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RESEARCH ARTICLE

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# The CUSUM curve combined with comprehensive complication index for assessing short-term complications of radical cystectomy

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## Abstract

**Objective:** To evaluate the comprehensive complication index(CCI) and Clavien-Dindo classification(CDC) for short-term postoperative complications in radical cystectomy and assess cumulative surgical morbidity to compare sufficient surgical skill.

**Methods:** From September 30, 2010, to October 1, 2020, clinical data of patients with urothelial carcinoma who underwent radical cystectomy with urinary diversion were gathered, patients who had only a urinary diversion, bladder sparing surgery, additional abdominal surgeries at the same time were all excluded. The CDC and CCI were utilized to evaluate 30-d complications after radical cystectomy and the relevance of hospital stay was compared between CCI and CDC. The cumulative sum control models (CUSUM) were used to evaluate the overall surgical morbidity of radical cystectomy in our facility and for comparisons between surgeons.

**Results:** This study enrolled a total of 635 individuals, 548 (86.3%) of whom had 1124 problems. The incidence of severe complications (CDC≥ Grade III) was 10.2%. The average CCI was 20.2 ± 14.7. Gender, urinary diversion subtype, procedure method, and surgeon were significantly correlated with the increase of CCI ($p < 0.05$). The CCI demonstrated a better relationship with hospital stay ($R^2 = 0.429$) than the CDC ($R^2 = 0.361$). The CUSUM-CCI model demonstrated a difference and growth distribution in dynamic time between individual surgeons.

**Conclusions:** CCI can better reflect the incidence of complications for radical cystectomy than CDC, and CCI is more strongly correlated with postoperative hospital stay. The CUSUM-CCI model can reflect the quality of surgical skill for each surgeon instantaneously.

KEYWORDS
clavien-dindo classification, comprehensive complication index, CUSUM curve, radical cystectomy

Diansheng Zhou and Jie Gao contributed equally to the work.

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## 1 | INTRODUCTION

The Comprehensive Complication Index (CCI) is a new complication management evaluation tool based on surgical risk index analysis methodologies used in economic science.[1] It integrates all postoperative complications of a patient exhibiting as a continuous number from 0 (no complications) to 100 (death). The Clavien-Dindo Classification (CDC) is widely applied to evaluate surgical complications through grading postoperative complications according to the degree of treatment required. Compared to the Clavien-Dindo Classification (CDC), CCI presents a more intuitive description of complication occurrence and has the advantage of showing cumulative complication rates.[2,3] Radical cystectomy (RC) represents a heavily complicated surgical procedure with significant short-term morbidity. Even though CCI is currently employed in the field of urology such as radical cystectomy,[4,5] Vetterlein et al. and Haas et al discussed the application of CCI within 30 and 90 days after RC, respectively,[6] there are still some limitations to CCI in urology in terms of implementation, it is worthy to attempt to the evaluation of cumulative surgical morbidity in radical cystectomy by CUSUM curve and contrast to surgical skill.

The main purpose of our study was to evaluate the CCI and CDC for short-term postoperative complications in radical cystectomy and apply CCI to establish a cumulative surgical morbidity model to assess the surgical skill of surgeons.

## 2 | PATIENTS AND METHODS

### 2.1 | Patient materials

Patients with urothelial carcinoma who underwent RC between September 30, 2010, and October 1, 2020, were chosen from the Department of Urology, Tianjin Medical University's second Hospital's bladder cancer database. Different extracorporeal urinary diversions were included. Patients who had only a urinary diversion, bladder sparing surgery, and additional abdominal surgeries at the same time were all excluded.

Age, gender, BMI, age-adjusted Charlson Comorbidity Index (ACCI), smoking status, length of stay, and readmission were all taken into consideration. Urinary diversion subtype, procedure method (open radical cystectomy, ORC; laparoscopic radical cystectomy, LRC; robot-assisted radical cystectomy, RARC), and surgeon were all included in the surgical data. The pathologic data were classified using the 8th version of the Union for International Cancer Control (UICC) TMN bladder cancer staging criteria. To assess the overall burden of disease, ACCI was calculated by collecting comorbidity data.[7] The missing data was obtained by comparing the original medical records (electronic or paper).

### 2.2 | The comprehensive complication index

Vetterlein et al. provided a list of perioperative complications for general and special procedures for RC.[6] Based on the medical records, we extracted detailed information of all postoperative complications within 30 days after surgery per patient and classified them into CDC, and then CCI was calculated.

CCI was based on the CDC and embraced all complications that occurred after the intervention,[1] which had the advantage of representing individual variances in accumulated complications over time. The overall incidence was measured on a scale of 0(no complication) to 100(death). The CCI was calculated for each patient using the online calculator provided on https:// www.assessurgery.com.

### 2.3 | Establishment of surgical morbidity monitoring model for RC

Cumulative sum technical analysis(CUSUM) was a graphical tool for discovering data trends and monitoring procedure outcomes,[8] which had been used in gastrectomy.[3] It could illustrate the cumulative difference between the event and the target value at each observation time point. The logical calculation formula was set as $\text{CUSUM-CCI} = \text{CUSUM-CCI}_{x-1} + (\text{CCI}_x - u)$, where $\text{CCI}_x$ was defined as the CCI value corresponding to each patient, and $u$ was defined as the target value, which was the events at each observation time point.

In the retrospective cohort, the surgical morbidity monitoring model of RC for surgeon A, B, and C were mainly discussed. Therefore, $u$ was set as the mean CCI of surgeons A, B, and C from the first 5 years. To evaluate the surgical morbidity monitoring model of overall RC in our institution, $u$ was set as the mean CCI from 2010 to 2015 and according to $u$ values, we depicted the relevant CUSUM-CCI monitoring model.

### 2.4 | Statistical analysis

We assessed the normality of variables using the Kolmogorov–Smirnov test. The cohort was separated into three groups based on ACCI cutoff (≤2, 3–5, and ≥6). Between groups, the Chi-square test, Fisher's exact test, and Kruskal-Wallis test were used. Later, we utilized the Chi-square test and analysis of covariance (ANCOVA) to examine the differences in various factors and then merged the factors with significant differences (($p < 0.05$) to conduct a multivariate analysis. The association between CDC and CCI with the length of stay days was compared by Spearman's rank test, followed by a multivariate analysis using a linear regression model. To examine the predictive effectiveness of CCI for the length of stay(LOS) > 30 days, the ROC curve was created using Logistic regression mixed with predictors. All statistical analyses were performed using SPSS 25.0(IBM,). The *p* values <0.05 were considered statistically significant.

## 3 | RESULTS

### 3.1 | Depictive analyses of clinical, surgical, and pathological characteristics

All patient characteristics are described in Table 1. Our study population involved 635 patients with a median age of 68 years (interquartile range IQR[61–74]), 552(86.9%) were male, and the median ACCI was 5(IQR 4–6) and 248(39.1%) underwent RC with ileal conduit and 56 patients (8.8%) with a neobladder and 331 patients (52.1%) with a cutaneous ureterostomy.

According to the ACCI cutoff groups, smoking status, type of urinary diversion, and length of stay were significant. Notably, the use of continent urinary diversion decreased with an increase of ACCI, but with an opposite trend for the length of stay, considered well physical condition might tolerate more complicated procedures while needing more time to recover. (all *p* values <0.05).

### 3.2 | Postoperative complications of 30-d

A detailed representation of all recorded complications and classifications according to the CDC is shown in Table 2. Overall, 1124 complications were recorded in 548 of 635 patients. Urogenital complications (52.3%), infectious complications (42.4%), and gastrointestinal complications (26.3%) were the most common complications in general. Wound, cardiac, pulmonary, vascular, and peripheral nervous system complications are infrequent. A total of 65 patients experienced 84 severe complications (CDC ≥Grade III), the majority of which were in the digestive system (20.2%), wound (20.2%), and cardiac (20.2%). 15 patients had a second operation, among 10 patients had a second abdominal closure due to dehiscence of abdominal incision, 3 patients had intestinal fistula repair for intestinal obstruction, one patient had an intestinal vaginal fistula repair, and one patient had a ureteral stent replaced for stent loss. 5 patients died of multiple organ dysfunction. Most complications occurred within 11d after RC and the highest complications rate focused on within 3–4d of RC (Figure 1D).

### 3.3 | Comparison of CDC and CCI

Figure 1A shows the distribution of CDC complications. The most common complications were grade I and grade II among 1124 complications. Because various types of complications can occur in the same patient, the distribution of the highest grade complication per patient is depicted in column charts in Figure 1B. The major CDC grade II complication was observed by 331 patients. The CCI values were focused on the two ranges of 0–10 and 20.1–25 in the grade distribution of CCI (Figure 1C).

The surgical and clinical factors relevant to complications are shown in Table S1. Gender, age, BMI, ACCI, tumor stage, and urinary diversion subtype had no significant impacts on the incidence of severe postoperative complications. Only procedure method had a significant impact on 30-d major complications. Gender, urinary diversion subtype, procedure method, and surgeon were all found to be statistically related to CCI.

Multivariate linear regression of the risk variables significantly associated with CCI had presented in Table S2. Female had a tremendous CCI than male, showing that male was adversely integrated with CCI increasing. In urinary diversion subtype, the orthotopic neobladder and ileum conduit associated with the increase of CCI is significant, as for procedure method, there was statistically significant between ORC and RARC, in addition, RARC versus LRC was no difference.

### 3.4 | Relationship with the length of stay

Patient characteristics and surgical factors and CCI or CDC were entered for the hospital stay-related general linear model. Following that, we compared CDC and CCI in terms of length of stay. Such individuals were removed considering grade V represented patient death events (Figure 2A,B). The correlation coefficients of CCI and CDC with the length of stay were 0.459 and 0.405, respectively. CCI, on the other hand, had a higher correlation than CDC, implying that CCI had a better significant correlation with the length of stay.

Patient characteristics, surgical factors, and CCI, or CDC were all integrated into a multivariate linear regression model of the length of stay, and the interaction of each variable with CDC or CCI was analyzed. Table S3 showed the result of significant features.

In the linear regression models, the $R^2$ value of CCI was 0.429 and CDC was 0.361, respectively. For the CCI-related model, BMI, urinary diversion subtype, and procedure method were significant factors and for the CDC-related model, the significant factors were urinary diversion subtype and procedure method.

Multivariate Logistic regression analyses demonstrated that the $R^2$ of CCI was 0.386, as well as CDC was 0.306 with ($p < 0.0001$. Hence CCI was used to predict patients who would have a longer LOS after surgery. The area under the curve (AUC) of CCI logistic regression combined with predictors was 0.894, and the optimal cutoff value was 30.5, according to the ROC curve resulted in Figure 3, with a sensitivity of 87.5% and specificity of 76.9%, the accuracy index was 0.644 (95% CI 0.850–0.938, ($p < 0.0001$).

### 3.5 | Establishment of the cumulative surgical morbidity monitoring model

The CUSUM-CCI monitoring model chart of surgeon A, B, and C were drawn, and u was set as $CCI_A = 22.8$; $CCI_B = 30.0$; $CCI_C = 20.5$. The CUSUM score of surgeon A hovered near the baseline at first, then reached its maximum value (CUSUM = 27.4) in the seventh

**TABLE 1** Clinical characteristics of 635 patients who underwent radical cystectomy for carcinoma of the urinary bladder between September 30, 2010 and October 1, 2020

| | The overall | ACCI≤2 | ACCI 3–5 | ACCI≥6 | *p* values |
|---|---|---|---|---|---|
| Clinical preoperative characteristics | | | | | |
| Number of patients(%) | 635 (100.0) | 32 (5.0) | 404 (63.6) | 199 (31.3) | – |
| Age (year), median (IQR) | 68 (61–74) | 49 (40 to 59) | 65 (59–70) | 76 (72–83) | <0.0001 |
| Gender, *N* (%) | | | | | 0.499 |
| Male | 552 (86.9) | 27 (84.4) | 356 (88.1) | 169 (84.9) | |
| Female | 83 (13.1) | 5 (15.6) | 48 (11.9) | 30 (15.1) | |
| BMI (kg/m$^2$), median (IQR) | 24.1 (21.7 26.2) | 24.6 (22.3 26.9) | 24.2 (21.9 26.2) | 23.9 (21.2 26.1) | 0.609 |
| Smoking status, *N* (%) | | | | | 0.017 |
| Never | 204 (32.1) | 11 (34.4) | 114 (28.2) | 79 (39.7) | |
| Ever | 431 (67.9) | 21 (65.6) | 290 (71.8) | 120 (60.3) | |
| Surgical characteristics of patients | | | | | |
| Type of urinary diversion, *N* (%) | | | | | <0.0001 |
| Continent | 56 (8.8) | 8 (25) | 46 (11.4) | 2 (1.0) | |
| Incontinent | 579 (91.2) | 24 (75). | 358 (88.6) | 197 (99.0) | |
| Urinary diversion subtype, *N* (%) | | | | | <0.0001 |
| Orthotopic neobladder | 56 (8.8) | 8 (25) | 46 (11.4) | 2 (1.0) | |
| Ileal conduit | 248 (39.1) | 18 (56.3) | 189 (46.8) | 41 (20.6) | |
| Cutaneous ureterostomy | 331 (52.1) | 6 (18.7) | 169 (41.8) | 156 (78.4) | |
| Length of stay (d), median (IQR) | 14.9 (9–16) | 16.4 (10.8 17.8) | 15.3 (10.0 17.0) | 13.8 (8.0 15.0) | 0.006 |
| Surgical procedure, *N* (%) | | | | | 0.571 |
| Laparoscope | 380 (59.8) | 20 (62.5) | 246 (60.9) | 114 (57.3) | |
| Open | 210 (33.1) | 10 (31.3) | 126 (31.2) | 74 (37.2) | |
| Robot | 45 (7.1) | 2 (6.2) | 32 (7.9) | 11 (5.5) | |
| Pathological features | | | | | |
| Pathological tumor staging, *N* (%) | | | | | |
| pT0/Ta/Tis | 10 (1.6) | 2 (6.3) | 7 (1.7) | 1 (0.5) | 0.216 |
| pT1 | 176 (27.7) | 10 (31.3) | 115 (28.5) | 51 (25.6) | |
| pT2 | 182 (28.7) | 9 (28.1) | 113 (28.0) | 60 (30.2) | |
| pT3 | 155 (24.4) | 4 (11.3) | 95 (23.5) | 56 (28.1) | |
| pT4 | 112 (17.6) | 7 (20.0) | 74 (18.3) | 31 (15.6) | |
| Pathological lymph node staging, N (%) | | | | | 0.392 |
| pN0 | 226 (35.6) | 10 (31.3) | 151 (37.4) | 65 (32.7) | |
| pN+ | 67 (10.6) | 6 (18.7) | 42 (10.4) | 19 (9.5) | |
| pNx | 342 (53.8) | 16 (50.0) | 211 (52.2) | 115 (57.8) | |

patient, as shown in Figure 4A. Then, starting with the 22nd patient, it began to deteriorate steadily. Finally, after 112 operations, CUSUM = −657.7, suggesting that surgical morbidity had improved, and his cumulative complication rate had dropped to 76.8%. The CUSUM score of surgeon B was shown in Figure 4B. Showed that the CUSUM score had fallen since the first patient, with a CUSUM of −1132.3 after 130 surgeries. Although surgeon B's procedure got improved, the cumulative surgical complication rate remained high (92.3%), and simultaneously, the severity of complications was progressively reduced. And the specific results of surgeon C were depicted in Figure 4C. From the second patient onwards, the CUSUM score began to fall. The ultimate CUSUM was −267.4 after 87 surgeries with an 82.8% cumulative incidence of surgical complications.

To make a longitudinal comparison of surgeons, the target value was defined as 24.4, which was the average CCI of the three surgeons from 2013 to 2016. Figure 5 exhibited the result, the linear formulas were $y_A = -8.1715x_A + 99.78$ ($R^2 = 0.9863$); $y_B = -3.1763x_B + 35.944$ ($R^2 = 0.966$); $y_C = -6.1038x_C$-48.865 ($R^2 = 0.9361$). The results showed that surgical morbidity of all surgeons had improved, but the coefficient of surgeon A and C decreased more than surgeon B, and surgeon A, B, and C had their final CUSUM scores of −836.9, −411.2, and − 606.7. Finally, Figure 4D depicted the surgical morbidity

TABLE 2 Details of postoperative complications

| Classification of complications | The CDC classification | Principles of management of postoperative complications | Total patients ($n$ = 635), $n$ (%) | Orthotopic neobladder ($n$ = 56), $n$ (%) | Ileal conduit ($n$ = 248), $n$ (%) | Cutaneous ureterostomy ($n$ = 331), n (%) |
|---|---|---|---|---|---|---|
| Gastrointestinal | | | 167 (26.3) | 22 (39.3) | 94 (37.9) | 51 (15.4) |
| Paralytic ileus | II | Conservative observation; Chinese medicine treatment (intestinal adhesion relieving soup);iv fluid support | 83 (13.1) | 11 (19.6) | 43 (17.3) | 29 (8.8) |
| Mechanical ileus of the small intestine | IIIa | Placement of small intestinal catheter | 13 (2.0) | 0 (0.0) | 10 (4.0) | 3 (0.9) |
| | IIIb | Open surgical exploration/laparoscopic exploration | 2 (0.3) | 0 (0.0) | 2 (0.8) | 0 (0.0) |
| Constipation | I | Conservative observation; purge; iv fluid support | 2 (0.3) | 1 (1.8) | 0 (0.0) | 1 (0.3) |
| Gastrointestinal hemorrhage | I | Conservative treatment; acid suppression | 29 (4.6) | 5 (8.9) | 19 (7.7) | 5 (1.5) |
| | II | Blood transfusion treatment | 4 (0.6) | 0 (0.0) | 4 (1.6) | 0 (0.0) |
| Vomiting | I | Conservative observation; anti-nausea; iv fluid support | 22 (3.5) | 4 (7.1) | 8 (3.2) | 10 (3.0) |
| Small intestinal anastomotic fistula | IIIb | Open surgical exploration/laparoscopic exploration | 2 (0.3) | 0 (0.0) | 2 (0.8) | 0 (0.0) |
| Diarrhea | I | Conservative treatment; antidiarrheal; iv fluid support; | 10 (1.6) | 1 (1.8) | 6 (2.4) | 3 (0.9) |
| Infection | | | 269 (42.4) | 46 (82.1) | 110 (44.4) | 112 (33.8) |
| Fever of unknown origin | II | Antibiotic treatment; supportive treatment; defervescence | 121 (19.1) | 14 (25.0) | 58 (23.4) | 49 (14.8) |
| Asymptomatic bacteriuria (asymptomatic, urine culture colonies >10^5 cfu/mL) | I | Clinical conservative observation | 13 (2.0) | 7 (12.5) | 4 (1.6) | 2 (0.6) |
| Urinary tract infection | II | Antibiotic treatment; defervescence | 93 (14.6) | 13 (23.2) | 32 (12.9) | 48 (14.5) |
| Abdominal abscess | II | Antibiotic therapy | 2 (0.3) | 0 (0.0) | 0 (0.0) | 2 (0.6) |
| | IIIa | The puncture drainage | 3 (0.5) | 0 (0.0) | 1 (0.4) | 2 (0.6) |
| Sepsis | II | Antibiotic treatment; support treatment | 17 (2.7) | 3 (5.4) | 11 (4.4) | 3 (0.9) |
| | IVb | Septic shock; multiple organ failure was transferred to the ICU | 3 (0.5) | 1 (1.8) | 0 (0.0) | 2 (0.6) |
| | V | Death | 2 (0.3) | 1 (1.8) | 0 (0.0) | 1 (0.3) |
| Pyelonephritis | II | Antibiotic treatment; support treatment | 7 (1.1) | 5 (8.9) | 2 (0.8) | 0 (0.0) |
| Gastroenteritis | II | Antibiotic treatment; anti-nausea antidiarrheal | 3 (0.5) | 1 (1.8) | 0 (0.0) | 2 (0.6) |
| Cholecystitis | II | Conservative observation; antibiotic treatment; support treatment | 1 (0.2) | 0 (0.0) | 1 (0.4) | 0 (0.0) |

(Continues)

TABLE 2 (Continued)

| Classification of complications | The CDC classification | Principles of management of postoperative complications | Total patients ($n$ = 635), $n$ (%) | Orthotopic neobladder ($n$ = 56), $n$ (%) | Ileal conduit ($n$ = 248), $n$ (%) | Cutaneous ureterostomy ($n$ = 331), n (%) |
|---|---|---|---|---|---|---|
| Peripheral neuritis | II | Neurotrophic drugs; support treatment | 3 (0.5) | 1 (1.8) | 1 (0.4) | 1 (0.3) |
| Parotiditis | II | Conservative observation; antibiotic treatment; support treatment | 1 (0.2) | 0 (0.0) | 0 (0.0) | 1 (0.3) |
| Wound | | | 54 (8.5) | 2 (3.6) | 17 (6.9) | 35 (10.6) |
| Incision hematoma | I | Conservative observation | 2 (0.3) | 0 (0.0) | 0 (0.0) | 2 (0.6) |
| | IIa | Debridement drainage | 7 (1.1) | 0 (0.0) | 5 (2.0) | 2 (0.6) |
| Infection of incision, | II | Antibiotic treatment; dressing | 1 (0.2) | 0 (0.0) | 0 (0.0) | 1 (0.3) |
| Incision dehiscence | I | Conservative observation; dressing | 34 (5.4) | 2 (3.6) | 8 (3.2) | 24 (7.3) |
| | IIIb | Secondary closure | 10 (1.6) | 0 (0.0) | 4 (1.6) | 6 (1.8) |
| Genitourinary | | | 332 (52.3) | 18 (32.1) | 162 (65.3) | 152 (45.9) |
| Acute renal injury | I | Conservative observation; iv fluid management | 5 (0.8) | 1 (1.8) | 1 (0.4) | 3 (0.9) |
| | II | Kidney protective drug therapy | 7 (1.1) | 0 (0.0) | 4 (1.6) | 3 (0.9) |
| Hydronephrosis/ureter obstruction | I | Conservative observation | 287 (45.2) | 11 (19.6) | 139 (56.0) | 137 (41.4) |
| | IIIa | Ureteral stent replacement/ nephrolithostomy | 7 (1.1) | 3 (5.4) | 4 (1.6) | 0 (0.0) |
| | IIIb | Ureteral stent replacement under general anesthesia | 1 (0.2) | 0 (0.0) | 1 (0.4) | 0 (0.0) |
| Urine leakage/urinary cyst | I | Conservative observation; fluid support therapy | 20 (3.1) | 2 (3.6) | 11 (4.4) | 7 (2.1) |
| | IIIa | The puncture drainage | 2 (0.3) | 0 (0.0) | 1 (0.4) | 1 (0.3) |
| Ischemia of the ureterostomy | I | Clinical conservative observation | 1 (0.2) | 0 (0.0) | 1 (0.4) | 0 (0.0) |
| Scrotal edema | II | Conservative observation; diuretic detumescence medication | 1 (0.2) | 0 (0.0) | 0 (0.0) | 1 (0.3) |
| Ileal vaginal fistula | IIIb | Secondary surgical repair | 1 (0.2) | 1 (1.8) | 0 (0.0) | 0 (0.0) |
| Cardiac | | | 49 (7.7) | 3 (5.4) | 14 (5.6) | 32 (9.7) |
| An irregular heartbeat | II | Conservative observation; anti-arrhythmia drugs | 32 (5.0) | 2 (3.6) | 13 (5.2) | 17 (5.1) |
| Myocardial infarction, | IVa | Coronary angiography; heart stents; anticoagulant heart; transferred to the ICU | 3 (0.5) | 0 (0.0) | 0 (0.0) | 3 (0.9) |
| Acute congestive heart failure | IVa | ICU admission for acute heart failure | 11 (1.7) | 1 (1.8) | 1 (0.4) | 9 (2.7) |
| | V | Death | 3 (0.5) | 0 (0.0) | 0 (0.0) | 3 (0.9) |

TABLE 2 (Continued)

| Classification of complications | The CDC classification | Principles of management of postoperative complications | Total patients ($n$ = 635), $n$ (%) | Orthotopic neobladder ($n$ = 56), $n$ (%) | Ileal conduit ($n$ = 248), $n$ (%) | Cutaneous ureterostomy ($n$ = 331), n (%) |
|---|---|---|---|---|---|---|
| Pulmonary | | | 80 (12.6) | 6 (10.7) | 44 (17.7) | 30 (9.1) |
| Pneumonia | II | Antibiotic treatment; expectorant | 14 (2.2) | 1 (1.8) | 3 (1.2) | 10 (3.0) |
| Pleural effusion | I | Clinical conservative observation | 57 (9.0) | 5 (8.9) | 38 (15.3) | 14 (4.2) |
| | IIIa | Chest puncture and drainage | 4 (0.6) | 0 (0.0) | 2 (0.8) | 2 (0.6) |
| Respiratory failure | IVa | ICU | 5 (0.8) | 0 (0.0) | 1 (0.4) | 4 (1.2) |
| Vascular | | | 128 (20.2) | 10 (17.9) | 35 (14.1) | 83 (25.1) |
| Anemia (blood transfusion required) | II | Blood transfusion | 121 (19.1) | 10 (17.9) | 30 (12.1) | 81 (24.5) |
| Deep vein thrombosis | II IIIa | Anticoagulation Lower limb filter implantation | 2 (0.3) 3 (0.5) | 0 (0.0) 0 (0.0) | 2 (0.8) 2 (0.8) | 0 (0.0) 1 (0.3) |
| Pulmonary embolism | II | Anticoagulation; thrombolysis | 2 (0.3) | 0 (0.0) | 1 (0.4) | 1 (0.3) |
| Nervous system | | | 10 (1.6) | 0 (0.0) | 3 (1.2) | 7 (2.1) |
| CVA/TIA | II | Anticoagulation | 7 (1.1) | 0 (0.0) | 2 (0.8) | 5 (1.5) |
| | IVa | Transferred to the ICU. anticoagulation; thrombolysis | 2 (0.3) | 0 (0.0) | 1 (0.4) | 1 (0.3) |
| Look forward | I | Clinical conservative observation | 1 (0.2) | 0 (0.0) | 0 (0.0) | 1 (0.3) |
| Others | | | 35 (5.5) | 5 (8.9) | 9 (3.6) | 21 (6.3) |
| Acidosis | I | Clinical conservative observation; | 5 (0.8) | 2 (3.6) | 0 (0.0) | 3 (0.9) |
| Hypokalemia | I | Potassium supplement | 18 (2.8) | 3 (5.4) | 7 (2.8) | 8 (2.4) |
| Lower extremity edema, | I | Conservative observation; diuretics | 11 (1.7) | 0 (0.0) | 2 (0.8) | 9 (2.7) |
| Arthritis | I | Conservative observation; diet control | 1 (0.2) | 0 (0.0) | 0 (0.0) | 1 (0.3) |

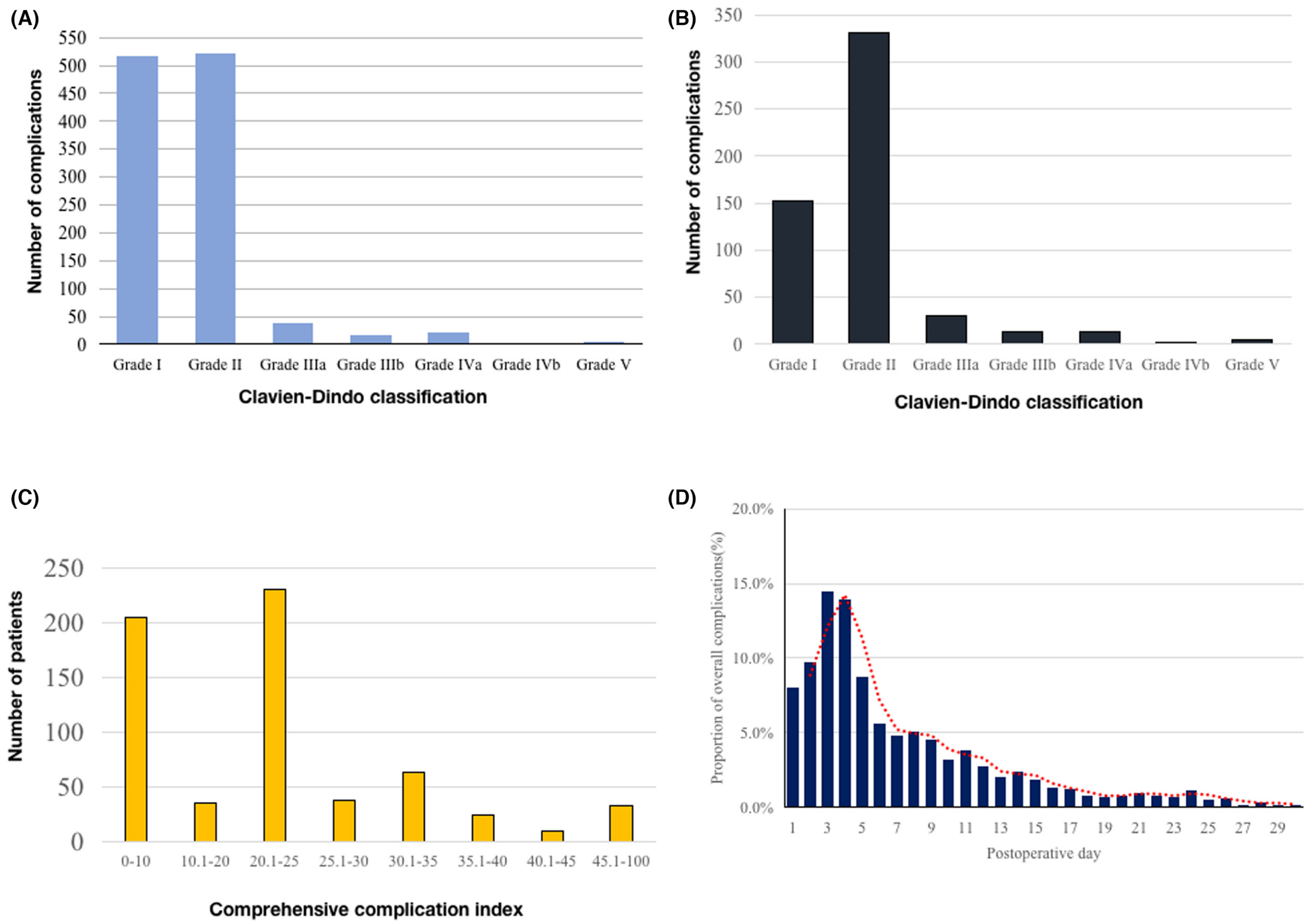


FIGURE 1 (A) CDC (Clavien-Dindo Classification) classification and distribution of complications and (B) column charts depicting the distribution of the highest grade complication per patient. (C)The distribution of CCI (Comprehensive Complication Index) and (D) The incidence of overall complications within 30 d following radical cystectomy

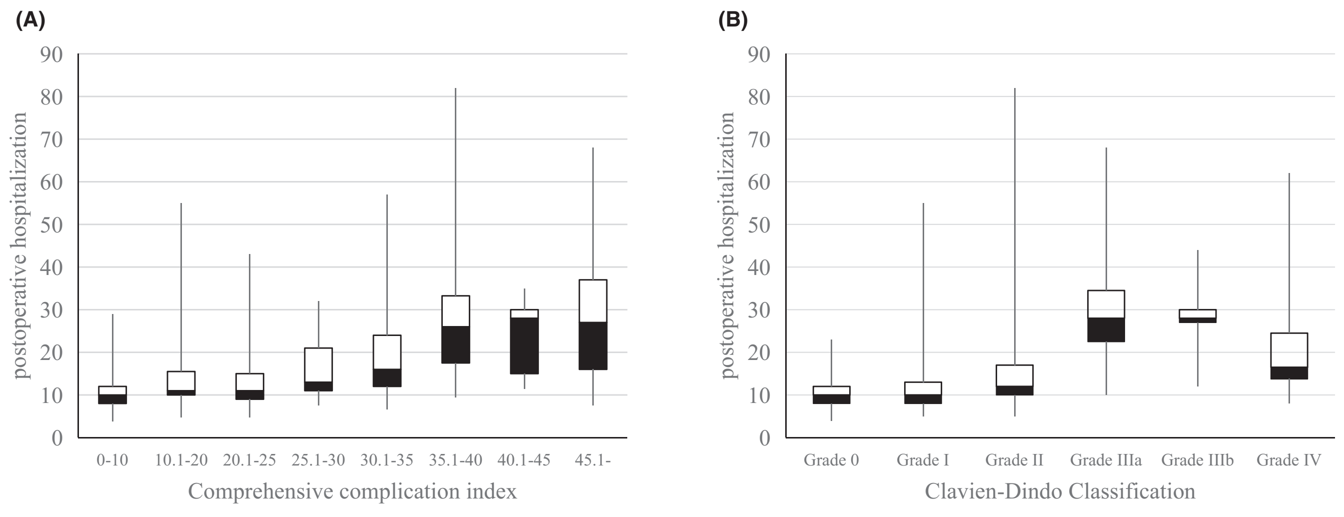


FIGURE 2 (A) relationship between postoperative hospital stay with CCI and (B) relationship between postoperative hospital stay with CDC

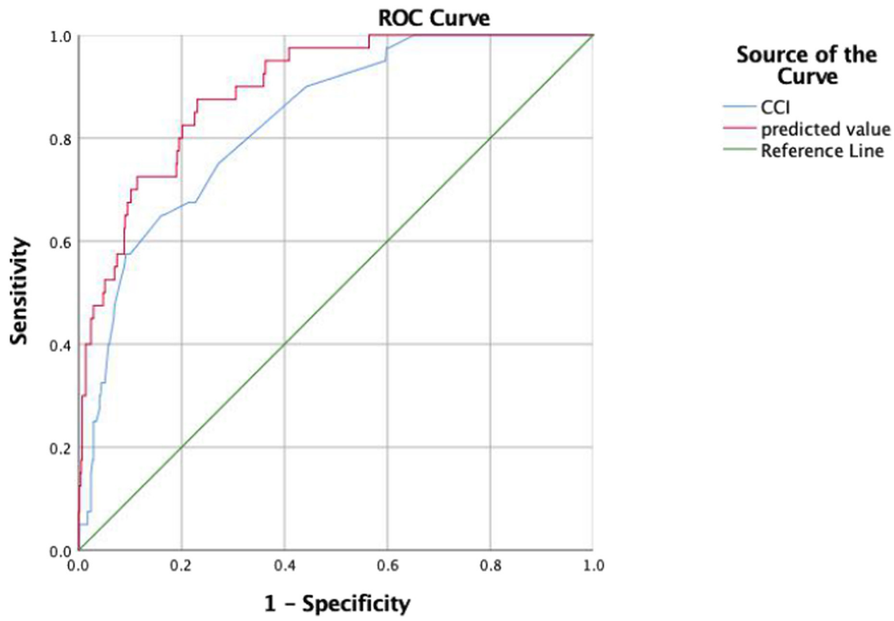


**FIGURE 3** ROC curve of CCI correlation to over 30d hospitalization

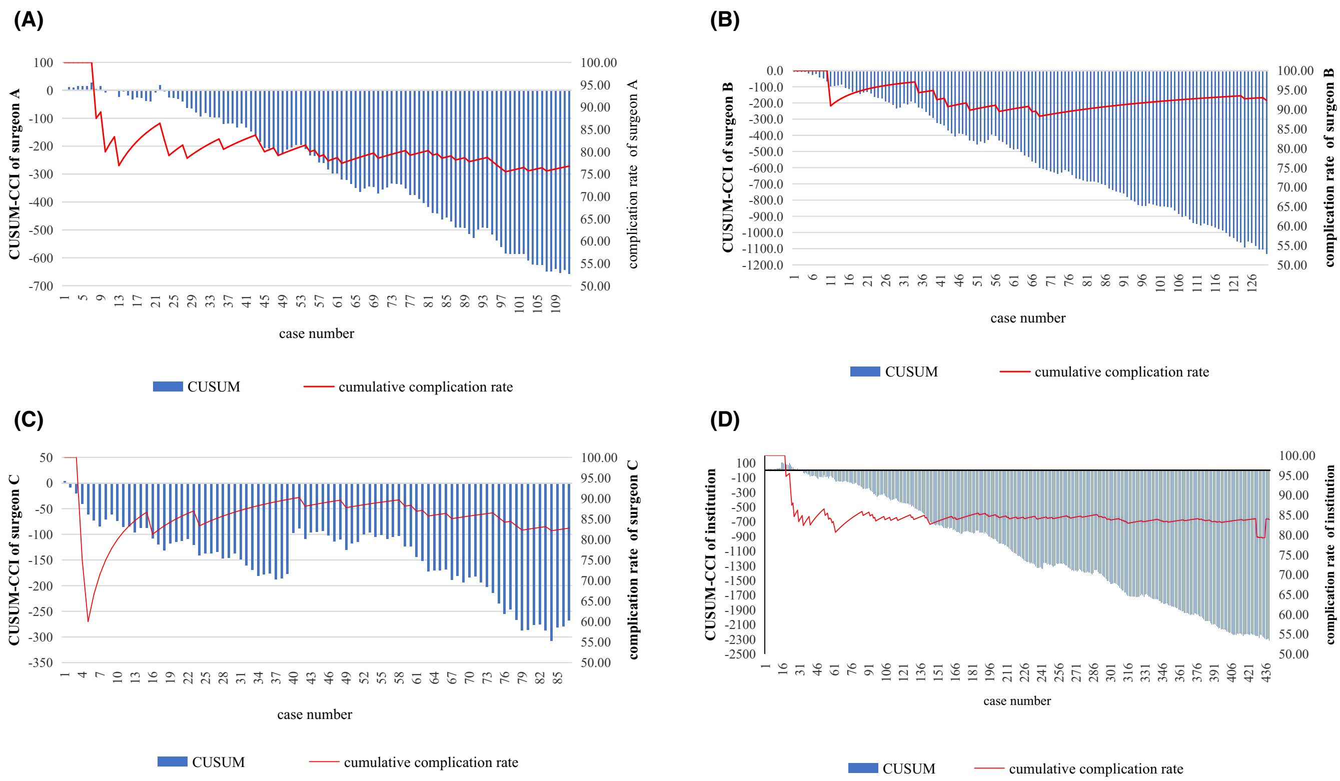


**FIGURE 4** (A) CUSUM-CCI monitoring model for surgeon A and (B) for surgeon B and (C) for surgeon C and (D) for the institution

monitoring chart for RC across the entire institution. 439 operations had been completed in the last 4 years, with a final CUSUM of −2314.0.

## 4 | DISCUSSION

Radical cystectomy is a difficult urological procedure that involves organ removal and reconstruction and is associated with a remarkable complication rate.[9] So our study reported a series of postoperative complications in patients who underwent RC by CCI. CCI could be valid to evaluate the burden of cumulative complications after RC and further assess the prediction efficacy for patients with prolonged postoperative stay. The CUSUM-CCI model can be utilized as a comprehensive measure to evaluate the surgical skill of surgeons.

When the CDC is used in many surgical fields, it is frequently discovered that it can only show the most serious complication, and

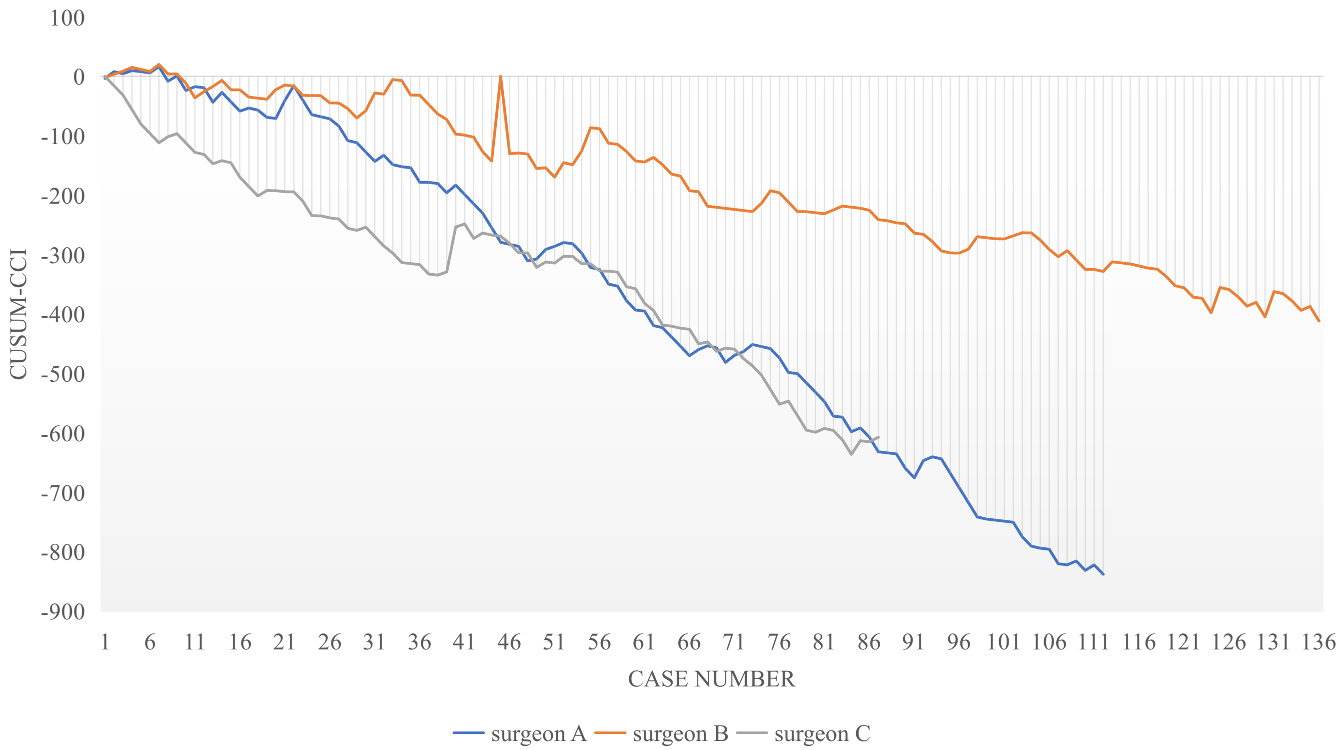


**FIGURE 5** Longitudinal comparison of CUSUM-CCI among surgeons

the ability to report additional complications or the total number of complications is insufficient, resulting in a poor assessment of the cumulative incidence of complications.[6,10–17] Compared to the CDC, the CCI as a continuous variable scoring system not only includes all postoperative complications, but also the cumulative complications in patients with a greater load rate. It can also be combined with the cumulative sum model, which can be used in monitoring surgical morbidity and comparing different surgical operation performances.

A recent study evaluated the learning curve of robotic radical cystectomy with intracorporeal neobladder and established a cutoff of 60 procedures to reach the pentafecta,[18] and Brassetti et al highlighted that the learning curve in RARC-intracorporeal neobladder had a significant impact on surgical quality, cancer control and functional outcomes.[19] The robotic approach may emerge with several advantages including reduced blood loss, length of stay and operative times compared to open surgery.[20] However, it must be considered that laparoscopic surgery is still the dominant surgical method in our center and most developing countries. The institution for robotic platform had just set up and had not launched robotic intracorporeal surgery cases for the moment, but we did mix different ways of urinary diversion, and further reviewed the cases of 10 years, according to the results in the regression model of CCI, different ways of urinary diversion showed significant effect on the postoperative complications.

The 30-d complication rates were no difference between the ORC, LRC, and RARC, but on the contrary, ORC patients had significantly more 30-d major complications compared with others. It is indisputable that ORC patients suffered more complications compared with LRC or RARC. However no significant difference was found in 30-d CCI between LRC and RARC, we found an overall trend toward reduced complication rates for LRC, which agreed with previously published outcomes.[21,22] But Mastroianni et al carried out a randomized controlled trial about comparison between ORC and RARC with intracorporeal urinary diversion and they demonstrated that perioperative complications was largely comparable between groups.[23] Our research may indicate that LRC could enforce better benefits compared to RARC due to extracorporeal diversion operation. We also realized that a surgeon bias and the number of robotic surgery could have influenced the results, and as robot-assisted operations become more proficient, RARC may show a significant improvement.

Complications are mostly caused by surgical stress, particularly age and physical conditions, all of which have recently been found as predictors of higher complication rates.[17,24,25] We used the ACCI in our study to account for patients' characteristics. However, our findings revealed that age and ACCI scores were not prognostic indicators for severe complication rates, neither the CDC nor the CCI grading exhibited statistically significant differences. We believe that the urinary diversion subtype should be chosen based on the patient's gender, age, physical condition, personal will, financial circumstances, and other considerations. Patients in poor physical condition are more likely to be selected for cutaneous ureterostomy, which takes less risk and less surgical trauma. As a result, variations in age and ACCI might be unconsciously eliminated; thus, age and ACCI are not shown to be risk factors for increased complication rates in our study. However, this does not rule out the possibility that age and physical conditions have a role in the occurrence of complications. On the contrary, data suggests that personalizing a treatment plan to each patient's unique physical needs can relieve pain and limit the risk of consequences. It is easy to notice that the cutaneous ureterostomy chosen rate was unusual higher than Europe and US, and the same for the length of stay. It is attributed that the patients' families might play a dominant role in the discharge decision owing to achieving a complete recovery for the patient. So our findings are not surprised that it is hard to promote the ERAS protocol, especially for such complicated surgical procedures.

As the CCI is a broad continuous scoring variable, it may be computationally integrated and combined with CUSUM to track surgical morbidity. This approach provides more information about maintaining an optimal level of surgical morbidity and timely detection of surgical errors than tracking the incidence of complications when considering the number and severity of complications. The CUSUM-CCI model depicts the vital changes in time-event settings for each surgeon. This method allows individual physicians and institutions to assess surgical performance and progress of surgical skill, as well as gather and analyze prospective data on complications over time. The results provide feedback to surgeons, allowing them to appraise surgical abilities and improve standard procedures.

But we should not overlook the role of the CDC. The CDC≥ grade III incidence can be used to assess surgical performance and short-term postoperative outcomes. Oversimplified results, on the other hand, can lead to the exclusion of the true complication burden, particularly in extreme cases where many or a succession of complications arise.[26,27] This is why it is important to have a set of standardized complication assessment procedures, especially for RC, a surgical procedure with a high rate of postoperative complications and a unique set of complications definitions, making it critical to choose a highly adaptable and repeatable complication definition catalog.[15]

The study suffers from several limitations. As negative surgical margins and the intraoperative complication rate and other relevant variables that usually improve with surgical proficiency, we have to admit that we are not able to identify intraoperative complications by pre-existing criteria or information loss and these may be underestimated in our retrospective study. However, this does not prevent the cumulative model from playing a positive role in the monitoring of surgical morbidity and proficiency and further facilitates closure on the timeline and corresponding cases. Although various clinical factors have been considered, except social factors. Immediate surgical intervention to correct complications is costlier and takes more time to treat than conservative care. As a result, the surgeon's practice has an impact on the decision to undertake interventional surgery and maintaining a consistent and standard treatment consensus takes a lot of work.

## 5 | CONCLUSION

The implementation of CCI to reflect the cumulative incidence can help to improve and optimize the evaluation of complications after radical cystectomy. In comparison to CDC, CCI has efficacy in evaluating postoperative complications but can also be used to assess the length of stay. CUSUM-CCI can be used to continuously and effectively monitor the morbidity of radical cystectomy, allowing clinical surgeons to quickly rectify issues caused by surgical errors, and enhancing surgery quality.

### AUTHOR CONTRIBUTION

Changli Wu conceptualized the study; Dawei Tian, Hailong Hu, and Jianqiang Zhu designed the study; Diansheng Zhou, Jie Gao, and Jian Wang acquired the data; Keke Wang and La Da involved in the quality control of the data and algorithms; Yihao Liao analyzed and interpreted the data; Diansheng Zhou statistically analyzed, prepared and edited the manuscript; Yihao Liao and Jie Gao reviewed the manuscript.

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### CONFLICTS OF INTEREST

None of the authors have any relevant conflicts of interest about the studies and data in this manuscript.

### DATA AVAILABILITY STATEMENT

All data and materials are available.

### ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

This study does not involve studies of human participants and/or animals.

### CONSENT FOR PUBLICATION

Informed consent of all authors.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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