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Preoperative Dehydration Increases Risk of Postoperative Acute Renal Failure in Colon and Rectal Surgery

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Abstract

Objectives There is limited data regarding the effects of preoperative dehydration on postoperative renal function. We sought to identify associations between hydration status before operation and postoperative acute renal failure (ARF) in patients undergoing colorectal resection.

Methods The NSQIP database was used to examine the data of patients undergoing colorectal resection from 2005 to 2011. We used preoperative blood urea nitrogen (BUN)/creatinine ratio >20 as a marker of relative dehydration. Multivariate analysis using logistic regression was performed to quantify the association of BUN/Cr ratio with ARF.

Results We sampled 27,860 patients who underwent colorectal resection. Patients with dehydration had higher risk of ARF compared to patients with BUN/Cr <10 (AOR, 1.23; $P=0.04$). Dehydration was associated with an increase in mortality of the affected patients (AOR, 2.19; $P<0.01$). Postoperative complication of myocardial infarction (MI) (AOR, 1.46; $P<0.01$) and cardiac arrest (AOR, 1.39; $P<0.01$) was higher in dehydrated patients. Open colorectal procedures (AOR, 2.67; $P=0.01$) and total colectomy procedure (AOR, 1.62; $P<0.01$) had associations with ARF.

Conclusion Dehydration before operation is a common condition in colorectal surgery (incidence of 27.7 %). Preoperative dehydration is associated with increased rates of postoperative ARF, MI, and cardiac arrest. Hydrotherapy of patients with dehydration may decrease postoperative complications in colorectal surgery.

Introduction

Postoperative acute renal failure (ARF) is associated with increased morbidity and cost, prolonged hospital stay, and greater than 50 % mortality rate in colorectal surgery.^{1,2} It is important to identify risk factors associated with postoperative ARF and potentially employ risk reduction strategies in an effort to reduce the risk of ARF. A number of previous studies have identified risk factors influencing ARF rates in surgical patients. Some of the ARF predictors include liver disease, congestive heart failure, alcohol abuse, and obesity.¹ There is limited information regarding the association between preoperative hydration status and postoperative ARF.

Preoperative fluid administration with the goal of correcting dehydration and decreasing postoperative complications has been an area of investigation in the literature, as has the concept of goal-directed therapy.^{3,4} Although some studies report that postoperative nausea, dizziness, and hospital stay are significantly lower in patients with preoperative hydrotherapy,^{3–5} there is limited data about more serious postoperative complications such as ARF. Also, previous studies had limited information about the hydration status of their patients undergoing surgery, and most of them are limited in

their conclusions due to the small size of the index population. A study of the association between preoperative hydration status and development of postoperative ARF is lacking.

BUN/Cr ratio has been previously introduced as a marker of relative dehydration.^{6–8} It can estimate the hydration status of patients and help determine the type of azotemia in patients with renal dysfunction and predict mortality of hospitalized patients.^{3,4,6–8} In considering BUN/Cr ratio as a relative marker of hydration status, we aim to report the association between preoperative dehydration and ARF in patients undergoing colorectal resection.

Materials and Methods

This study was performed utilizing the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database from January 1, 2005 to December 31, 2011. ACS NSQIP is a nationally validated, risk-adjusted, outcome-based program to measure and improve the quality of surgical care in the USA.⁹ ACS NSQIP provides preoperative to 30-day postoperative surgical outcomes based on clinical data. We looked at patients who had undergone colorectal resections for the diagnosis of benign or malignant colorectal tumor, diverticular diseases, and ulcerative colitis using the appropriate procedural and diagnosis codes as specified by the International Classification of Diseases, 9th Revision, clinical modifications (ICD-9-CM). Patients who had colorectal procedures were defined based on the following Current Procedural Terminology (CPT) codes: 44140–44160, 44204–44212, 45110, and 45395. Patients who underwent colorectal surgery without colon or rectal resection, patients younger than 18 years, patients with preoperative serum creatinine level ≥ 1.5 mg/dL, patients with preoperative acute renal failure (ARF), patients who need preoperative dialysis, and patients who did not have preoperative laboratory biochemical parameters of blood urea nitrogen (BUN) and creatinine on the surgery day were excluded from the study (Fig. 1). Patients' diagnosis was defined based on the following ICD-9 codes: malignant neoplasm of colon and rectum (153.0–153.9, 154.0, 154.1, 230.3, and 230.4), benign neoplasm of colon and rectum (211.3 and 211.4), diverticulosis or diverticulitis (562.10–562.13), Crohn's disease (555.0, 555.1, 555.2, and 555.9), and ulcerative colitis (556.0–556.9). We used the ratio of blood urea nitrogen (BUN, mg/dl) over serum creatinine level (Cr, mg/dl) as a marker of relative dehydration in line with the literature.^{6,7} Considering BUN/Cr lower than 10 and more than 20 as the normal level and prerenal azotemia conditions, respectively, in line with the literature^{6,7}, we divided the patients into three groups: group A (patients who had preoperative BUN/Cr < 10), group B (patients who had preoperative $10 \leq \text{BUN/Cr} \leq 20$), and group C (patients who had preoperative BUN/Cr > 20). Postoperative renal function complications of groups B and C were compared with group A.

Preoperative factors that were analyzed include patient characteristics (age, sex, and race) and nine comorbidity conditions including hypertension, diabetes, congestive heart failure (CHF) within 30 days before surgery, myocardial infarction (MI) within 6 months before surgery, ascites, obesity (body mass index ≥ 30), history of severe chronic obstructive pulmonary disease (COPD), alcohol abuse (more than two drinks per day in

the 2 weeks before admission), and cardiac angina. Other factors analyzed include chemotherapy for malignancy in the last 30 days before operation, radiotherapy for malignancy within the last 90 days before operation, need for preoperative transfusion more than 4 units, length of hospitalization, postoperative acute renal failure (ARF), pathologic conditions (colorectal cancer, diverticulosis or diverticulitis, ulcerative colitis, Crohn's disease, and benign colorectal tumor), surgical procedures (total colectomy, partial colectomy, and abdominoperineal resection [APR]), admission type (emergent vs. non-emergent), and surgical techniques (laparoscopic vs. open). The overall rate of postoperative ARF and the rate of postoperative acute renal complications by pathologic condition and procedure type were examined. Risk-adjusted analysis was performed to identify independent predictors of postoperative ARF following colorectal surgery. Female gender, age <70 years, and benign colorectal tumor were used as reference data points for comparison in line with the literature.^{1,10,11}

Statistical Analysis

Statistical analysis was performed with SPSS® software, Version 19 (SPSS Inc., Chicago, IL). Logistic regression was used for comparing groups B and C patients with group A patients regarding postoperative ARF. Also, logistic regression was used to describe the weights assigned to preoperative and intraoperative variables that best discriminate patients with postoperative ARF from those without. For each variable, the adjusted odds ratio (AOR) with a 95 % confidence interval was calculated and reported to estimate the relative risk associated with postoperative ARF. P values less than 0.05 were considered statistically significant. Adjustments were made for age, sex, race, hypertension, diabetes, CHF, COPD, preoperative MI, cardiac angina, weight loss, ascites, obesity (body mass index ≥ 30), alcohol abuse, need for preoperative transfusion more than 4 units, radiotherapy, chemotherapy, type of the procedure, patient's pathology, surgical technique (open vs. laparoscopic), and admission type (emergent vs. non-emergent).

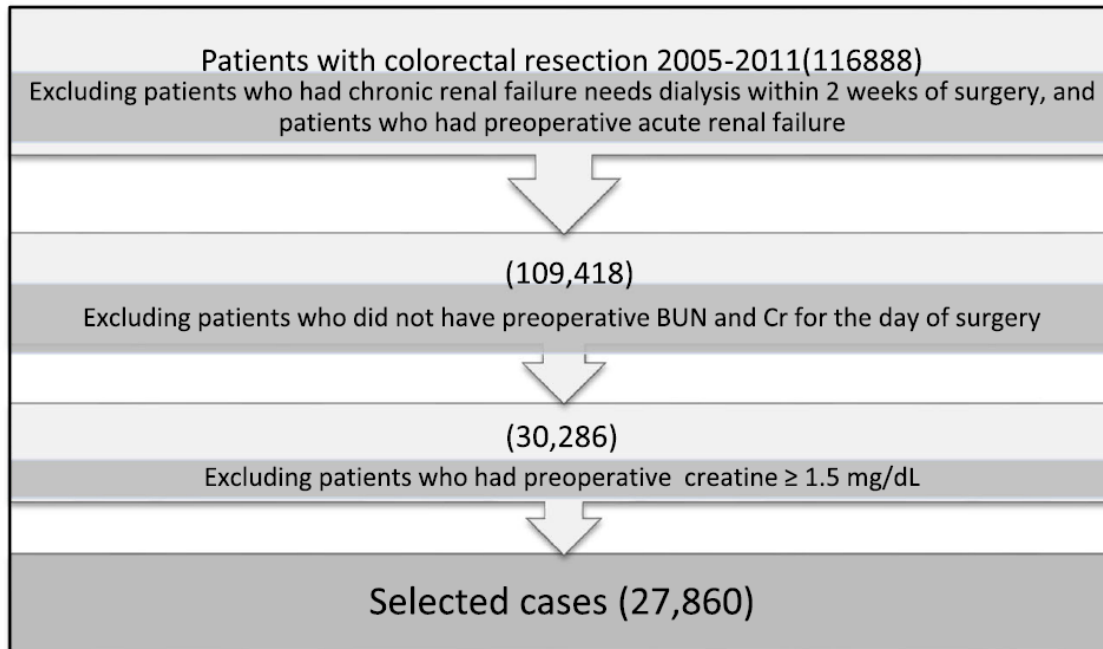


Fig. 1 Inclusion and exclusion criteria in case selection for the study

Results

We sampled 27,860 patients who underwent colorectal resection from 2005 to 2011. The mean age of patients was 62 ± 16 years; the majority of the patients were Caucasian (85.2 %) and female (53.9 %). Demographic data of patients are reported in Table 1.

Of the patients sampled, 6478 (23.3 %) had $BUN/Cr < 10$, 13,807 (49.6 %) had $10 \leq BUN/Cr \leq 20$, and 7575 (27.7 %) of the patients had $BUN/Cr > 20$ before operation. In total, 290 (1 %) patients had postoperative acute renal failure (ARF). After multivariate analysis of the data, we found that group C patients had higher risk of ARF compared to group A; however, there was no significant difference in rates of ARF between groups A and B patients (Table 2).

Rates of ARF of patients are reported by BUN/Cr ratio in Fig. 2. The lowest ARF rate occurred at BUN/Cr ratio levels lower than 2 (0 %) and the highest ARF rate occurred at BUN/Cr ratio level higher than 45 (2.3 %). In a multivariate analysis of the BUN/Cr cutoff points, the highest increase in the rate of ARF (the highest adjusted odd ratio) exists at the cutoff point of 23 (AOR, 1.58; CI, 1.14–2.19; $P < 0.01$). For patients with $BUN/Cr > 20$, the median length of stay in the hospital was 13 days, while for patients with $BUN/Cr < 10$, it was 10 days.

The adjusted mean difference in hospitalization was 2 days (CI, 2.04–2.60; $P < 0.01$). The unadjusted mortality rate in patients with $BUN/Cr > 20$ and $BUN/Cr < 10$ was 12.4 and 2.5 %, respectively, while the adjusted risk of mortality in patients with $BUN/Cr > 20$ was higher than patients without dehydration ($BUN/Cr < 10$) (AOR, 1.67; CI, 1.50–1.84, $P < 0.01$).

Table 3 reports the associations between preoperative and intraoperative factors and ARF. Factors such as open surgery, emergency admission, dehydration (BUN/Cr

>20), etc. are shown to significantly discriminate between patients with and without ARF. Also, the total colectomy procedure has higher risk of ARF compared to partial colectomy procedure. However, there was no significant association between the patients' pathologic conditions and postoperative ARF.

Table 4 reports the risk-adjusted analysis for postsurgical complications associated with dehydration (BUN/Cr >20). The comparison of patients who had dehydration (BUN/Cr >20) with patients without dehydration (BUN/Cr ≤20) shows the in-hospital mortality rate (AOR, 2.19; P<0.01), postoperative cardiac arrest (AOR, 1.39; P<0.01), MI (AOR, 1.46; P<0.01), and ARF (AOR, 1.32; P=0.01) have associations with dehydration (Table 4).

Finally, Table 5 estimates the increased risk of postoperative ARF associated with the presence of multiple risk factors in colorectal surgery. For example, dehydrated patients who were admitted emergently with one of the comorbidities of diabetes, obesity, COPD, or alcohol abuse and who underwent open colorectal resection had approximately 11 times increased risk of postoperative ARF.

Table 1 Demographics of patients who underwent colon and rectal surgery in the USA, NSQIP 2005–2011

Factors		Patients without acute renal failure (27,570)	Patients with acute renal failure (290)	P value	Odd ratio and 95 % CI
Age	Mean, year	62	67	–	–
	Median, year	64	68	–	–
Sex	Male	12,678 (46.1 %)	148 (51.2 %)	0.08	1.22 (0.97–1.54)
Race	White	21,360 (85.2 %)	202 (79.8 %)	0.01	0.68 (0.50–0.93)
	African-American	2740 (10.9 %)	40 (15.8 %)	0.01	1.53 (1.08–2.14)
	Asian	545 (2.2 %)	3 (1.2 %)	0.28	0.54 (0.17–1.69)
	Other	416 (1.7 %)	8 (3.2 %)	0.06	1.93 (0.95–3.93)
Admission	Emergency	9786 (35.5 %)	166 (57.2 %)	<0.01	2.43 (1.92–3.07)
Comorbidity	Hypertension	14,026 (50.9 %)	191 (65.9 %)	<0.01	1.86 (1.46–2.37)
	Diabetes	4134 (15 %)	81 (27.9 %)	<0.01	2.19 (1.69–2.84)
	Body Mass Index ≥30	7639 (28.2 %)	113 (39.6 %)	<0.01	1.66 (1.31–2.11)
	Severe COPD	2450 (8.9 %)	60 (20.7 %)	<0.01	2.67 (2.00–3.56)
	Ascites	1086 (3.9 %)	22 (7.6 %)	<0.01	2.00 (1.29–3.10)
	Alcohol abuse	1023 (4.2 %)	20 (7.6 %)	<0.01	1.87 (1.18–2.97)
	MI (in the last 30 days)	296 (1.2 %)	8 (3.1 %)	<0.01	2.54 (1.24–5.19)
	Cardiac angina	252 (1 %)	7 (2.7 %)	0.01	2.61 (1.22–5.59)
	Congestive heart failure	602 (2.2 %)	18 (6.2 %)	<0.01	2.96 (1.82–4.80)
	Surgical technique	Open procedures	21,159 (76.7 %)	268 (92.4 %)	<0.01
Laparoscopic		6,606 (24 %)	24 (8.3 %)	<0.01	0.28 (0.18–0.43)
Procedure	Partial colectomy	24,292 (88.1 %)	239 (82.4 %)	<0.01	0.63 (0.46–0.85)
	Total colectomy	2,792 (10.1 %)	50 (17.2 %)	<0.01	1.84 (1.36–2.51)
	APR	534 (1.9 %)	3 (1 %)	0.26	0.52 (0.16–1.65)
Pathology	Colorectal cancer	7,140 (46.4 %)	60 (53.1 %)	0.15	1.31 (0.90–1.89)
	Diverticulitis	5,844 (37.9 %)	39 (34.5 %)	0.45	0.86 (0.58–1.27)
	Benign colorectal tumor	1,100 (7.1 %)	4 (3.5)	0.13	0.47 (0.17–1.29)
	Ulcerative colitis	886 (5.9 %)	8 (7.1 %)	0.54	1.24 (0.60–2.57)
	Crohn's disease	434 (2.8 %)	2 (1.8 %)	0.50	0.62 (0.15–2.52)
Other factors	Preoperative transfusion more than 4 units	1,254 (4.5 %)	24 (8.3 %)	<0.01	1.89 (1.24–2.88)
	Chemotherapy (in the last 30 days)	740 (3.1 %)	6 (2.3 %)	0.47	0.74 (0.33–1.67)
	Radiotherapy (in the last 90 days)	539 (2.2 %)	2 (0.8 %)	0.10	0.33 (0.08–1.36)

COPD chronic obstructive pulmonary disease, *MI* myocardial infarction, *APR* abdominoperineal resection of rectum

Discussion

Our data shows that preoperative dehydration increases postoperative complications in colorectal surgery. BUN/Cr ratio has been introduced as a sensitive marker for predicting the degree of dehydration.^{12,13} According to our results, BUN/Cr ratio with a cutoff point of 20 can be used as a marker to predict the risks of postoperative mortality, postoperative MI, cardiac arrest, prolonged hospitalization, and ARF in colorectal surgery. This is in line with earlier findings of BUN and BUN/Cr ratio as markers of increased mortality in hospitalized patients.^{11,14,15} Also, our finding of higher rate of prolonged hospitalization in patients with BUN/Cr >20 is consistent with the previously reported decrease in length of stay of patients treated with preoperative hydration by Holter.⁵ Using the BUN/Cr ratio as a marker for estimating the hydration condition and predicting postoperative ARF and mortality of patients undergoing colorectal surgery are supported by this study.

Preoperative dehydration is a common condition in colorectal patients. Our results show that dehydration (BUN/Cr >20) has a rate of 27.7 % in colorectal surgery. This may be related to the effects of preoperative bowel preparations in patients undergoing colorectal resection. Dehydration has been previously identified as a complication of bowel preparation.¹⁶ Correcting dehydration before starting the operation in high risk patients may decrease postoperative ARF.

Patients with BUN/Cr ratio higher than 20 have the highest risk of postoperative ARF compared to patients with lower BUN/Cr ratios. AFR has been introduced as a complication which significantly increases mortality and hospitalization length of patients underwent surgery.¹ Prerenal azotemia

BUN/Cr level	<i>P</i> value	Adjusted odds ratio	95 % confidence interval
Group A (BUN/Cr <10)	Reference	Reference	Reference
Group B (10 ≤ BUN/Cr ≤ 20)	0.69	1.07	0.74–1.56
Group C (BUN/Cr >20)	0.04	1.23	1.008–1.51

Table 2 Risk adjustment analysis of BUN/Cr ratio regarding the postoperative acute renal failure complication in colon and rectal surgery patients

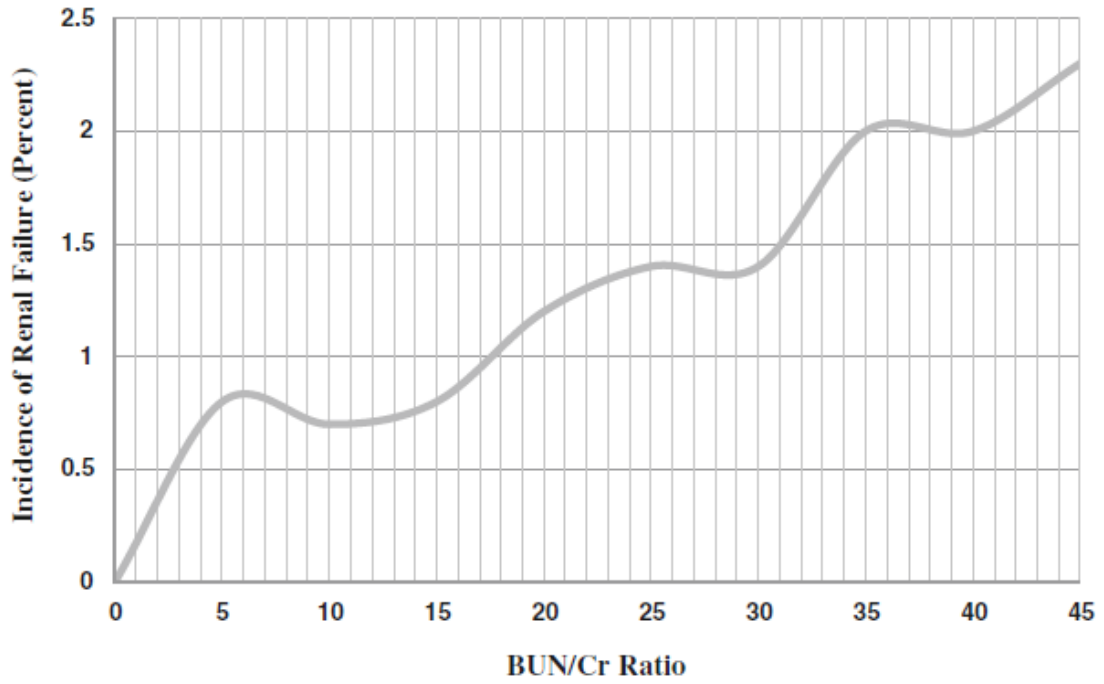


Fig. 2 Incidence of postoperative renal failure according to the BUN/Cr ratio

Table 3 Risk-adjusted analysis of variables associated with postoperative acute renal failure in colon and rectal surgery patients

Factors		P value	Adjusted odds ratio	95 % confidence interval
Age	Age >70	0.07	1.27	0.97–1.68
Sex	Female	Reference	Reference	Reference
	Male	0.04	1.30	1.01–1.68
Admission	Non-emergent	Reference	Reference	Reference
	Emergency	<0.01	1.76	1.33–2.32
Comorbidity	No complication	Reference	Reference	Reference
	Body Mass Index ≥ 30	<0.01	1.71	1.31–2.23
	Severe chronic obstructive pulmonary disease	<0.01	1.78	1.29–2.46
	Ascites	0.14	1.41	0.89–2.25
	Alcohol abuse	0.01	1.87	1.16–3.03
	Diabetes	<0.01	1.60	1.19–2.15
	Myocardial infarction (in the last 30 days)	0.66	1.18	0.55–2.53
	Cardiac angina	0.35	1.46	0.65–3.27
	Congestive heart failure	0.06	1.63	0.97–2.75
	Hypertension	0.08	1.28	0.96–1.70
	Surgical technique	Laparoscopic	Reference	Reference
Open procedures		<0.01	2.67	1.60–4.44
Procedures	Partial colectomy	Reference	Reference	Reference
	Total colectomy	<0.01	1.62	1.14–2.31
	Abdominoperineal resection of rectum	0.80	0.85	0.26–2.76
Pathology	Benign colorectal tumor	Reference	Reference	Reference
	Diverticulitis	0.27	2.33	0.51–10.74
	Colorectal cancer	0.17	2.72	0.64–11.45
	Crohn's disease	0.73	2.11	0.03–151.31
	Ulcerative colitis	0.77	1.44	0.11–18.05
Other factors	BUN/Cr >20	0.04	1.32	1.006–1.74
	Radiotherapy (in the last 90 days)	0.27	0.45	0.10–1.90
	Chemotherapy (in the last 30 days)	0.50	0.75	0.32–1.74
	Preoperative transfusion more than 4 units	0.15	1.41	0.87–2.27

Table 4 Risk-adjusted analysis of complications associated with BUN/Cr ratio in colon and rectal surgery patients

Complications	Patients with BUN/Cr ≤ 20	Patients with BUN/Cr >20	P value	Adjusted odds ratio	95 % confidence interval
In-hospital mortality	791 (3.8 %)	883 (12.9 %)	<0.01	2.19	1.94–2.48
Hospitalization more than 30 days	1057 (5 %)	1037 (15.2 %)	<0.01	2.61	2.35–2.90
Acute renal failure	181 (0.9 %)	109 (1.6 %)	0.04	1.32	1.006–1.74
Cardiac arrest	184 (0.9 %)	120 (1.7 %)	0.01	1.39	1.05–1.84
Myocardial infarction	138 (0.7 %)	95 (1.4 %)	0.01	1.46	1.06–1.99

(BUN/Cr >20) has been introduced as one of the most common reasons of acute renal failure in the literature.^{8,17} Our study, by dividing patients according to the preoperative hydration status into three groups, found the highest rate of ARF in patients with BUN/Cr level higher than 20 (Table 2).

In an analysis of the BUN/Cr cutoff points, the highest increase in the rate of postoperative ARF exists at the cutoff point of 23 (AOR, 1.58; CI, 1.14–2.19; P<0.01). This estimate corroborates the use of BUN/Cr cutoff of 20 as the demarcation point for postoperative risk of ARF. Hydrotherapy of patients with dehydration especially BUN/Cr ratio more than 23 may decrease postoperative ARF in colorectal surgery. However, clinical studies are needed to see if correcting the BUN/Cr ratio can decrease postoperative ARF and mortality rate.

Cardiac complications also have associations with dehydration. Our results show that patients with dehydration (BUN/Cr >20) have higher risk of myocardial infarction and cardiac arrest. The association between dehydration and myocardial infarction has been previously reported.¹⁸

Utilizing the power of the large NSQIP database, this study identified nine significant risk factors of ARF in colorectal patients, including the previously reported factor of male gender, and total colectomy procedure.¹ Also, this study introduced BUN/ Cr >20, COPD, emergent admission, alcohol abuse, diabetes, and obesity (BMI ≥30) as other risk factors of ARF in colorectal surgery. However, in multivariate analysis, we did not find a statistically significant association between ARF and CHF, which was previously reported as a risk factor of ARF.¹

Among colorectal procedures, open surgical technique has the highest risk of postoperative ARF. In line with the literature, in multivariate analysis, we found the open surgical technique as a risk factor of postoperative ARF compared to the laparoscopic approach.¹ Also, total colectomy procedure has increased risk of ARF compared to a partial colectomy procedure. We confirm the previous report by Masoomi et al.¹ of total colectomy as the procedure which has the highest risk of postoperative ARF in colorectal surgery.

Table 5 Multivariate risk estimating acute renal failure in colon and rectal surgery patients (increased risk calculated compared to patients admitted nonemergently without any comorbidity or dehydration and underwent laparoscopic colorectal resections)

Hydration status	Surgical technique	Admission type	Additional risk factors	Estimated increased risk of acute renal failure
Dehydrated patients	Open surgery	Emergent admission	Obesity	10.60 times
			Chronic obstructive pulmonary disease	11.04 times
			Alcohol abuse	11.59 times
			Diabetes	9.92 times
		Non-emergent admission	Obesity	6.02 times
			Chronic obstructive pulmonary disease	6.26 times
			Alcohol abuse	6.58 times
			Diabetes	5.63 times
	Laparoscopic surgery	Emergent admission	Obesity	3.97 times
			Chronic obstructive pulmonary disease	4.12 times
			Alcohol abuse	4.33 times
		Non-emergent admission	Diabetes	3.71 times
			Obesity	2.25 times
			Chronic obstructive pulmonary disease	2.34 times
			Alcohol abuse	2.46 times
			Diabetes	2.11 times

Dehydrated patients who underwent open colorectal procedures have at least five times higher risk of ARF compared with patients without comorbidity or dehydration who underwent laparoscopic surgery. Laparoscopic surgery in such patients may decrease the risk of ARF (Table 5). Dehydrated patients with comorbidity of alcohol abuse, COPD, obesity, or diabetes who underwent emergent colorectal resection have an approximately four times higher risk of ARF compared to patients without comorbidity or dehydration

who underwent laparoscopic operation. Since comorbidities of alcohol abuse, COPD, and obesity are not acutely correctable risk factors, intraoperative intense hydrotherapy for such high risk patients may decrease postoperative ARF. However, further studies are indicated to see if intensive intraoperative hydrotherapy in high risk patients can decrease postoperative ARF in colorectal surgery.

Study Limitations

This study is a large retrospective review and is subject to the usual retrospective study limitations, including selection bias. The population of the study was selected from the NSQIP database on the basis of ICD-9 and CPT codes at almost 500 hospitals in the USA between the years 2005 and 2011, and there is a wide variety of in-hospital settings and surgeons' expertise that can affect the study outcome. Although we only include patients who had both BUN and Cr parameters on the day of surgery, we did not have any information regarding perioperative hydrotherapy or information about bowel preparation for surgery. Also, intraoperative hydrotherapy in patients with high BUN/Cr ratio may cause the associations between preoperative BUN/Cr ratio and postoperative ARF to be underestimated. Due to the restriction of the database, we also lack information about the use of nephrotoxic medications that may have associations with ARF as well as other causes of abnormal BUN/Cr ratio (i.e., fever).^{6, 19} Also, coding errors may exist because of the use of discharge data (ICD-9 codes).²⁰

Conclusion

Dehydration before operation (BUN/Cr >20) is a common condition in colorectal surgery with an incidence of 27.7 %. BUN/Cr ratio is a useful marker for estimating postoperative ARF, MI, cardiac arrest, and mortality rates of patients undergoing colorectal resection. Dehydrated patients (BUN/Cr >20) have a higher risk of postoperative ARF compared to patients with normal range of BUN/Cr (BUN/Cr <10). The highest increase in the rate of ARF exists at the BUN/Cr ratio cutoff point of 23. In non-emergent situations, hydration therapy may decrease the risk of postoperative ARF in such high risk patients undergoing colorectal resection. However, further studies should be planned to see if the correction of BUN/Cr ratio can decrease postoperative ARF and mortality rate of patients.

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