

# Impact of outcomes and costs for implementation of robotic radical cystectomy with full intracorporeal urinary diversion

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**Introduction** Radical cystectomy (RC) remains a surgery with important morbidity despite technical advances. Our aim was to determine the impact on outcomes and costs of robot-assisted radical cystectomy (RARC) with full intracorporeal diversion.

**Material and methods** We retrospectively included 196 consecutive patients undergone RC for bladder cancer between 2017 and 2022. Comparisons were done between the open radical cystectomy (ORC; n = 166) and RARC with full intracorporeal diversion (n = 30) in the overall cohort and after matched pair analysis.

**Results** More neobladders were performed in the RARC group (40% vs 18.7%, p = 0.011). Peri-operative parameters continuously improved over time in the RARC cohort despite an increased proportion of elderly patients with higher comorbidity index. RARC patients had lower prolonged stay (33.3% vs 68.3%, p = 0.002), lower grade 1 complication rates (26.7% vs 53.3%, p = 0.016) and blood loss (185 vs 611 ml, p < 0.001) than ORC patients. RARC was an independent favorable predictor for prolonged stay (OR 0.199) and complication (OR 0.334). Cost balance favored ORC, with an increase of hospitalization cost at 816 euros for RARC.

**Conclusions** After matching, RARC with full intracorporeal diversion was associated with improved outcomes and a moderated increase of post-operative costs mainly due to the use of robotic devices.

**Key Words:** bladder cancer <> radical cystectomy <> enhanced recovery after surgery <> cost <> robot

## INTRODUCTION

The morbidity associated with radical cystectomy (RC) remains significant despite technical improvements such as robotic and image guided surgery and peri-operative management optimization, including the introduction of enhanced recovery after surgery protocols (ERAS) [1, 2]. Retrospective studies have suggested that robotic approach can accelerate recovery after radical cystectomy [3–6].

However, the spread of robotic-assisted radical cystectomy (RARC) remains limited by technical issues and by the higher costs due to robot equipment [7].

Several cost analyses are limited by the lack of indirect cost-drivers such as complication rate, length of stay, transfusion rate, the absence of stratification by the type of diversion, or the patient accrual in the pre-ERAS era [8–11]. Another point is that patient selection may greatly influence the post-operative course and the complications risk and grade. Such an uncontrolled selection favors RARC over open RC (ORC) and may impact on outcomes and costs comparisons.

The aim was to assess and compare the clinical outcomes and the costs between RARC and ORC from a single tertiary robotic center. The novelties were

to compare both approaches in a cohort of consecutive patients who were all managed perioperatively by an ERAS protocol, who underwent a full intracorporeal diversion in the RARC group (no extracorporeal diversion). Patients that underwent RARC during the learning curve of the surgeon performing robotic surgery were also included.

## MATERIAL AND METHODS

We included 196 consecutive patients undergoing RC with lymph node dissection for urothelial bladder cancer at our institution from 2017 to 2022. All surgeries were performed by six experienced surgeons who were beyond their learning curve for open RC procedures (having performed more than 100 surgeries) and by one robotic surgeon expert for kidney and prostate cancer surgery who started RARC in early 2019. Only one surgeon at our institution is performing RARC. All patients were included into an ERAS program according to current evidence-based guidelines [2].

The cost study was performed with the help of the Finance Department and represented the amount of resources consumed by each patient (medications, supplies, salaries, operating room, support costs). It assessed the overall cost of each surgical approach in RC in the most exhaustive manner. In the French health care system, patients are classified into four levels of severity, according to risk factors, comorbidities, surgical complications and length of stay. An algorithm determines the level of severity for each patient and provides the corresponding reimbursement rate to be perceived by the institution for the procedure. In this study, we assessed the average costs of a non-complicated case, level one or two (stay, operating room, instrumentation) and added the extra costs induced by the complicated patients, level three and four (extra stay in surgery ward as well as in intensive care unit (ICU)) [12, 13]. Hospital costs in surgery ward were then added with costs related to complications, stay in ICU, instrumentations, accessories and robot devices and operating room.

Primary endpoints were the impact of robot use (RARC vs ORC) on perioperative parameters such as hospital length of stay (LOS) duration (days, proportion of prolonged length of stay), complications (grade two to five according to Clavien-Dindo classification), operative time (from incision to skin closure), and blood loss during surgery. A prolonged hospital stay was defined by a hospital stay superior to 10 days for ileal conduit and to 15 days for neobladder. These thresholds have been chosen as they correspond to the mean LOS for both procedures before ERAS implementation in our center. Secondary

outcomes included overall costs per procedure. Medical data were collected retrospectively from medical records and double-checked with the 'Programme Médicalisé des Systèmes d'Informations' (PMSI).

The evolution of all these parameters over time according to the RC technique was assessed using two-tailed tests as appropriate. Five consecutive 40-patient periods have been separated. RARC program was started at the beginning of period 4. Univariate and multivariate logistic regression analyses were used for comparisons. Analysis was performed in the overall cohort and in matched pair analysis. Age, sex, ASA score, BMI, and ORC vs RARC variables were included in the multivariable model. ORC patients were selected for matched pair analysis with a 2:1 ratio and blinded to outcomes. Exact matching was performed for the following primary factors potentially correlated to the initial status mismatch: age at operation, BMI, and comorbidity profile. The matching process resulted in 90 patients involved (ORC = 60; RARC = 30). Continuous variables were compared using a Mann-Whitney or Student-t test as appropriate, qualitative variables were compared using a Fisher test. The limit of statistical significance was defined as  $p < 0.05$ . The SPSS 22.0 (Chicago, Illinois) software was used for analysis.

## RESULTS

Patient age increased over time (from 71.1 to 80.4 years in the ORC cohort, and from 64.9 to 74.5 years in the RARC cohort). The proportion of patients with ASA score of 3 or more significantly increased over time in both cohorts ( $p < 0.001$ ). The complication rate continuously decreased over time in the RARC cohort, from 33.3% (10 out of 30 patients) to 21.7% (6.5 out of 30 patients). Operative time decreased continuously over time in both cohorts (from 190 to 140 minutes in ORC, from 319 to 233 minutes in RARC cohorts, respectively,  $p < 0.001$ ). The proportion of RARC increased from 39.5% to 60.0% of all RC cases over time.

Comparisons between ORC and RARC cases in the overall cohort ( $n = 196$ ) and after matching are listed in Table 1. After matching, statistically significant differences remained regarding the rate of prolonged stay (33.3% vs 68.3%,  $p = 0.002$ ) and the complication rate (26.7% vs 53.3%,  $p = 0.016$ ). There were not significant trends toward shorter hospital/ICU stay in the RARC cohort. Estimated blood loss in the RARC cohort was significantly inferior to that reported in the ORC cohort ( $p < 0.001$ ). Operative time was shorter when ORC was performed ( $p < 0.001$ ). In the overall cohort, the use of robot was associated with less frequent prolonged length of stay (OR 0.13;

**Table 1.** Comparisons between open radical cystectomy and robot-assisted radical cystectomy patients in the overall cohort and after matching (means or rates)

Overall cohort	RARC n = 30	ORC n = 166	p value
Age (years)	69.7	73.5	0.058
Male/Female	22/8	152/14	0.004
ASA score (mean)	2.1	2.3	0.048
ASA score 3 or more	13.3%	35.0%	0.031
Diversion:			
Ileal conduit	18 (60.0%)	135 (81.3%)	0.011
Neobladder	12 (40.0%)	31 (18.7%)	
Operative time (minutes) :	276	184	<0.001
Hospital stay (days)	15.3	19.5	0.008
Prolonged stay (%)	10 (33.3%)	130 (78.3%)	<0.001
Complications (%)	8 (26.7%)	95 (57.2%)	0.002
After matching	RARC n = 30	ORC n = 60	
Age (years)	69.7	69.6	0.968
Male/Female	22/8	54/6	0.040
Charlson comorbidity index >1	21 (70.0%)	37 (61.6%)	0.436
BMI (Kg/m <sup>2</sup> )	27.2	27.4	0.887
ASA score (mean)	2.1	2.1	0.807
ASA score 3 or more	13.3%	13.3%	0.868
Diversion			
Ileal conduit	18 (60.0%)	44 (73.3%)	0.198
Neobladder	12 (40.0%)	16 (26.7%)	
Operative time (minutes)			
Overall cohort	276	194	<0.001
Ileal conduit group	247	186	0.001
Neobladder group	318	217	<0.001
Blood loss (ml)			
Overall cohort	185	611	<0.001
Ileal conduit group	161	481	<0.001
Neobladder group	220	658	<0.001
Hospital stay (days)	15.3	19.0	0.232
Prolonged stay (%)	10 (33.3%)	41 (68.3%)	0.002
Complications (%)	8 (26.7%)	32 (53.3%)	0.016

IC – ileal conduit; ICU – intensive care unit; RARC – robot-assisted radical cystectomy; ORC – open radical cystectomy; BMI – body mass index

95% confidence interval: 0.05–0.35;  $p < 0.001$ ) and complications (OR 0.27; 95% confidence interval: 0.10–0.70;  $p = 0.008$ ) in multivariable analysis). In the matched pair cohort, the impact of robot on both outcomes remained independently significant. Robot use was associated with less frequent prolonged length of stay (OR 0.20; 95% confidence interval: 0.07–0.58) and complication (OR 0.33; 95% confidence interval: 0.11–0.98) (Table 2).

When comparing ORC and RARC in the overall cohort, the use of robot was correlated with reduced hospital costs, mainly due to shorter hospital stay

**Table 2.** Multivariate analysis for predictors of prolonged length of stay and of complications in the matched pair cohort

	p value	OR (95% CI)
After Matching (n=90)		
Endpoint : Prolonged stay		
Age	0.195	1.03 (0.98–1.09)
Male	0.173	0.37 (0.10–1.54)
BMI	0.942	1.01 (0.88–1.14)
ASA score 3 or more	0.161	2.87 (0.66–12.59)
Robot	0.003	0.20 (0.07–0.58)
Endpoint : Complications		
Age	0.386	1.02 (0.97–1.07)
Male	0.801	1.19 (0.30–4.76)
BMI	0.173	0.91 (0.79–1.04)
ASA score 3 or more	0.181	2.44 (0.66–8.99)
Robot	0.045	0.33 (0.11–0.98)

BMI – body mass index; OR – odds ratio

in surgical units and ICU, and to fewer complications. The increased intraoperative costs per procedure due to robot equipment (+3386.7 euros; 6328.7 euros for RARC vs 2941 euros for ORC) were counter-balanced by decreased post-operative costs linked to shorter hospitalization and fewer complications (-8028 euros favoring RARC). Cost savings per procedure provided by RARC were estimated at 4641.3 euros. Same cost analyses were performed after matching and are showed in Table 3. We confirmed the post-operative costs reduction (including complications, hospitalization and transfusion costs) with the use of RARC. All these costs were decreased by 65% and 15% in case of robotic neobladder and ileal conduit, respectively. After adding the intraoperative costs which were higher for RARC, the final cost imbalance favored ORC: -2328 euros for ileal conduit cases; -815.9 euros for neobladder.

## DISCUSSION

The morbidity associated with radical cystectomy remains important in spite of technical improvements and peri-operative management optimization [2]. The minimally invasive and robotic surgery have been suggested to improved peri-operative parameters by reducing blood loss, complications and hospital stay [4, 6]. However, at least one randomized clinical trial comparing ORC and RARC failed to demonstrate a large advantage for RARC in terms of 90-day complications, hospital stay, and quality-of-life outcomes [5]. High level of evidence does not exist regarding cost comparison between both techniques.

**Table 3.** Cost analysis performed in the matched pair cohort: directed and indirect costs of open radical cystectomy and robot-assisted radical cystectomy

Cost per procedure	RARC		ORC	
	Neobladder	IC	Neobladder	IC
Fixed cost per procedure				
Instrumentations and accessories	2694.6	2514.7	664.8	644.8
Operating room and personal	3184.2	2478.9	2302.9	1974.5
Robot costs				
Maintenance	397.5	397.5	NA	NA
Capital	463.7	463.7		
Total operating room costs	6740.0	5854.8	2967.7	2619.3
Hospitalization/complication				
Surgical/ICU unit	3767.8	4450.3	4507.0	4843.7
Complications	771.8	1746.1	2962.4	2203.0
Transfusion	11.5	12.0	58.1	69.2
Total post-operative costs	4551.1	6208.4	7527.5	7115.9
Total (according to the diversion)	11291.2	12063.2	10475.3	9735.2
Total (RARC versus ORC)		11754.4		9932.8
Increased costs induced by RARC:				
For all procedures		+1821.6		
For neobladder only		+815.9		
For IC only		+2328.0		

IC – ileal conduit; ICU – intensive care unit; RARC – robot-assisted radical cystectomy; ORC – open radical cystectomy

Several limitations from published cost analyses studies can be highlighted [8–11]. Such studies often included a small sample size for modelling and ileal conduits as the only type of urinary diversion. Patients eligible for continent diversion and neobladder may have skewed cost performance [10]. Another point is that it has been demonstrated that postoperative complications after RC contributed most to cost variations, followed by patient (age and comorbidity status), surgical and hospital characteristics [14]. However, most studies considered only extracorporeal urinary diversions whereas cost performance of RARC may be impacted by a full intracorporeal reconstruction. Lee et al. have previously reported the greatest reduction in cost of complications for RARC ileal conduit (–77%) over orthotopic neobladder (+12%) [15]. Conversely, Lenfant et al. reported that intracorporeal diversion was associated with lower estimated blood loss and transfusion rates compared with extracorporeal diversion [16].

Flamiatos et al. recently showed that RARC was associated with a 18% reduction in total cost-to-patient compared to ORC when considering all 30-day post-operative services with fewer complications compared to ORC [17]. However, Michels et al. reported in a cost-effectiveness study that it was unlikely

that RARC will become less expensive than ORC in a close future despite fewer high-grade complications [11]. Smith et al. showed that the rate and cost impact of complications was equal between ORC and RALRC [18].

The present study showed that the operative room costs for RARC was 2.2-times more expensive than ORC for both neobladder and ileal conduit diversions. It is worthy to note that the costs related to operative time are influenced by surgeon experience and decreased over time (–37% of operative time in RARC procedures between period 4 and 5) [19]. Moreover, this cost imbalance favoring ORC at the time of surgery was corrected when taking into account the post-operative course.

Indeed, we confirmed that RARC contributed to a decrease in hospital stay, complication rate and blood loss compared with ORC. The interesting point was that benefits from RARC remained even in a cohort of patients undergoing ERAS which was standardized clinical pathways for both groups and which tended to standardize length of stay. All comparisons between ORC and RARC may be biased by cohort differences in terms of age, comorbidity, BMI, which may favorize RARC over ORC. Indeed, we reported in the present series that RARC was more frequently offered to younger and healthier patients. In that

case, the benefits in terms of costs and clinical outcomes tremendously favored RARC.

After matching, we still confirmed the advantages of RARC regarding blood loss and rates of complication and prolonged stay. However, the cost imbalance favored ORC in this sub-group analysis, mainly in case of ileal conduit. The extra cost due to robot use was only 816 euros when a neobladder was performed. This finding comes against a previous simulation made by Lee et al. showing that RARC cost-effectiveness decreased with complex urinary diversions [10]. The authors reported that RARC may not be cost-effective in patients undergoing orthotopic neobladder due to erosion in the cost of complications, given that the patients are younger and/or healthier, meaning at lower risk of complications. They only noted a cost effectiveness of RARC in patients with ileal conduit. On the other hand, based on our results, we believe that RARC should be preferred in complex procedures as it has been proved for nephron sparing surgery versus radical nephrectomy. In healthier patients undergoing complex procedure like orthotopic neobladder or continent diversion, the advantages of minimally invasive surgery will be the best exploited by reducing surgical complications and improving post-operative recovery. In older patients with several comorbidities, the operative benefits achieved by RARC may be mitigated by a higher risk of medical, non-surgically related complications which could lead to increased hospital stay and to further treatments.

The main finding of the present study was that one average RARC procedure cost 4641 euros less than ORC in the overall cohort. This can be explained at least partly by uncontrolled selection biases, with younger and healthier patients in the RARC cohort. However, more complex diversions and neobladders have been performed in this group and this invariably generated longer hospital stay.

The costs of complications contributed to 22–28% of overall costs for ORC, and to 6–15% for RARC, depending on the type of diversion. These rates were higher than those reported in previous studies, but it probably reflected more the reality. Bansal et al. reported of complication cost contribution of 1.3%

in RARC and 2.4% in ORC cohort [7]. However, the calculation was different by assigning extra days of hospital stay per the severity of complication. This assumption, as perfectly highlighted by the authors, probably under-estimated the true cost of a complication and its treatment. They emphasized that high-grade complications requiring admission to intensive care units were captured with this approach. The primary limitations of our study were the sample size and the use of a single institution for data analysis. Our findings may not be generalizable to other institutions and in other health care systems. Another limitation of our study is represented by the retrospective design. However, we chose to include all ORC and RARC patients undergoing surgery in the ERAS era. Moreover, the data from RARC comes in part from procedures performed during the learning curve. We did not include the cost related to the post-operative admission to a high-dependency unit. However, no difference was seen between ORC and RARC cohorts concerning the proportion of patients admitted to these units. Finally, as an additional limitation, we did not assess neither patient-reported outcomes nor quality-of-life measurements. Several comparative and prospective trials are ongoing to provide a more complete evaluation of the potential cost-effectiveness of RARC [20].

## CONCLUSION

Implementation of RARC with full intracorporeal diversion significantly changed the patient post-operative course. This study also highlighted the challenges to compare outcomes and procedure-specific costs between ORC and RARC due to selection biases. Based on the analysis from our institution, RARC was globally less expensive than ORC in the overall cohort when including direct and indirect costs. After matching, RARC with full intracorporeal diversion was associated with outcome improvements and a moderated increase of post-operative costs mainly due to robot devices.

## CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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