Langenbeck's Archives of Surgery (2019) 404:853–863
https://doi.org/10.1007/s00423-019-01834-6

ORIGINAL ARTICLE

Early removal of urinary drainage in patients receiving epidural analgesia after colorectal surgery within an ERAS protocol is feasible

André Schreiber[1] · Emine Aydil[1] · Uwe Walschus[1] · Anne Glitsch[1] · Maciej Patrzyk[1] · Claus-Dieter Heidecke[1] · Tobias Schulze[1]

Received: 19 April 2019 / Accepted: 21 October 2019 / Published online: 9 November 2019

Abstract

Background ERAS guidelines recommend early removal of urinary drainage after colorectal surgery to reduce the risk of catheter-associated urinary tract infections (CAUTI). Another recommendation is the postoperative use of epidural analgesia (EA). In many types of surgery, EA was shown to increase the risk of postoperative urinary retention (POUR). This study determines the impact of early urinary catheter removal on the incidence of POUR and CAUTI under EA after colorectal surgery.

Methods Eligible patients were scheduled for colorectal surgery within the local ERAS protocol between April 2015 and September 2016. Urinary drainage was removed on the first postoperative day while EA was still in place (early removal group (ER)). The incidences of POUR and CAUTIs were recorded prospectively. Results were compared with a historical control (CG), which was operated between October 2013 and March 2015.

Results POUR occurred significantly more often in the ER (ER 7.8%; CG 2.6%), while CAUTIs were significantly less frequent in the ER (13.8%) compared with the CG (30.4%). Patients who developed POUR were characterised by a significantly higher rate of abdominoperineal resections, by a higher frequency of rectal cancer, and a higher male-to-female ratio compared with patients who did not develop POUR.

Conclusion Early removal of urinary drainage after colorectal surgery while EA is still in place is feasible; it reduces the incidence of CAUTI but increases the risk of POUR. Thus, screening for POUR in patients with failure to void after six to 8 h is mandatory under these clinical conditions.

Keywords urinary retention · catheter associated urinary tract infection · urinary drainage · epidural analgesia · enhanced recovery after surgery

Introduction

The development and implementation of enhanced recovery after surgery (ERAS) programmes in colorectal surgery during the last 25 years have been associated with a significant decrease in non-surgical complications and length of hospital stay [1, 2]. Although ERAS protocols show considerable heterogeneity concerning the number of included items and their practical implementation, regional techniques for intra- and postoperative analgesia and early ambulation are key features of the majority of ERAS protocols and compliance with these items is high [3]. Intra- and postoperative EA has been shown to favour the early onset of bowel movements and to provide superior pain relief in both open and laparoscopic procedures [4, 5]. However, it is also associated with significant negative side effects including arterial hypotension, increased incidence of pruritus, and a higher frequency of urinary retention. EA has also been reported to influence urodynamic parameters and to be a risk factor for POUR [6].

The perioperative use of indwelling urinary tract catheters is frequent in abdominal, and especially in colorectal surgery, in order to improve the exposure in the pelvis and to guide intraoperative fluid management. After major abdominal surgery under EA, it is currently clinical practice to leave the urinary catheter in place postoperatively to prevent urinary

Parts of this paper were presented at the meeting '200. Tagung der Vereinigung Norddeutscher Chirurgen' in Hamburg, November 30–December 2, 2017.

✉ Tobias Schulze
schulzet@uni-greifswald.de

[1] Department of General Surgery, Visceral, Thoracic and Vascular Surgery, Universitätsmedizin Greifswald, Greifswald Germany

retention [7, 8]. Moreover, continuous monitoring of urine production offers the possibility of assessing renal function and is a valuable tool for postoperative fluid management. However, persistent postoperative catheterisation can have several significant side effects. Prolonged postoperative catheterisation results in an increased risk of postoperative CAUTI as approximately 50 % of patients with postoperative bladder catheterisation persisting for more than four days develop bacteriuria or candiduria [9–11]. After two days of persistent bladder catheterisation, the frequency of urinary tract infections increases twofold [12]. In addition, transurethral catheterisation is associated with significant discomfort and pain, potentially resulting in decreased mobilisation and ambulation [13–15]. These latter side effects impede the efficacy of ERAS programmes which is one reason that current European ERAS Guidelines recommend early removal of transurethral catheters after colorectal surgery [16, 17]. Moreover, both European and American infection control institutions advocate early removal of indwelling bladder catheters after abdominal surgery, except in situations with appropriate indications for continued bladder drainage [18, 19].

Given the strong recommendations for early postoperative removal of urinary catheters, the Department of Surgery at the Universitätsmedizin Greifswald revised the colorectal ERAS protocol in vigour in March 2015. Before this date, urinary drainage (UD) was continued postoperatively in patients with EA until the epidural infusion was stopped. From April 2016, urinary catheters were routinely removed on the first postoperative day while EA was still in place. To evaluate the influence of early catheter removal on the postoperative course, we prospectively determined the incidence of urinary retention (UR), catheter reinsertion for other reasons (CI) and CAUTIs. We compared our findings with a historical control group which was operated in the same department before April 2015.

Patients and methods

The study was planned in accordance with the ethical principles for medical research and has been approved by the Ethical Committee of the Universitätsmedizin Greifswald. It is a retrospective study of a prospectively collected database and includes patients who were treated according to the ERAS protocol implemented in the Department of Surgery at the Universitätsmedizin Greifswald. The ERAS protocol defines perioperative treatment modalities in patients undergoing elective abdominal surgery of the lower digestive tract and contains the following items: preoperative: counselling and education, no mechanical bowel preparation, curtailed fasting, and carbohydrate loading; intraoperative: active warming, epidural anaesthesia, restriction of intravenous fluids, and restricted indications for the insertion of nasogastric tubes; postoperative: early oral fluids and diet, fluid restriction, early postoperative mobilisation on postoperative day 1, restriction of postoperative opioids, oral laxatives, and continuation of EA.

Patients

Prospective data were collected after a modified ERAS protocol was implemented in standard patient care from April 2015 until September 2016. The modification concerned early removal of the indwelling urinary catheters on the first postoperative day. Only elective patients having both a transurethral catheter inserted on the day of surgery and EA were included. Exclusion criteria comprised of patients with pre-existing UD, pre-existing urinary incontinence, and intraoperative bladder resections/damage requiring prolonged UD. Patients with suprapubic catheters were also generally excluded. As a historical control cohort, we analysed patients with EA who were treated according to the former ERAS programme between October 2013 and March 2015. At that time, the indwelling catheter was routinely removed only after discontinuation of the EA.

Treatment

Perioperative antibiotic prophylaxis was given to all patients. A Foley catheter was inserted in the operating room after the induction of anaesthesia by a member of the operating team. Postoperatively, all patients were transferred to the surgical intermediate care unit for at least 24 h. The epidural catheter was inserted before the induction of anaesthesia on the day of surgery by the anaesthetist. Ropivacain (0.2%), either with or without sufentanyl (100 μg/200 ml), was administered via a patient-controlled epidural anaesthesia (PCEA) technique. The basal rate was titrated by a pain team, and patients could self-administer a bolus of analgesics in the case of breakthrough pain. The insertion site of the catheter was checked twice daily by the pain team, and pain scores were assessed by the ward team every 8 h using a visual analogue scale (1–10). The epidural catheter was removed on postoperative day 4 unless the patient reported a pain score of > 3 after reduction of the EA or the insertion site showed signs of infection. UD was systematically removed at postoperative day 1 in the ER group. In the CG, UD was removed only after discontinuation of the EA.

Primary and secondary outcome measures

The primary outcome measures was the frequency of UR, while secondary outcome measures were the frequency of reinsertion of an indwelling catheter, the frequency of CAUTI, and the frequency of pyuria.

Urinary retention was defined as a bladder volume of more than 600 ml. In the ER, a bladder ultrasound was routinely

performed 6 h after catheter removal. When bladder volume was higher than 500 ml and the patient had no sensation to void, re-catheterisation was performed after one further hour without voiding. The reasons for catheter reinsertions not complying with the criteria described above were documented. The final decision as to whether or not to reinsert an indwelling catheter was left to the team of treating surgeons.

Urine samples were not collected routinely for all patients but only for those patients where a urinary tract infection (UTI) was clinically suspected. UTI was defined according to the CDC definitions from 1988 [20]. Pyuria was defined as the presence of ten or more white cells per cubic millimetre in a urine specimen as assessed by urinary dipstick based on the presence of leukocyte esterase [21].

Data collection

Data from the ER group were collected prospectively by the team of treating surgeons. Clinicopathological parameters including patient demographics, diagnosis, history of prostatism and medication for benign prostatic hypertrophy, previous neoadjuvant therapy, co-morbidities (diabetes mellitus, neurological disorders), co-medication, previous abdominal surgery and pre-existing medications susceptible to favour UR as well as intraoperative (type of surgery, operative time, perioperative fluid administration) and postoperative details (time of catheter removal, time of first spontaneous micturition, UR, UTI and length of hospital stay) were prospectively collected postoperatively. In the CG where the patients were treated according to the same ERAS protocol except for early catheter removal, data were collected retrospectively from the electronic patient records.

Statistics

Categorical variables were described using frequency measures. Continuous variables were described using the non-parametric measures median and interquartile range. For the univariate comparison of categorical variables, the Chi square test was applied; while for the continuous variables, the non-parametric Mann-Whitney *U* test was applied. A threshold of $p < 0.05$ was considered to determine statistical significance. In order to determine associations between clinicopathological parameters and the occurrence of primary and secondary endpoints, univariate regression was used. For multivariate comparison, multivariate two-sample configural frequency analysis was performed. Statistical analysis was conducted using SPSS software version 17.0 (IBM Inc., Armonk, NY) with the exception of multivariate two-sample configural frequency analysis which was performed using BiAS 11.10 (epsilon-Verlag/ University of Frankfurt, Germany).

Results

Patient characteristics

A total of 124 patients who underwent colorectal surgery between April 1, 2015, and September 30, 2016 were treated according to the modified ERAS protocol including early removal of UD on the first postoperative day (POD1). Eight patients were excluded from the analysis due to the fact that seven of them required prolonged postoperative screening of urine output due to persistent arterial hypotension, while the other patient developed haematuria requiring bladder irrigation. Thus, 116 patients were available for analysis in the ER group. A total of 115 patients who underwent colorectal surgery between October 1, 2013, and March 31, 2015 were included in the CG. The main patient and treatment characteristics are shown in Table 1. There were no statistically significant differences between the two groups except for operation time and volume infused during anaesthesia. Both parameters were significantly lower in the ER group. In the CG, the UD was removed after 7.1 ± 13.9 days, while it was discontinued after 18.3 ± 2.6 h in the ER group.

Frequency of catheter reinsertion and urinary retention

A transurethral catheter was reinserted in three patients (2.6%) in the CG and 26 patients (22.4%) in the ER group. Detailed analysis of the reasons for catheter reinsertion revealed that in the ER group, only nine patients (7.8%) experienced UR. Reasons for catheter reinsertions comprised patient complaints (three patients (2.6%)), re-occurrence of the necessity to screen urinary output in seven patients (6.0%), and the individual decision of the surgeon on-call without ultrasound screening of the bladder in seven further patients (6.0%). In those patients in the ER group who did not require re-catheterisation, the first micturition occurred after 5.3 ± 5.0 h. In those patients who experienced UR, the urinary catheter was reinserted 15.9 ± 8.9 h after initial removal of UD. The mean urine volume after bladder catheterisation in ER patients suffering from UR was 656 ± 191 ml. In the CG, all three cases of catheter reinsertion were due to UR. The mean urine volume after bladder catheterisation in this group was 850 ± 70 ml. Table 2 summarises the outcome data concerning the occurrence of catheter reinsertion and UR.

Since the risk of developing POUR is higher in patients undergoing rectal surgery than in those undergoing colon surgery [22, 23], we compared these patients' groups in the ER and CG separately (Table 2). Interestingly, while the differences in the frequency of catheter reinsertion and the incidence of UTI remained highly significant in patients after rectal surgery, colon cancer patients of the ER showed no statistically significant increase in the incidence of UR compared with colon cancer patients in the CG.

Table 1 Demographic and perioperative data (n = 231)

	Control group	Early removal (ER) group	p
Age (years)	66.3 ± 12.8	63.5 ± 11.5	0.078
BMI (kg/m^2)	27.2 ± 4.1	27.4 ± 5.6	0.730
Gender			
Male (%)	66 (57.4)	53 (45.7)	0.087
Female (%)	49 (42.6)	63 (54.3)	
Diagnosis			
Benign	28 (24.3)	40 (34.5)	0.112
Malignant	87 (75.7)	76 (65.5)	
Adenocarcinoma			
Right hemicolon	24 (20.9)	31 (26.7)	0.273
Left hemicolon	6 (5.2)	2 (1.7)	
Sigma	15 (13.0)	17 (14.7)	
Rectum ≥ 5 cm	30 (26.1)	26 (22.4)	
Rectum < 5 cm	6 (5.2)	9 (7.8)	
Other	0 (0)	1 (0.9)	
Benign diseases of the colorectum	26 (22.6)	19 (16.4)	
Presence of colostomy	7 (6.1)	5 (4.3)	
Others	1 (0.9)	6 (5.2)	
Neoadjuvant therapy			
Yes	21 (18.3)	21 (18.1)	1.0
No	94 (81.4)	95 (81.9)	
Type of surgery			
Right colectomy	24 (20.9)	34 (29.3)	0.108
Left colectomy	6 (5.2)	2 (1.7)	
Anterior resection	64 (55.7)	54 (46.6)	
Abdominoperineal resection	9 (7.8)	12 (10.3)	
Other colon resection	4 (3.5)	3 (2.6)	
Re-established intestinal continuity	8 (7.0)	6 (5.2)	
No bowel resection	0 (0)	5 (4.3)	
Type of access			
Open	90 (78.3)	79 (68.1)	0.102
Laparoscopic	25 (21.7)	37 (31.9)	
Duration of surgery (min)	141.5 ± 70.2	117.5 ± 53.3	< 0.05
Intraoperative fluids (ml)	2605.9 ± 970.9	1723.1 ± 690.0	< 0.05
Catheter level of insertion			
High (Th6-8)	48 (42.5)	45 (38.8)	0.294
Middle (Th9-12)	58 (51.3)	68 (58.6)	
Low (Th12-LWK3)	7 (6.2)	3 (2.6)	
Time to removal of urinary catheter	7.1 ± 13.9	1.0 ± 0	< 0.05

Frequency of urinary tract infection

In the ER group, 16 patients (13.9%) experienced an UTI, while in the CG, 35 patients (30.4%) suffered from a UTI. Pyuria was diagnosed in 14 (12.2%) and 22 (19.1%) patients in the ER and CG, respectively. Pyuria and positive urine culture were present in two (1.7%) in the ER and 13 (11.3%) patients in the CG. Antibiotic treatment for the indication 'urinary tract infection' was given to five patients (4.3%) in the ER and 21 patients (18.3%) in the CG (Table 2). These differences were highly significant. When patients of the CG and ER after rectal and colon surgery were compared separately, this significant reduction in UTIs was only observed in patients after rectal surgery. In patients who had undergone colon surgery in the ER, UTIs were significantly less frequently treated by antibiotics compared with patients after colon surgery in the CG.

Complications

Complications occurred in 38 patients (32.8%) in the ER and 42 patients (36.5%) in the CG. In the ER, 17 complications (14.7%) were classified as surgical and 21 (18.1%) as non-surgical complications. In the CG, 25 (21.7%) and 17 (14.8%) events were classified as surgical and non-surgical complications, respectively. There were no statistically significant differences between the two groups. In both groups, Clavian-Dindo Grade III complications were the most common. The distribution of the severity of complications according to the Clavian-Dindo-Classification did not differ significantly between both groups (Table 3).

Risk factors for urinary retention

To assess the relevance of previously published risk factors for UR in our patient group (early removal of UD under persistent EA), we evaluated the distribution of these items in patients of the ER with and without UR (Table 4). Among all items tested only male sex, rectal cancer, and abdominoperineal resection were significantly more common in patients with UR. Multivariate two-sample configural frequency analysis identified male patients who had undergone abdominoperineal resection as being at particular risk of UR (Table 5). Patients combining these two characteristics had a relative risk for developing UR of 10.5 (95% confidence interval 3.8–28.9).

In patients after rectal surgery, male sex, neoadjuvant therapy, and abdominoperineal resection were significantly more frequent in individuals developing POUR (Table 6). However, multivariat analysis was not performed due to the low number of patients in this subgroup.

Discussion

Values for the incidence of POUR vary considerably in the literature. POUR has been reported to occur in up to 41% of surgical patients after general anaesthesia [6]. On the other hand, the incidence of POUR was 2.1% in a mixed surgical population in a nationwide cohort from the United States. POUR occurred more frequently in patients undergoing knee,

Table 2 Frequency of catheter reinsertion, urinary tract infection, and antibiotic treatment (n = 231)

	Control group	Early removal (ER) group	p	Rectal surgery			Colon surgery		
				Control group	Early removal (ER) group	p	Control group	Early removal (ER) group	p
Reinsertion of urinary catheter									
Yes (%)	3 (2.6)	26 (22.4)	< 0.05	2 (2.5)	16 (22.2)	< 0.05	1 (2.9)	10 (22.7)	< 0.05
No (%)	112 (97.4)	90 (77.6)		79 (97.5)	56 (77.8)		33 (97.1)	34 (77.3)	
Motive for catheter reinsertion									
No reinsertion	112 (97.4)	90 (77.6)		79 (97.5)	56 (77.8)		33 (97.1)	34 (77.3)	
Urinary retention	3 (2.6)	9 (7.8)		2 (2.5)	7 (9.7)		1 (2.9)	2 (4.5)	
Patient complaints	0	3 (2.6)	<0.05	0	3 (4.2)	< 0.05	0	0	0.066
Monitoring of renal function	0	7 (6.0)		0	3 (4.2)		0	4 (9.1)	
Others	0	7 (6.0)		0	3 (4.2)		0	4 (9.1)	
Urinary tract infection									
Diagnosis									
None	80 (69.6)	100 (86.2)		59 (72.8)	63 (87.5)		21 (61.8)	37 (84.1)	
Pyuria	22 (19.1)	14 (12.1)	< 0.05	12 (14.8)	8 (11.1)	< 0.05	10 (29.4)	6 (13.6)	0.074
Positive urine culture	13 (11.3)	2 (1.7)		10 (12.3)	1 (1.4)		3 (8.8)	1 (2.3)	
Antibiotics for urinary tract infection									
Yes	21 (18.3)	5 (4.3)	< 0.05	14 (17.3)	3 (4.2)	< 0.05	7 (20.6)	2 (4.5)	< 0.05
No	95 (81.7)	111 (95.7)		67 (82.7)	69 (95.8)		27 (79.4)	42 (95.5)	

hip, or colorectal surgery compared with patients who had undergone vascular or cardiac surgery [24]. The large variation in reported incidences of POUR is due to the high heterogeneity of patient populations, the surgery performed, and the anaesthetic techniques applied. Among the anaesthetic techniques reported to favour POUR, EA is particularly prominent. However, EA has also been shown to have numerous beneficial effects on various postoperative outcome measures [25]. As a consequence, EA is an important element of many ERAS protocols. Given the potentially detrimental consequences of POUR [6, 26], it is currently clinical practice to leave the perioperative UD in place postoperatively until the EA has been discontinued. In several reviews, EA was found to be a significant risk factor for POUR [6, 27]. However, the patient populations considered were heterogeneous concerning the surgery performed. Moreover, doses of epidural anaesthetics and the type of epidural opioids varied greatly between the studies considered. The different locations of catheter insertion (lumbar versus thoracic) were not considered separately. In our opinion, this heterogeneity limits the generalizability of thoracic EA as a risk factor for POUR. George et al. found POUR to be as frequent in patients receiving thoracic EA as in patients with intravenous patient-controlled analgesia (PCA) after upper gastrointestinal surgery [28]. Only two of six recent studies of POUR after colorectal surgery identified EA as a risk factor [23, 29-33]. In our present study, we report a rate of POUR of 8.7% in the ER. This is within the range recently reported both in patients with (reported POUR incidence 9–27%) and without EA (reported POUR incidence 4.8–41%) after colorectal surgery [23,29-32,34-44]. These data suggest that EA itself may not significantly contribute to the risk of POUR after colorectal surgery.

In our present study, we demonstrate that early removal of the urinary catheter after colorectal surgery and under EA is associated with a higher POUR rate. Reported outcomes of early removal of the urinary catheter after colorectal surgery with and without EA are heterogeneous. In 1999, Benoist et al. had reported a higher incidence of POUR in patients after colorectal surgery but without EA when the UD was removed at the first postoperative day compared with the fifth postoperative day [38]. Kwaan et al. found that early removal of the UD after colorectal surgery resulted in a higher incidence of POUR independently of the presence of EA [30]. Stubbs et al. also found that the early removal of the UD was a risk factor for POUR [37]. In this study, the presence of EA was not a risk factor in the development of POUR. In contrast, Zmora et al. found no correlation between early urinary catheter removal and the incidence of POUR [29]. In a randomised setting, Patel et al. reported no difference between

Table 3 Postoperative complications ($n = 231$)

	Control group ($n = 115$)	Early removal (ER) group ($n = 116$)	p
Total complications			
Yes (%)	42 (36.5)	38 (32.8)	0.58
No (%)	73 (63.5)	78 (67.2)	
Clavien-Dindo classification			
Grade I (%)	9 (7.8)	11 (9.5)	0.72
Grade II (%)	5 (4.3)	8 (6.9)	
Grade III (%)	23 (20.0)	16 (13.8)	
Grade IV (%)	3 (2.6)	2 (1.7)	
Grade V (%)	2 (1.7)	1 (0.9)	
Type of complication			
Surgical (%)	25 (21.7)	17 (14.7)	0.34
Non-surgical (%)	17 (14.8)	21 (18.1)	

early and late UD removal after pelvic colorectal surgery. However, patients with EA were excluded from this study [40]. Yoo et al. also reported no difference between early and late removal of UD after excision for rectal cancer. The presence of EA was not reported in this study [41]. Finally, although the reported incidence of POUR after early (20%) and late (10%) removal of the UD differed considerably, Coyle et al. found a lack of statistical significance for this difference [36]. Our results identify early removal of the UD while the EA is still in place as being a risk factor in the development of POUR. However, in the majority of patients (77.6%) discontinuation of the UD at the first postoperative day while EA was still in place was successful.

Interestingly, we could show that the impact of early removal of UD on the occurrence of POUR while EA was still in place was particularly pronounced in rectal surgery patients, while there were no statistically significant differences in the incidence of POUR in colon surgery patients. This corresponds to the reported lower overall incidence of POUR in colon surgery patients compared with those who had undergone rectal procedures in a setting without EA [22].

Reported compliance with guidelines recommending early removal of UD after colorectal surgery is reported to be relatively low, ranging from 47.2% to 69.5% in colon and rectal surgery, respectively [33]. This probably indicates the conviction of healthcare workers that POUR is a frequent complication after colorectal surgery requiring prolonged UD. Although POUR only occurred in 7.8% of patients in the ER group, a urinary catheter was reinserted in a further 14.6% of patients. A considerable number of patients (6%) underwent re-catheterisation due to the absence of spontaneous voiding for longer time periods judged inadequate by the surgeon in charge. In these cases, pre-interventional bladder ultrasound was not performed, and urine volume after catheterisation was inferior to those defining POUR. Bladder ultrasound before re-catheterisation would have prevented the reinsertion of the transurethral catheter and favoured more appropriate measures to maintain diuresis, i.e., optimisation of the volume status. We think that conducting a bladder ultrasound before bladder re-catheterisation should be mandatory in order to prevent unnecessary invasive procedures that could potentially cause significant complications including CAUTI, urethral trauma and patient discomfort [45].

Though the incidence of catheter reinsertion and POUR was significantly higher in patients of the ER group, the results demonstrate a clear reduction of CAUTI in this group. Reported incidences of CAUTI after colorectal surgery vary widely. European data show CAUTI rates of up to 20% after one day of transurethral catheterisation [38]. More recent data from Israel show CAUTI rates of 12% after one day of transurethral catheterisation [29]. This surprisingly high incidence can increase up to 42% after five days of transurethral drainage [38]. In the United States, the American College of Surgeons' National Surgical Quality Improvement Program (NSQIP) was introduced to reduce postoperative complications including CAUTI, the incidences which varied from 2.5%–6.8% depending on the type of colorectal surgery [46]. These considerable differences may stem from different definitions of CAUTI used by the investigators. While the European data are based on microbiological analysis ($> 10^5$ colony forming units per millilitres, with or without clinical symptoms), the American investigators used the NSQIP definitions of CAUTI involving both microbiological and clinical criteria [46]. In our present study, we describe a CAUTI incidence of 13.8% in the ER and 30.4% in the CG. These values are lower than those reported by Benoist et al. [38], most probably due to the inclusion of clinical symptoms for the diagnosis of CAUTI in our study. In 2007, treatment of CAUTI generated total costs between $390–$450 million dollars per year in the USA [47]. By reducing the duration of postoperative UD, significant reductions in CAUTI-related healthcare costs could be achieved [48]. Moreover, the data in the present study clearly demonstrate that patients that had their urinary catheter removed early not only developed fewer UTIs but also required fewer episodes of antibiotic treatment for CAUTI. Antibiotic usage profoundly affects the pattern of local antibiotic resistance. Intensive usage of antibiotics appears to favour the development of resistant pathogens, while a cautious indication of antimicrobial treatment may positively influence the development of resistance [49]. Thus, early removal of transurethral catheters while EA is still in place may be an appropriate tool to safely reduce healthcare related morbidity and CAUTI-related

Table 4 Univariate analysis of risk factors for urinary retention in ER patients ($n = 99$)

	No urinary retention	Urinary retention	p
Age (years)	62.4 ± 12.0	64.6 ± 8.9	0.60
BMI (kg/m^2)	27.4 ± 5.5	29.3 ± 8.2	0.35
Gender			
Male (%)	38 (82.6)	8 (17.4)	0.01
Female (%)	52 (98.1)	1 (1.9)	
Medication			
Present (%)	42 (93.3)	3 (6.7)	0.51
Absent (%)	48 (88.9)	6 (11.1)	
Diabetes mellitus			
Yes (%)	17 (85.0)	3 (15.0)	0.38
No (%)	73 (92.4)	6 (7.6)	
Neurological disease			
Yes (%)	3 (75.0)	1 (25.0)	0.32
No (%)	87 (90.9)	8 (9.1)	
Previous pelvic surgery			
Yes (%)	43 (91.5)	4 (8.5)	1.00
No (%)	47 (90.4)	5 (9.6)	
Diagnosis			
Benign (%)	32 (97.0)	1 (3.0)	0.27
Malignant (%)	58 (87.9)	8 (12.1)	
Adenocarcinoma			
Right hemicolon (%)	25 (96.2)	1 (3.8)	< 0.05
Left hemicolon (%)	1 (100.0)	0 (0.0)	
Sigma (%)	15 (100.0)	0 (0.0)	
Rectum ≥ 5 cm (%)	18 (75.0)	6 (25.0)	
Rectum < 5 cm (%)	6 (85.7)	1 (14.3)	
Other (%)	0 (0.0)	1 (100.0)	
Benign diseases of the colorectum (%)	17 (100.0)	0 (0.0)	
Presence of colostomy (%)	4 (100.0)	0 (0.0)	
Others (%)	4 (100.0)	0 (0.0)	
Type of surgery			
Right colectomy (%)	28 (96.6)	1 (3.4)	< 0.05
Left colectomy (%)	1 (100.0)	0 (0.0)	
Anterior resection (%)	45 (93.8)	3 (6.2)	
Abdominoperineal resection (%)	6 (60.0)	4 (40.0)	
Other colon resection (%)	0 (0.0)	1 (100.0)	
Re-established intestinal continuity (%)	5 (100.0)	0 (0.0)	
No bowel resection (%)	5 (100)	0 (0.0)	
Surgical approach			
Laparoscopic (%)	33 (97.1)	1 (2.9)	0.16
Open (%)	57 (87.7)	8 (12.3)	
Duration of surgery (min)	118.0 ± 54.2	105.1 ± 42.2	0.49
Intraoperative fluids (ml)	1661.2 ± 630.9	2061.1 ± 969.5	0.09
Time to removal of UD (h)	18.4 ± 2.6	18.7 ± 2.4	0.87
Catheter level of insertion			
High (Th6-8) (%)	36 (97.3)	1 (2.7)	0.11
Middle (Th9-12) (%)	52 (88.1)	7 (11.9)	
Low (Th12-LWK3) (%)	2 (66.7)	1 (33.3)	

costs and could positively influence antibiotic use and the local spectrum of antibiotic resistance.

Although early removal of the UD was possible in the majority of our patients, the occurrence of POUR in 7.8% of

Table 5 Combined comparison of gender, diagnosis, and type of surgery between ER patients with and without urinary retention using multivariate two-sample configural frequency analysis

Gender	Type of surgery	Patients without urinary retention			Patients with urinary retention			Sum	
		n	Chi^2	*p*	*n*	Chi^2	*p*	Chi^2	*p*
Male	Re-established intestinal continuity	2	0.02	0.8927	0	0.18	0.6698	0.20	0.6547
Male	Anterior resection	20	0.04	0.8424	3	0.4	0.5295	0.44	0.5097
Male	Other colon resection	0	0.91	0.3404	1	9.09	0.0026	10.00	0.0016
Male	Abdominoperineal resection	3	1.78	0.1824	4	17.78	0.0000	19.56	< 0.0001
Male	Right colectomy	13	0.12	0.7310	0	1.18	0.2770	1.30	0.2542
Female	Re-established intestinal continuity	3	0.03	0.8688	0	0.27	0.6015	0.30	0.5839
Female	No bowel resection	5	0.05	0.8312	0	0.45	0.5002	0.50	0.4795
Female	Anterior resection	25	0.23	0.6336	0	2.27	0.1317	2.50	0.1138
Female	Abdominoperineal resection	3	0.03	0.8688	0	0.27	0.6015	0.30	0.5839
Female	Right colectomy	15	0.01	0.9051	1	0.14	0.7063	0.15	0.6926
Female	Left colectomy	1	0.01	0.9240	0	0.09	0.7630	0.10	0.7518

patients underlines the necessity to identify risk factors in the development of POUR after colorectal surgery and under EA. Ideally; the presence of these risk factors should trigger a close follow-up to detect the presence of POUR. This follow-up should not be limited to clinical evaluation, since up to 50% of patients with bladder volumes higher than 600 ml do not report symptoms of bladder fullness, even in the absence of EA [50, 51]. At least for the spinal application of high-dose local anaesthetics, it has been shown that the sensation of urgency to void is strongly impaired, making the clinical complaints of the patients an unreliable marker for the presence of POUR [52]. Thus, assessment of bladder volume by ultrasound should be favoured in order to screen for the presence of POUR in patients after colorectal surgery and under EA. The best timepoint for ultrasound screening remains to be determined. Hu et al. proposed an interval of 8 h postoperatively [53]. Other authors practiced a 3-hourly interval to screen bladder volume but did not report the timepoint when re-catheterisation for POUR occurred [54, 55]. In our study, patients voided spontaneously after 5.3 ± 5.0 h. In those patients who experienced UR, the catheter was reinserted 15.9 ± 8.9 h after the initial removal of UD, suggesting an interval of 6 to 8 h for the first ultrasound screening in case of failure to void. The presence of risk factors for POUR may help to identify patients in need of a denser screening. Numerous risk factors for POUR after colorectal surgery have been described (for review see [6], but also [30, 31, 34, 36, 37]. In our present study, we could confirm that male sex, rectal cancer, and certain types of colorectal surgery were significantly more frequent in patients with POUR. Interestingly, all patients who developed POUR after abdominoperineal resection were male. Multivariate analysis identified male patients after abdominoperineal resection as being a particularly high-risk group for POUR. Therefore, early removal of the UD should be undertaken only with caution and under close monitoring for adequate and timely voiding.

In patients after rectal surgery, POUR was significantly more frequent in patients after neoadjuvant therapy. Although a population-based study showed clearly that the frequency of adverse urinary events after radiotherapy significantly increased [56], many other investigators did not report neoadjuvant therapy as being a risk factor for UR after colorectal surgery [23, 30, 31, 34, 35, 41]. We cannot, however, exclude the possibility that the administration of neoadjuvant therapy simply reflects the presence of more advanced states of rectal cancer in our patient cohort.

A major limitation of our study was its non-randomised design which is associated with a high risk of bias. During the different periods of data acquisition (ER: April 2015 until September 2016; CG: October 2013 and March 2015) anaesthesiological policies changed in favour of a more restrictive perioperative fluid management protocol leading to significantly lower perioperative fluid volumes in the CG. In addition, laparoscopic techniques and the laparoscopic experience of the surgeons developed during this period, resulting in a non-significant increase in the frequency of laparoscopic procedures and significantly reduced operating times in the EG. Although no significant differences occurred concerning the type of surgery performed, some operations, such as anterior resections, showed a tendency to be performed more frequently in the ER. This may be problematic since rectal surgery appears to result in higher incidences of UR than colon surgery [22, 23]. Other limitations included a relatively small sample size and the single institution setting. A further potential limitation of our study is the lack of data on post-void residuals (PVR) after spontaneous micturition after urinary catheter removal which could vary between CG and ER. However, Zaouter et al. showed in a mixed patient population that although PVR was initially higher and time to reach normal PVR in ER patients was significantly longer, all patients finally reached normal PVRs and did not require further

Table 6 Univariate analysis of risk factors for urinary retention in ER patients undergoing rectal surgery ($n = 63$)

	No urinary retention	Urinary retention	p
Age (years)	60.1 ± 11.5	65.6 ± 6.0	0.23
BMI (kg/m^2)	27.6 ± 4.8	30.3 ± 9.2	0.21
Gender			
Male (%)	25 (78.1)	7 (21.9)	< 0.05
Female (%)	31 (100)	0 (0.0)	
Medication			
Present (%)	28 (93.3)	2 (6.7)	0.44
Absent (%)	28 (84.8)	5 (15.2)	
Diabetes mellitus			
Yes (%)	9 (75.0)	3 (25.0)	0.12
No (%)	47 (92.2)	4 (7.8)	
Neurological disease			
Yes (%)	1 (50.0)	1 (50.0)	0.21
No (%)	55 (90.2)	6 (9.8)	
Previous pelvic surgery			
yes (%)	24 (88.9)	3 (11.1)	1.00
no (%)	32 (88.9)	4 (11.1)	
Neoadjuvant therapy			
Yes (%)	14 (70.0)	6 (30.0)	< 0.05
No (%)	42 (97.7)	1 (2.3)	
Diagnosis			
Benign (%)	18 (100.0)	0 (0.0)	0.18
Malignant (%)	38 (84.4)	7 (15.6)	
Adenocarcinoma			0.07
Sigma (%)	15 (100.0)	0 (0.0)	
Rectum ≥ 5 cm (%)	18 (75.0)	6 (25.0)	
Rectum < 5 cm (%)	6 (85.7)	1 (14.3)	
Benign diseases of the rectum (%)	13 (100.0)	0 (0.0)	
Presence of colostomy (%)	4 (100.0)	0 (0.0)	
Type of surgery			
Anterior resection (%)	45 (93.8)	3 (6.2)	< 0.05
Abdominoperineal resection (%)	6 (60.0)	4 (40.0)	
Re-established intestinal continuity (%)	5 (100.0)	0 (0)	
Surgical approach			
Laparoscopic (%)	28 (96.6)	1 (3.4)	0.11
Open (%)	28 (82.4)	6 (17.6)	
Duration of surgery (min)	126.0 ± 57.7	111.9 ± 43.0	0.54
Intraoperative fluids (ml)	1600.8 ± 588.5	2042.9 ± 1116.3	0.10
Time to removal of UD (h)	18.5 ± 2.6	18.7 ± 2.1	0.80
Catheter level of insertion			
High (Th6-8) (%)	20 (100)	0 (0)	0.10
Middle (Th9-12) (%)	34 (85.0)	6 (15.0)	
Low (Th12-LWK3) (%)	2 (66.7)	1 (33.3)	

therapy [55]. This confirms further reports that after a longer follow-up time, the voiding functions of the bladder after early removal of UD under EA returned to normal [7].

Conclusion

Our present data show that early removal of the UD after colorectal surgery and while EA is still in place is feasible. This approach may constitute an appropriate way to safely reduce CAUTI-related morbidity and ensuing costs and could positively influence antibiotic use and the local spectrum of antibiotic resistance. However, given the increased incidence of POUR, ultrasound screening must be used to identify patients developing this complication. Particularly in male patients after abdominoperineal resection, early removal of UD should not be practised or should only be attempted under close monitoring since this group has a significantly increased risk of developing POUR.

Author contributions André Schreiber: conception of the work, interpretation of the data, revising the manuscript for important intellectual content. Emine Aydil: conception of the work, data acquisition, revising the manuscript for important intellectual content. Uwe Walschus: analysis, interpretation of the data, revising the manuscript for important intellectual content. Anne Glitsch: data acquisition, revising the manuscript for important intellectual content. Maciej Patrzyk: data acquisition, revising the manuscript for important intellectual content. Claus-Dieter Heidecke: conception of the work, revising the manuscript for important intellectual content. Tobias Schulze: conception of the work, data acquisition, analysis, interpretation of the data, drafting the work. All authors listed above approved the version submitted and agree to be accountable for all aspects of the work. In addition, they will ensure that questions regarding the accuracy and integrity of any part of the work are appropriately investigated and resolved.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethical Committee of the Universitätsmedizin Greifswald (reference number: BB075/16)

References

1. Greco M, Capretti G, Beretta L, Gemma M, Pecorelli N, Braga M (2014) Enhanced recovery program in colorectal surgery: a meta-analysis of randomized controlled trials. World J Surg 38(6):1531–1541
2. Zhuang CL, Ye XZ, Zhang XD, Chen BC, Yu Z (2013) Enhanced recovery after surgery programs versus traditional care for colorectal surgery: a meta-analysis of randomized controlled trials. Dis Colon Rectum 56(5):667–678
3. Ahmed J, Khan S, Lim M, Chandrasekaran TV, MacFie J (2011) Enhanced recovery after surgery protocols - compliance and variations in practice during routine colorectal surgery. Colorectal Dis 14(9):1045–1051
4. Khan SA, Khokhar HA, Nasr AR, Carton E, El-Masry S (2013) Effect of epidural analgesia on bowel function in laparoscopic colorectal surgery: a systematic review and meta-analysis. Surg Endosc 27(7):2581–2591
5. Marret E, Remy C, Bonnet F (2007) Meta-analysis of epidural analgesia versus parenteral opioid analgesia after colorectal surgery. Br J Surg 94(6):665–673
6. Baldini G, Bagry H, Aprikian A, Carli F (2009) Postoperative urinary retention: anesthetic and perioperative considerations. Anesthesiology 110(5):1139–1157
7. Basse L, Werner M, Kehlet H (2000) Is urinary drainage necessary during continuous epidural analgesia after colonic resection? Reg Anesth Pain Med 25(5):498–501

8. Hilton P (1988) Bladder drainage: a survey of practices among gynaecologists in the British Isles. Br J Obstet Gynaecol 95(11): 1178–1189
9. Stamm WE (1991) Catheter-associated urinary tract infections: epidemiology, pathogenesis, and prevention. Am J Med. 91(3B):65S–71S
10. Warren JW (1991) The catheter and urinary tract infection. Med Clin North Am 75(2):481–493
11. Crouzet J, Bertrand X, Venier AG, Badoz M, Husson C, Talon D (2007) Control of the duration of urinary catheterization: impact on catheter-associated urinary tract infection. J Hosp Infect 67(3):253–257
12. Wald HL, Ma A, Bratzler DW, Kramer AM (2008) Indwelling urinary catheter use in the postoperative period: analysis of the national surgical infection prevention project data. Arch Surg 143(6):551–557
13. McPhail MJ, Abu-Hilal M, Johnson CD (2006) A meta-analysis comparing suprapubic and transurethral catheterization for bladder drainage after abdominal surgery. Br J Surg 93(9):1038–1044
14. Tan GW, Chan SP, Ho CK (2010) Is transurethral catheterisation the ideal method of bladder drainage? A survey of patient satisfaction with indwelling transurethral urinary catheters. Asian J Surg 33(1): 31–36
15. Ahmed MR, Sayed Ahmed WA, Atwa KA, Metwally L (2014) Timing of urinary catheter removal after uncomplicated total abdominal hysterectomy: a prospective randomized trial. Eur J Obstet Gynecol Reprod Biol 176:60–63
16. Gustafsson UO, Scott MJ, Schwenk W, Demartines N, Roulin D, Francis N, McNaught CE, Macfie J, Liberman AS, Soop M, Hill A, Kennedy RH, Lobo DN, Fearon K, Ljungqvist O (2013) Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS((R))) Society recommendations. World J Surg 37(2):259–284
17. Alfonsi P, Slim K, Chauvin M, Mariani P, Faucheron JL, Fletcher D (2014) French guidelines for enhanced recovery after elective colorectal surgery. J Visc Surg 151(1):65–79
18. Gould CV, Umscheid CA, Agarwal RK, Kuntz G, Pegues DA (2010) Guideline for prevention of catheter-associated urinary tract infections 2009. Infect Control Hosp Epidemiol 31(4):319–326
19. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) (2015) Prävention und Kontrolle Katheter-assoziierter Harnwegsinfektionen. Bundesgesundheitsbl 58(6):641–650
20. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM (1988) CDC definitions for nosocomial infections, 1988. Am J Infect Control 16(3):128–140
21. Horan TC, Andrus M, Dudeck MA (2008) CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. Am J Infect Control 36(5):309–332
22. Changchien CR, Yeh CY, Huang ST, Hsieh ML, Chen JS, Tang R (2007) Postoperative urinary retention after primary colorectal cancer resection via laparotomy: a prospective study of 2,355 consecutive patients. Dis Colon Rectum. 50(10):1688–1696
23. Ghuman A, Kasteel N, Karimuddin AA, Brown CJ, Raval MJ, Phang PT (2018) Urinary retention in early urinary catheter removal after colorectal surgery. Am J Surg 215(5):949–952
24. Wu AK, Auerbach AD, Aaronson DS (2012) National incidence and outcomes of postoperative urinary retention in the Surgical Care Improvement Project. Am J Surg 204(2):167–171
25. Popping DM, Elia N, Van Aken HK, Marret E, Schug SA, Kranke P, Wenk M, Tramer MR (2014) Impact of epidural analgesia on mortality and morbidity after surgery: systematic review and meta-analysis of randomized controlled trials. Ann Surg 259(6): 1056–1067
26. Saito M, Shimizu S, Kinoshita Y, Satoh I, Shomori K, Dimitriadis F, Satoh K (2010) Bladder dysfunction after acute urinary retention in the rats: a novel over active bladder model. Mol Cell Biochem 333(1-2):109–114
27. Dolin SJ, Cashman JN (2005) Tolerability of acute postoperative pain management: nausea, vomiting, sedation, pruritus, and urinary retention. Evidence from published data. Br J Anaesth 95(5):584–591
28. George KA, Wright PM, Chisakuta AM, Rao NV (1994) Thoracic epidural analgesia compared with patient controlled intravenous morphine after upper abdominal surgery. Acta Anaesthesiol Scand 38(8):808–812
29. Zmora O, Madbouly K, Tulchinsky H, Hussein A, Khaikin M (2010) Urinary bladder catheter drainage following pelvic surgery–is it necessary for that long? Dis Colon Rectum 53(3): 321–326
30. Kwaan MR, Lee JT, Rothenberger DA, Melton GB, Madoff RD (2015) Early removal of urinary catheters after rectal surgery is associated with increased urinary retention. Dis Colon Rectum 58(4):401–405
31. Grass F, Slieker J, Frauche P, Sola J, Blanc C, Demartines N, Hubner M (2017) Postoperative urinary retention in colorectal surgery within an enhanced recovery pathway. J Surg Res 207:70–76
32. Duchalais E, Larson DW, Machairas N, Mathis KL, Dozois EJ, Kelley SR (2019) Outcomes of early removal of urinary catheter following rectal resection for cancer. Ann Surg Oncol 26(1):79–85
33. Okrainec A, Aarts MA, Conn LG, McCluskey S, McKenzie M, Pearsall EA, Rotstein O, Victor JC, McLeod RS (2017) Compliance with urinary catheter removal guidelines leads to improved outcome in enhanced recovery after surgery patients. J Gastrointest Surg 21(8):1309–1317
34. Kin C, Rhoads KF, Jalali M, Shelton AA, Welton ML (2013) Predictors of postoperative urinary retention after colorectal surgery. Dis Colon Rectum 56(6):738–746
35. Lee SY, Kang SB, Kim DW, Oh HK, Ihn MH (2015) Risk factors and preventive measures for acute urinary retention after rectal cancer surgery. World J Surg 39(1):275–282
36. Coyle D, Joyce KM, Garvin JT, Regan M, McAnena OJ, Neary PM, Joyce MR (2015) Early post-operative removal of urethral catheter in patients undergoing colorectal surgery with epidural analgesia - a prospective pilot clinical study. Int J Surg 16(Pt A):94–98
37. Stubbs BM, Badcock KJ, Hyams C, Rizal FE, Warren S, Francis D (2013) A prospective study of early removal of the urethral catheter after colorectal surgery in patients having epidural analgesia as part of the Enhanced Recovery After Surgery programme. Colorectal Dis 15(6):733–736
38. Benoist S, Panis Y, Denet C, Mauvais F, Mariani P, Valleur P (1999) Optimal duration of urinary drainage after rectal resection: a randomized controlled trial. Surgery 125(2):135–141
39. Hayami S, Ueno M, Kawai M, Kuriyama T, Kawamata T, Yamaue H (2018) Optimal timing of removal of epidural and urethral catheters to avoid postoperative urinary retention undergoing abdominal surgery. Dig Surg 26:1–5
40. Patel DN, Felder SI, Luu M, Daskivich TJ (2018) K NZ, Fleshner P. Early urinary catheter removal following pelvic colorectal surgery: a prospective, randomized, noninferiority trial. Dis Colon Rectum 61(10):1180–1186
41. Yoo BE, Kye BH, Kim HJ, Kim G, Kim JG, Cho HM (2015) Early removal of the urinary catheter after total or tumor-specific mesorectal excision for rectal cancer is safe. Dis Colon Rectum 58(7):686–691
42. Eriksen JR, Munk-Madsen P, Kehlet H, Gogenur I (2019) Postoperative urinary retention after laparoscopic colorectal resection with early catheter removal: a prospective observational study. World J Surg 43(8):2090–2098
43. Hoppe EJ, Main WP, Kelley SR, Hussain LR, Dunki-Jacobs EM, Saba AK (2017) Urinary retention following colorectal surgery. Am 83(1):3–7

44. Alyami M, Lundberg P, Passot G, Glehen O, Cotte E (2016) Laparoscopic colonic resection without urinary drainage: is it "feasible"? J Gastrointest Surg 20(7):1388–1392
45. Tammela T, Kontturi M, Lukkarinen O (1986) Postoperative urinary retention. I. Incidence and predisposing factors. Scand J Urol Nephrol 20(3):197–201
46. Regenbogen SE, Read TE, Roberts PL, Marcello PW, Schoetz DJ, Ricciardi R (2011) Urinary tract infection after colon and rectal resections: more common than predicted by risk-adjustment models. J Am Coll Surg 213(6):784–792
47. Scott RD. The direct medical costs of healthcare-associated infections in US hospitals and the benefits of prevention. US Centers for Disease Control and Prevention Web site. Published 2009; (Available at: http://www.cdc.gov/HAI/pdfs/hai/Scott_CostPaper.pdf): Accessed December 14, 2017.
48. Kennedy EH, Greene MT, Saint S (2013) Estimating hospital costs of catheter-associated urinary tract infection. J Hosp Med 8(9):519–522
49. Patrick DM, Hutchinson J (2009) Antibiotic use and population ecology: how you can reduce your "resistance footprint". CMAJ 180(4):416–421
50. Stallard S, Prescott S (1988) Postoperative urinary retention in general surgical patients. Br J Surg 75(11):1141–1143
51. Pavlin DJ, Pavlin EG, Fitzgibbon DR, Koerschgen ME, Plitt TM (1999) Management of bladder function after outpatient surgery. Anesthesiology 91(1):42–50
52. Kamphuis ET, Ionescu TI, Kuipers PW, de Gier J, van Venrooij GE, Boon TA (1998) Recovery of storage and emptying functions of the urinary bladder after spinal anesthesia with lidocaine and with bupivacaine in men. Anesthesiology 88(2):310–316
53. Hu Y, Craig SJ, Rowlingson JC, Morton SP, Thomas CJ, Persinger MB, Isbell J, Lau CL, Kozower BD (2014) Early removal of urinary catheter after surgery requiring thoracic epidural: a prospective trial. J Cardiothorac Vasc Anesth 28(5):1302–1306
54. Zaouter C, Kaneva P, Carli F (2009) Less urinary tract infection by earlier removal of bladder catheter in surgical patients receiving thoracic epidural analgesia. Reg Anesth Pain Med 34(6):542–548
55. Zaouter C, Wuethrich P, Miccoli M, Carli F (2012) Early removal of urinary catheter leads to greater post-void residuals in patients with thoracic epidural. Acta Anaesthesiol Scand 56(8):1020–1025
56. Kwaan MR, Fan Y, Jarosek S, Elliott SP (2017) Long-term risk of urinary adverse events in curatively treated patients with rectal cancer: a population-based analysis. Dis Colon Rectum 60(7):682–690