complications had the greatest impact on ICER. At the £30,000/QALY threshold, RARC was more cost-effective and could result in improved utility in patients with bladder cancer.

However, evidence that RARC is the most suitable treatment remains inconclusive, because a recently released Dutch prospective study does not support the superiority of RARC over ORC in terms of cost-effectiveness [72]. They performed incremental cost per QALY at 1 year (post-operative) analysis and concluded that RARC shows no difference in terms of QALYs, but is more expensive than ORC. Hence, the RARC does not seem to provide better value for money compared to the ORC. Although there is a rough consensus, we still need stronger evidence that RARC is more cost-effective than ORC.

CONCLUSIONS

Oncologically, RARC showed comparable oncological outcomes to ORC. With regard to complications, RARC was associated with lower estimated blood loss, lower intraoperative transfusion rates, shorter LOS, lower risk of Clavien–Dindo grade III–V complications, and lower 90-day rehospi-

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Table 2. Comparison of cost-effectiveness between RARC and ORC

Reference	Year	Surgical approach	Method	Summary of findings
Smith et al. [65]	2010	ORC vs. RARC	Comparative cost analysis including variability of operating room time, transfusion requirements, and hospital stay.	RARC is associated with a higher financial cost (+$1,640) than ORC.
Martin et al. [66]	2011	ORC vs. RARC (ileal conduit)	A cost-decision tree model was constructed. Costs included hospital room and board, operating room costs, and blood transfusion rate.	RARC was 16% more expensive when only comparing direct operative costs. Actual total patient costs revealed a 38% cost advantage favoring RARC, due to increased hospitalization costs for ORC.
Wittig et al. [67]	2016	RARC with ECUD	Cost analysis was performed. Summation of the direct costs of hospital care, including initial RARC hospitalization and available readmission stays (n=78, 80%).	Forty percent of patients were readmitted to the hospital at least once within 90 d after RARC, of which 77% were readmitted within 30 d. Patients readmitted to the hospital had direct costs that were 1.42 times that of those who did not require readmission.
Bansal et al. [1]	2018	ORC vs. RARC (ileal conduit)	A cost-decision tree model was constructed. Data on LOS, OT, transfusion rates, volume, and complication rates were considered.	RARC is 18.9% more expensive than ORC, including operative and hospitalization costs. LOS and OT were the most important cost drivers. However, only minimal improvements in quality of life (QALYs of 0.0988) are required for RARC to be considered a cost-effective alternative to ORC.
Michels et al. [69]	2019	ORC vs. RARC	A decision analytical model was developed to study the 30 d and 90 d postoperative complications and QALYs with RARC vs. ORC and their related costs in bladder cancer patients.	Three scenarios resulted in cost savings for RARC: operating time (threshold: ≤175 min), LOS (≤4 d), and RARC equipment (≤€281). Extra RARC costs are worthwhile, as the impact of complications on patients' quality of life is unknown.
Kukreja et al. [70]	2020	ORC vs. RARC with ICUD	A cost-decision tree model was constructed. Complications, readmissions, and/or transfusions, and QALYs were included in a 90-d time horizon model.	RARC cost $2,969 less per QALY when compared to ORC. RARC is the preferred strategy if a complication can be prevented 74% of the time, or transfusion prevented 70% of the time. As long as RARC can prevent complications and transfusions, it is the preferred cost-effective treatment when compared to ORC.
Machleid et al. [71]	2022	ORC vs. RARC (ileal conduit)	A cost-decision tree model and ICER were implemented. Readmission or transfusion and short-term complications were considered. QALYs were converted into net monetary benefits.	Intervention costs of RARC or ORC and the probabilities of complications had the greatest impact on ICER. At the £30,000/QALY threshold, RARC is more cost-effective for National Health Service England and could have improved utility for patients with bladder cancer.
Michels et al. [72]	2022	ORC vs. RARC	Incremental cost per quality-adjusted life year (QALY) at 1 y.	RARC shows no difference in terms of QALYs, but is more expensive than ORC. Hence, RARC does not seem to provide value for money in comparison to ORC.

ORC, open radical cystectomy; RARC, robot-assisted radical cystectomy; ECUD, extracorporeal urinary diversion; LOS, length of stay; OT, operative time; QALYs, quality-adjusted life years; ICER, incremental cost-effectiveness ratio.

talization rates than ORC. In particular, RARC with ICUD performed by high-volume centers significantly reduced the risk of post-operative major complications. In terms of QoL, RARC with ECUD showed comparable results to ORC, while RARC with ICUD was superior in some respects. High-volume center-based RCTs are required. Finally, although there is a rough consensus that only minimal improvements in QALYs are required for RARC to be a cost-effective alternative to ORC, more evidence is needed to draw more definite conclusions. Collectively, outcomes of RARC with ECUD were similar to those of ORC in several respects, while RARC with ICUD showed a tendency to produce better outcomes. It is necessary to solidify these conclusions through additional RCTs with patients undergoing RARC with ICUD.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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AUTHORS' CONTRIBUTIONS

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