



Impact of preoperative body mass index on perioperative outcomes is optimized by enhanced recovery protocols in laparoscopic radical cystectomy with intracorporeal urinary diversion

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Background: We aimed to examine whether body mass index (BMI) had an impact on clinical outcomes of laparoscopic radical cystectomy with intracorporeal urinary diversion. Furthermore, we analyzed the optimization of enhanced recovery protocols (ERPs) on the impact of BMI on clinical outcomes.

Methods: By searching our database, data of 83 consecutive patients were retrospectively collected, including 37 patients with a BMI <24 kg/m² (group A) and 46 patients with a BMI ≥24 kg/m² (group B). The baseline and peri-operative variables of the two groups were compared. Subgroup analysis was conducted for ERPs (11 patients in group A₁, 18 patients in group B₁) and conventional recovery protocols (CRPs; 26 patients in group A₂, 28 patients in group B₂). The primary outcomes were 30-day overall complication rate and Δ ALB_{min} (reduction proportion of minimum albumin). The secondary outcomes were operative time and length of stay.

Results: The baseline variables were similar between the two groups (P>0.05). The 30-day overall complication rate, operative time, and length of stay were similar between the two groups (P>0.05). But post-operative nausea and vomiting (PONV) was higher in group A than in group B (32.4% vs. 8.7%, P=0.014). Group A was associated with lower serum albumin level pre-operatively and on post-operative days 1–3. Δ ALB_{min} was higher in group A than in group B (33.08%±9.88% vs. 27.92%±8.52%, P<0.05). In the subgroup analysis, the CRPs group presented similar results, with group A₂ showing higher PONV rate, lower albumin level pre- and post-operatively, and higher level of reduction proportion (P<0.05). For the ERPs group, the PONV rate, pre-operative albumin level, and reduction proportion were similar between group A₁ and B₁ (P>0.05). Multivariable analysis showed that PONV and CRPs were independently associated with Δ ALB_{min} ≥34% (P<0.05).

Conclusions: BMI had no impact on the 30-day overall complication rate, operative time, and length of stay of patients who underwent laparoscopic radical cystectomy with intracorporeal urinary diversion. BMI <24 kg/m² was associated with higher PONV rate and more albumin loss, both of which could be optimized by ERPs.

Keywords: Enhanced recovery protocols (ERPs); body mass index (BMI); intracorporeal urinary diversion (ICUD); post-operative nausea and vomiting (PONV); serum albumin

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Introduction

Radical cystectomy (RC) with lymph node dissection is regarded as the gold standard for treatment of muscle-invasive bladder cancer. Several randomized controlled trials indicated that minimally invasive surgery, including laparoscopic and robot-assisted radical cystectomy (LRC/RARC), could benefit patients during the peri-operative period with equivalent oncologic results as compared with the open approach (1-5). However, these trials only included extracorporeal urinary diversion and evidence of intracorporeal urinary diversion (ICUD) is sparse.

Enhanced recovery protocols (ERPs) originated from colorectal surgery (6) and have been gradually implemented in other surgeries such as RC (7). High-level evidence for its performance in RC is limited. Only a few studies have reported the outcomes of ERPs implementation on ICUD (8-10).

The impact of body mass index (BMI) on the clinical outcomes of ICUD, including parameters such as operative time, length of stay and complications, has been sporadically reported before (11,12). However, to the best of our knowledge, whether BMI could influence peri-operative albumin level and whether ERPs would optimize the clinical impact of BMI on clinical outcomes have not been examined before. In this study, we retrospectively compared the peri-operative outcomes of patients with BMI <24 or ≥ 24 kg/m² and conducted a subgroup analysis for ERPs and conventional recovery protocols (CRPs).

We present the following article in accordance with the STROBE reporting checklist (available at <http://dx.doi.org/10.21037/tau-21-171>).

Methods

Study population

A total of 83 patients with bladder cancer underwent LRC with ICUD between March 2014 and September 2020 at our institution. The 83 patients were divided into two groups according to the Chinese BMI criteria. Group A included 37 patients with BMI <24 kg/m² and group B included 46 patients with BMI ≥ 24 kg/m². Subgroup analysis was conducted for ERPs (11 patients in group A₁,

18 patients in group B₁) and CRPs (26 patients in group A₂, 28 patients in group B₂). The ERPs of our institution have been performed since April 2017. The detailed elements of ERPs and CRPs are presented in *Table 1*. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Beijing Chaoyang Hospital, Capital Medical University (NO.: 2020-Ke-546) and informed consent for this retrospective analysis was waived.

Surgical technique

Our institution has performed nearly 500 cases of RC since 2000. LRC was performed using a six-port transperitoneal approach. Our technique has also been previously reported (13,14). Standard lymph node dissection was performed conventionally; extended lymph node dissection was performed when needed. An intracorporeal ileal conduit or Studer orthotopic ileal neobladder was performed in accordance with the surgeon's opinions and the patient's preference was also taken into consideration. Modifications to both types of urinary diversions, including procedure adjustment and a novel end-to-end reflux uretero-intestinal anastomosis, have been previously described (13,14). After the ileal conduit, the retroperitoneum was closed so that the conduit and uretero-intestinal anastomosis were totally retroperitonealized. The neobladder was constructed with bilateral isoperistaltic afferent limbs. A single three-lumen catheter and bilateral single-J stents were placed through the urethra without performing a suprapubic cystostomy.

Data collection

Baseline characteristics and perioperative outcomes were retrospectively collected. The serum albumin concentration was measured pre-operatively and on post-operative days (POD) 1–3. Moreover, within three PODs, the minimum albumin (ALB_{min}) level was also analyzed. The reduction degree was defined as the difference between the pre- and post-operative albumin level. The reduction proportion (Δ POD 1–3 and Δ ALB_{min}) was defined as the reduction degree/pre-operative albumin level $\times 100\%$. Complications within 30 days were collected and graded according to

Table 1 Elements of ERPs and CRPs

Time point	ERPs	CRPs	
Preoperative	1. Counselling and education of ERPs protocol	1. None	
	2. Evaluation of comorbidities and medical optimization	2. Evaluation of comorbidities and medical optimization	
	3. Evaluation of nutritional status, and oral support if needed	3. None	
	4. Thromboprophylaxis: low molecular weight heparin and compression stockings	4. Compression stockings	
Prior to surgery	3 d	Normal diet	Low residue diet Oral antibiotics (fluoroquinolones and metronidazole)
		2 d	Normal diet
	1 d		Low residue diet
		Laxatives	Enema Oral antibiotics Parenteral nutrition
		6 h	Potable water
	2 h	NPO	NPO
		Oral carbohydrate loading 2 h prior to surgery (5 mL/kg)	
	30 min	Intravenous antibiotics; Another dose of intravenous antibiotics if operative time exceeds 3 h	Intravenous antibiotics
	NGT	NGT intubation after anesthesia and removed after awaking or no NGT use	NGT intubation before surgery and removed after passing flatus
	Intraoperative	1. LRC with ICUD	1. LRC with ICUD
2. General intravenous and epidural anesthesia; removal of epidural catheter after surgery		2. General intravenous anesthesia	
3. Avoidance of long-acting sedatives and opioids		3. Conventional anesthetics	
4. Prevention of hypothermia (warm air blower or blanket)		4. None	
5. Goal-directed fluid administration		5. None	
6. Local infiltration of ropivacaine before wound closure		6. None	
7. Intravenous antiemetics before awaking		7. Intravenous antiemetics before awaking	
8. Pelvic drainage tube placement		8. Pelvic drainage tube placement	
9. Patient controlled intravenous analgesia placement		9. Patient controlled intravenous analgesia placement	
Postoperative	1. Recumbent position	1. Recumbent position without pillow	
	2. Opioid-sparing analgesia; NSAIDs for those with VAS more than 4	2. Conventional analgesics	

Table 1 (continued)

Table 1 (continued)

Time point	ERPs	CRPs
	3. Moderate mobilization 4 h after surgery	3. Prohibition of mobilization on postoperative day 1
	4. Potable water 6 h after surgery, 50 mL/h; Adding to 100 mL/h on postoperative day 1 if tolerated; resuming liquid diet after passing flatus and converting to normal diet gradually	4. NPO until passing flatus
	5. Chewing gum 3 times a day until passing flatus, 30 min each time	5. None
	6. Avoidance of fluid over-infusion, ≤ 30 mL/kg	6. None
	7. Thromboprophylaxis: low molecular weight heparin and compression stockings	7. Thromboprophylaxis: low molecular weight heparin and compression stockings

ERPs, enhanced recovery protocols; CRPs, conventional recovery protocols; LRC, laparoscopic radical cystectomy; ICUD, intracorporeal urinary diversion; NPO, nil per os; NGT, nasogastric tube; NSAIDs, non-steroidal anti-inflammatory drugs; VAS, visual analogue scale.

the Clavien-Dindo classification. Post-operative fever was defined as a body temperature of ≥ 38 °C. Post-operative nausea and vomiting (PONV) was defined as the need for rescue anti-emetics.

Statistical analysis

Statistical analyses were performed using the SPSS v26. Normally distributed continuous variables were presented as mean values with standard deviations and analyzed using the Student's *t*-test. Non-normally distributed continuous variables were presented as median and interquartile ranges and analyzed using the Mann-Whitney U test. Categorical variables were compared using Pearson's Chi-square test or Fisher's exact test. Univariable and multivariable regression analysis were performed for $\Delta\text{ALB}_{\min} \geq 34\%$. Statistical significance was set at $P < 0.05$.

Results

All patients underwent LRC with ICUD with no transition to open surgery. The baseline characteristics were similar between group A and B (Table 2). Eleven patients in group A and 18 in group B adhered to the ERPs (29.7% vs. 39.1%, $P=0.488$). Peri-operative outcomes and albumin loss are presented in Table 3. Most peri-operative parameters were similar in the two groups, including operative time, estimated blood loss, length of stay, and 30-day overall complications ($P > 0.05$). However, the post-operative PONV rate was significantly higher in group A (32.4% vs. 8.7%, $P=0.014$). When comparing peri-operative albumin level,

group A demonstrated lower albumin level pre-operatively (39.49 ± 4.85 vs. 42.29 ± 3.95 g/L, $P=0.005$) and on POD 1–3 and ALB_{\min} (26.23 ± 3.92 vs. 30.30 ± 3.08 g/L, $P < 0.001$). The reduction proportion was higher in group A on ΔPOD 1–2 and ΔALB_{\min} ($33.08\% \pm 9.88\%$ vs. $27.92\% \pm 8.52\%$, $P=0.013$).

Subgroup analysis for ERPs and CRPs with BMI < 24 or ≥ 24 kg/m² are presented in Table 4. In the CRPs subgroup, BMI < 24 kg/m² also showed a higher PONV rate (42.3% vs. 7.1%, $P=0.007$), lower albumin level pre-operatively (38.98 ± 4.62 vs. 41.85 ± 3.88 g/L, $P=0.016$) and on POD 1–3 and ALB_{\min} (24.77 ± 3.45 vs. 29.33 ± 2.93 g/L, $P < 0.001$), and higher reduction proportion on ΔPOD 1–2 and ΔALB_{\min} ($35.93\% \pm 9.42\%$ vs. $29.57\% \pm 7.65\%$, $P=0.009$). In ERPs subgroup, the clinical outcomes were optimized as patients with BMI < 24 or ≥ 24 kg/m² showed similar PONV rate (9.1% vs. 11.1%, $P=1.000$), similar pre-operative albumin level (40.69 ± 5.41 vs. 42.96 ± 4.09 g/L, $P=0.210$), and similar reduction proportion on ΔPOD 1–2 and ΔALB_{\min} ($26.35\% \pm 7.64\%$ vs. $25.35\% \pm 9.38\%$, $P=0.769$).

Multivariable analysis in Table 5 showed that PONV [odds ratio (OR) 3.901, 95% confidence interval (CI): 1.067–14.256, $P=0.040$] and CRPs (OR 3.243, 95% CI: 1.014–10.367, $P=0.047$) were independently associated with $\Delta\text{ALB}_{\min} \geq 34\%$.

Discussion

Our study is based on the following problems: (I) the impact of BMI on clinical outcomes and on the peri-operative albumin level in LRC with ICUD is unclear; (II) hypoalbuminemia is common after various surgeries,

Table 2 Baseline characteristics of patients with group A (<24 kg/m²) and B (≥24 kg/m²)

Characteristics	Group A (N=37)	Group B (N=46)	P
Mean age (years)	62.51±10.57	61.15±9.21	0.533
No. gender, n (%)			1.000
Male	31 (83.8)	39 (84.8)	
Female	6 (16.2)	7 (15.2)	
No. American Society of Anesthesiologists, n (%)			0.246
I-II	34 (91.9)	37 (80.4)	
III	3 (8.1)	9 (19.6)	
Median age-adjusted Charlson comorbidity index	3 [2–5]	4 [2–5]	0.611
No. transurethral resection of bladder tumor, n (%)	19 (51.4)	21 (45.7)	0.662
No. history of neoadjuvant chemotherapy, n (%)	10 (27.0)	4 (8.7)	0.055
No. history of abdominal surgery, n (%)	6 (16.2)	11 (23.9)	0.426
No. history of smoking, n (%)	18 (48.6)	19 (41.3)	0.515
No. type of urinary diversion, n (%)			1.000
Ileal conduit	23 (62.2)	28 (60.9)	
Orthotopic ileal neobladder	14 (37.8)	18 (39.1)	
No. with enhanced recovery protocols, n (%)	11 (29.7)	18 (39.1)	0.488

including RC, and has a predictive value for mortality and morbidity. Intravenous albumin supplementation is mainly used for remedial treatment, although the safety and efficacy of this treatment is controversial; and (III) the experience of implementing ERPs in LRC with ICUD has rarely been reported, and whether ERPs will change the impact of BMI remains unclear. We aimed to determine the impact of BMI on clinical outcomes and perioperative albumin level in LRC with ICUD, and whether ERPs could optimize the impact of BMI.

ICUD has been initiated since 2000 (15). Owing to its technical difficulty, the implementation of ICUD is still limited. No randomized controlled trials have been conducted to compare clinical outcomes between intracorporeal and extracorporeal urinary diversion. Research from the International Robotic Cystectomy Consortium indicated that the proportion of ICUD has increased significantly in high-volume centers in North America and Europe over the years. Compared with extracorporeal urinary diversion, ICUD reduced operative time and estimated blood loss but was associated with more complications and readmissions. The complications decreased with increasing surgeon volume, which indicated

the learning curve of this technique (16).

The association between BMI and the clinical outcomes in RC has been previously reported. Ahmadi *et al.* (12) reported the results for RARC with ICUD. They divided the patients into four groups according to BMI (<25, 25–29.9, 30–34.9, ≥35 kg/m²), and found that peri-operative, pathologic, and early oncologic results were all similar among the four groups; therefore, RARC with ICUD could be performed safely and feasibly in obese patients. Bagrodia *et al.* (17) reported that a high BMI would not increase peri-operative complications and costs in RC. However, several other studies have shown that high BMI has an adverse impact on clinical outcomes, such as higher major complication rate (18), more post-operative ileus (19), higher disease recurrence rate and cancer-specific mortality (20). Ghodoussipour *et al.* (21) also reported that patients with a high BMI were more likely to experience intra-operative conversion (from planned orthotopic to non-orthotopic urinary diversion).

In our study of LRC with ICUD, most peri-operative parameters, including 30-day overall complication rate, operative time, estimated blood loss and length of stay, were similar between group A and B. An interesting finding

Table 3 Perioperative results of patients with group A (<24 kg/m²) and B (≥24 kg/m²)

Variables	Group A (N=37)	Group B (N=46)	P
Median operative time (min)	360 [300–420]	360 [308–450]	0.786
Median estimated blood loss (mL)	200 [100–300]	200 [100–275]	0.756
No. intraoperative blood transfusion, n (%)	2 (5.4)	4 (8.7)	0.882
Median time to liquid diet (day)	73 [14–108]	72 [12–96]	0.102
Median time to pelvic drainage tube removal (day)	8 [6–11]	7 [6–11]	0.878
Median length of stay (day)	11 [8–15]	11 [9–15]	0.927
No. readmission, n (%)	1 (2.7)	4 (8.7)	0.499
No. 30-d overall complication, n (%)	28 (75.7)	33 (71.7)	0.804
No. 30-d minor complication, n (%)	27 (73.0)	32 (69.6)	0.810
Fever	13 (35.1)	17 (37.0)	1.000
PONV	12 (32.4)	4 (8.7)	0.014
Constipation	14 (37.8)	13 (28.3)	0.480
No. 30-d major complication, n (%)	1 (2.7)	2 (4.3)	1.000
Preoperative ALB (g/L)	39.49±4.85	42.29±3.95	0.005
Postoperative ALB (g/L)			
POD1	27.22±3.61	31.41±3.13	<0.001
POD2	27.17±3.61	31.24±3.01	<0.001
POD3	27.51±3.73	31.49±3.06	<0.001
ALB _{min}	26.23±3.92	30.30±3.08	<0.001
Reduction degree (g/L)			
ΔPOD1	12.61±4.50	10.87±4.00	0.069
ΔPOD2	12.25±4.39	11.02±3.95	0.201
ΔPOD3	11.63±4.63	11.24±3.74	0.711
ΔALB _{min}	13.26±4.68	11.99±4.19	0.197
Reduction proportion, n (%)			
ΔPOD1	31.22±9.07	25.33±8.25	0.003
ΔPOD2	30.54±9.32	25.72±8.25	0.019
ΔPOD3	29.08±10.60	26.01±7.70	0.188
ΔALB _{min}	33.08±9.88	27.92±8.52	0.013

Reduction degree = preoperative albumin level – postoperative albumin level; reduction proportion = reduction degree/preoperative albumin level ×100%. PONV, postoperative nausea and vomiting; ALB, albumin; POD, postoperative day; ALB_{min}, minimum albumin within 3 postoperative days.

was that patients in group A had more PONV, which has rarely been reported in RC in previous studies. Increased BMI was thought to be associated with a higher PONV rate. However, this opinion has been doubted over the

past several years, and many studies have found opposite results (22–25). In a recent large-scale study, Kim *et al.* (25) performed propensity score matching for 103,561 patients who underwent general anesthesia. The results showed that

Table 4 30-day complication and perioperative albumin level in ERPs and CRPs group with group A₁ (<24 kg/m²) vs. B₁ (≥24 kg/m²), and group A₂ (<24 kg/m²) vs. B₂ (≥24 kg/m²)

Variables	ERPs			CRPs		
	Group A ₁ (N=11)	Group B ₁ (N=18)	P	Group A ₂ (N=26)	Group B ₂ (N=28)	P
No. 30-d complication, n (%)	7 (63.6)	9 (50.0)	0.702	21 (80.8)	24 (85.7)	0.903
No. 30-d minor complication, n (%)	7 (63.6)	9 (50.0)	0.702	20 (76.9)	23 (82.1)	0.741
Fever	1 (9.1)	4 (22.2)	0.622	12 (46.2)	13 (46.4)	1.000
PONV	1 (9.1)	2 (11.1)	1.000	11 (42.3)	2 (7.1)	0.007
Constipation	4 (36.4)	5 (27.8)	0.694	10 (38.5)	8 (28.6)	0.566
No. 30-d major complication, n (%)	0	0	–	1 (3.8)	2 (7.1)	1.000
Mean preoperative ALB (g/L)	40.69±5.41	42.96±4.09	0.210	38.98±4.62	41.85±3.88	0.016
Mean postoperative ALB (g/L)						
POD1	29.97±2.71	32.92±2.47	0.006	26.00±3.30	30.44±3.15	<0.001
POD2	30.57±2.88	32.78±2.36	0.042	25.62±2.76	30.38±3.03	<0.001
POD3	30.74±2.96	32.84±2.38	0.060	25.73±2.83	30.49±3.18	<0.001
ALB _{min}	29.68±2.63	31.81±2.74	0.049	24.77±3.45	29.33±2.93	<0.001
Mean reduction degree (g/L)						
ΔPOD1	10.72±4.32	10.04±4.41	0.688	13.44±4.41	11.42±3.69	0.074
ΔPOD2	10.12±4.12	9.66±4.72	0.799	13.23±4.23	11.78±3.30	0.177
ΔPOD3	9.95±4.62	9.73±4.10	0.898	12.55±4.47	12.35±3.11	0.874
ΔALB _{min}	11.01±4.38	11.16±4.80	0.935	14.20±4.55	12.53±3.74	0.142
Mean reduction proportion, n (%)						
ΔPOD1	25.65±7.52	22.80±8.54	0.369	33.67±8.71	26.97±7.77	0.005
ΔPOD2	24.20±7.67	22.11±9.48	0.552	33.43±8.66	27.73±6.87	0.012
ΔPOD3	23.67±9.38	22.34±7.99	0.706	32.06±10.24	28.72±6.42	0.233
ΔALB _{min}	26.35±7.64	25.35±9.38	0.769	35.93±9.42	29.57±7.65	0.009

Reduction degree = preoperative albumin level – postoperative albumin level; reduction proportion = reduction degree/preoperative albumin level ×100%. ERPs, enhanced recovery protocols; CRPs, conventional recovery protocols; PONV, postoperative nausea and vomiting; ALB, albumin; POD, postoperative day; ALB_{min}, minimum albumin within 3 postoperative days.

both overweight (25.1–30 kg/m²) and obese (>30 kg/m²) patients experienced less PONV than normal patients (18.5–25 kg/m²). Another study (26) found that during 24–72 h after total hip/knee arthroplasty, patients with a lower BMI would experience more PONV. The mechanism underlying this phenomenon has not yet been clarified. Receptors of dopamine, acetylcholine, histamine, and serotonin participate in inducing nausea and vomiting (27). A study (28) compared 10 obese with 10 normal patients and indicated that the availability of dopamine D₂ receptor was significantly lower in obese patients; BMI had a

negative impact on D₂ receptors. Other studies (29,30) indicated that leptin, which could facilitate histamine release, decreased more significantly in obese-than-normal patients undergoing fasting. Therefore, during perioperative fasting, a higher reduction of leptin in obese patients may also contribute to this phenomenon.

Another finding was that group A presented lower albumin level pre- and post-operatively and a higher reduction proportion. Univariable analysis showed that a BMI of <24 kg/m² had an impact on ΔALB_{min} ≥34%. This finding has not been reported before; therefore, it would be

Table 5 Univariable and multivariable regression analysis of factors associated with $\Delta\text{ALB}_{\min} \geq 34\%$

Variables	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	P	Odds ratio (95% CI)	P
Age (continuous)	1.003 (0.957–1.050)	0.906	–	–
BMI <24 kg/m ² (yes vs. no)	3.800 (1.467–9.846)	0.006	2.816 (1.001–7.926)	0.050
Sex (male vs. female)	1.250 (0.349–4.474)	0.732	–	–
aCCI (continuous)	0.829 (0.662–1.038)	0.102	–	–
Operative time (continuous)	1.003 (0.999–1.007)	0.109	–	–
Estimated blood loss (continuous)	0.999 (0.996–1.002)	0.561	–	–
Lymph node yield (continuous)	1.006 (0.954–1.060)	0.837	–	–
Ileal conduit vs. orthotopic ileal neobladder	0.536 (0.213–1.347)	0.185	–	–
CRPs vs. ERPs	3.840 (1.274–11.570)	0.017	3.243 (1.014–10.367)	0.047
PONV (yes vs. no)	5.989 (1.827–19.630)	0.003	3.901 (1.067–14.256)	0.040

CI, confidence intervals; BMI, body mass index; aCCI, age-adjusted Charlson Comorbidity Index; ERPs, enhanced recovery protocols; CRPs, conventional recovery protocols; PONV, postoperative nausea and vomiting.

difficult to determine the underlying rationale. We think that the possible reasons included: (I) patients with higher BMI demonstrated better nutritional status, thus elevating baseline serum albumin level; (II) due to different baseline albumin level, even if the reduction degree was similar in both groups, group B demonstrated higher post-operative albumin level and lower reduction proportion; (III) in this cohort, patients with a higher BMI presented lower rates of PONV, which could reduce nutrient loss and avoid prolonged bowel function recovery. Multivariable analysis also indicated that PONV was independently associated with $\Delta\text{ALB}_{\min} \geq 34\%$ (Table 5); and (IV) it was reported that after intra-operative infusion of 20% albumin, BMI was positively correlated with intravascular half-life of the infused albumin, which indicated a possibility that higher BMI was associated with longer intravascular persistence of albumin (31).

ERPs are considered an evidence-based multi-modal and multi-disciplinary pathway for peri-operative management. It aims to minimize the stress response and optimize the recovery process. ERPs have been introduced in RC in recent years and have shown definite advantages. However, evidence of the implementation of ERPs on ICUD is limited. Koupparis *et al.* (8) reported the results of a combination of intracorporeal RARC (iRARC) and ERPs, which was compared with open RC with or without ERPs. The length of stay was reduced from 13 to 8 days ($P < 0.001$). The total complication rate was reduced from 48% to 31%,

although the difference was not significant. Tan *et al.* (10) compared the results of open RC and iRARC with or without ERPs. iRARC with ERPs demonstrated a shorter length of stay when compared with iRARC or open surgery alone (7 vs. 11 vs. 17 days, $P < 0.001$). It also presented fewer 90-day overall complications and readmissions ($P < 0.05$).

In our study, comparative results between BMI <24 or ≥ 24 kg/m² in the CRPs group were similar to those in the whole cohort. PONV occurrence was 42.3% in group A₂ and 7.1% in group B₂ ($P = 0.007$). Group A₂ also showed lower level of serum albumin pre- and post-operatively and a higher level of reduction proportion ($P < 0.05$). However, the results in the ERPs group were different. PONV was 9.1% in group A₁ and 11.1% in group B₁ ($P = 1.000$). A multi-institutional, randomized controlled trial (32) from China showed that ERPs demonstrated shorter recovery to bowel movement (88 vs. 100 h), fluid (68 vs. 96 h) or regular diet (125 vs. 168 h), and ambulation (64 vs. 72 h) when compared with conventional treatment. Tan *et al.* (10) also reported that iRARC combined with ERPs could decrease gastrointestinal complications. Based on these reports and our results, ERPs showed potential advantages in optimizing bowel function recovery and reducing PONV occurrence.

Although the albumin level on POD 1–2 was still lower in group A₁, the pre-operative level and its reduction proportion showed no difference between groups A₁ and B₁. Multivariable analysis showed that CRPs were

independently associated with $\Delta\text{ALB}_{\min} \geq 34\%$. These results indicated that the impact of BMI on peri-operative albumin level was optimized by ERPs implementation. It has been reported that transcappillary escape, which occurs during the inflammatory response, accounts for 77% of peri-operative albumin loss (33,34). Thus, ERPs could optimize peri-operative albumin level, which might be attributed to its aim of minimizing surgical stress and related inflammatory response.

Our study had several limitations: (I) the first of which was its small sample size. When performing subgroup analysis, there would be fewer cases divided into four subgroups; (II) due to the small sample size, we divided the whole cohort into two groups according to BMI (<24 or ≥ 24 kg/m²), not strictly following the Chinese BMI criteria, which spans from underweight to obese class III; (III) although there were several novel findings in this research, most of them had not been previously reported, such as the association between BMI and peri-operative albumin level, and that ERPs could optimize the impact of BMI on clinical outcomes. The underlying mechanisms are unclear, and we could only explain our results using limited evidence; (IV) multivariable analysis showed a strong correlation between PONV and $\Delta\text{ALB}_{\min} \geq 34\%$. However, both of them occurred in the early post-operative period; it was difficult to clarify which one caused the other.

Conclusions

In our research on LRC with ICUD, BMI had no impact on the 30-day overall complication rate, operative time, and length of stay. BMI <24 kg/m² was associated with higher PONV rate and more albumin loss, both of which could be optimized by ERPs.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Beijing Chaoyang Hospital, Capital Medical University (NO.: 2020-Ke-546) and informed consent for this retrospective analysis was waived.

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