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Predictive Factors of Ventilator Dependency after Colon and Rectal Surgery

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There is limited data analyzing ventilator dependency by operative diagnoses and types of the procedures performed in colorectal surgery. We sought to identify predictive factors of ventilator dependency in colorectal surgery and investigate complication rates across various colorectal procedures. The National Surgical Quality Improvement Program database was used to examine the clinical data of patients with ventilator dependency for more than 48 hours after colorectal resection during 2005–2013. Multivariate regression analysis was performed to identify predictors of ventilator dependency. A total of 219,716 patients who underwent colorectal resection were identified. The rate of ventilator dependency was 3.9 per cent. The rate varied significantly based on patient diagnosis; with the highest rate seen in patients with acutemesenteric ischemia (25.9%). The highest risk of ventilator dependency according to the patients indication of surgery, type of the procedure, and preoperative factors exist in lower gastrointestinal bleeding [adjusted odds ratio (AOR): 77.44, $P < 0.01$], total colectomy (AOR: 1.58, $P = 0.04$), and American Society of Anesthesiologists Classification of three or greater (AOR: 2.52, $P < 0.01$). Also, serum albumin level (AOR: 0.67, $P < 0.01$) seems to be associated with ventilator dependency. The overall rate of ventilator dependency is 3.9 per cent in colorectal surgery. However, depending on the indication for surgery, rates can be as high as 25.9 per cent. American Society of Anesthesiologist score can predict the risk of postoperative ventilator dependency in patients undergoing colorectal surgery. Serum albumin level is reversely associated with postoperative ventilator dependency.

What does this paper add to the literature?

In this manuscript, we report on 19 predictive factors of ventilator dependency after colorectal Surgery. Although ventilator dependency is not common after colorectal surgery, the rate can be significantly high depending on the type of the procedure performed and indication for surgery. Among preoperative factors, American Society of Anesthesiologist (ASA) score is the strongest predictor of ventilator dependency. Also, we analyzed the incidence and mortality of ventilator dependency in colorectal surgery. Moreover, additional factors such as, body mass index (BMI), serum albumin level, hematocrit, and anesthesia length seem to be associated with ventilator dependency. VENTILATOR DEPENDENCY IS a well-known complication in general surgery and associated with significant postoperative mortality and morbidity.¹⁻³ It is important to recognize risk factors before operation in an effort to decrease the morbidity and mortality of these patients.

Previous studies have introduced the concept of ventilator dependency as a multifactorial condition resulting from a combination of risk factors, partly due to the

patient comorbid conditions and partly to the process of patient care and type of the procedure.^{1,2} Ventilator dependency should be investigated separately with respect to different procedures. However, few reports have focused on the independent risk factors for ventilator dependency after colorectal operations.

According to the literature, the incidence of ventilator dependency after colorectal surgery is 5.7 per cent.³ However, patients can be very ill in some situations such as peritonitis or obstruction with a different risk of postoperative ventilator dependency. The purpose of this study is to evaluate the independent risk factors for postoperative ventilator dependency in the colorectal surgical population and investigate ventilator dependency according to various diagnoses and types of procedures to help identify high risk patients in colorectal surgery and help develop preventative measures in the future.

TABLE 1. *Variables of the Study*

Demographics	Other Factors
Age	Anesthesia length
Gender	Type of admission (emergent vs nonemergent)
Race	Surgical approach (open vs laparoscopic)
Comorbidities	BMI
Congestive heart failure (within 30 days before surgery)	Preoperative white blood cell count
Renal failure (need for dialysis)	Intraoperative transfusion of packed cell
Diabetes mellitus (with oral agents or insulin)	Serum albumin level
Weight loss (more than 10% in last six months)	Preoperative hematocrit
Steroid use (in the 30 days before surgery for a duration of more than 10 days)	Airway trauma (during intubation)
Severe chronic obstructive pulmonary disease	Postoperative pneumonia
Smoking (within one year)	Postoperative unplanned reintubation
Dyspnea (moderate or severe)	Postoperative myocardial infarction
Ascites (within 30 days before surgery)	Postoperative pulmonary embolism
Dependency before surgery (partial or complete)	Indications of surgery
Disseminated cancer	Colorectal cancer
Bleeding disorders (deficiency of blood clotting elements)	Cancer with origin other than colorectal
Pneumonia (presence at the time of operation)	Ulcerative colitis
Preoperative sepsis (sepsis, septic shock, or systemic inflammatory response syndrome)	Crohn's disease
ASA score	Rectal prolapse
Hypertension (requiring medication)	Benign colorectal tumor
Procedures	Diverticulitis
Total colectomy	Diverticulosis
Partial colectomy	Closure of colostomy
Proctectomy	Obstruction of colon or rectum
Anterior resection	Fistula (to bowel, skin, vagina, and bladder)
Pelvic exenteration	Acute mesenteric ischemia
Colostomy closure	Perforation of colon or rectum
	Lower gastrointestinal bleeding
	Acute generalized peritonitis

Materials and Methods

This study was performed using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database from January 1, 2005 to December 31, 2013. American College of Surgeons National Surgical Quality Improvement Program is an outcomes-based program used to improve the quality of surgical care in the United States.⁴ Approval for the use of the NSQIP patient-level data in this study was obtained from the Institutional Review Board of the University of California, Irvine Medical Center, and NSQIP. We included patients who underwent colorectal resections based on the Current Procedural Terminology codes of 44140–44160, 44204–44212, 44227, 44625, 45110–45114, 45119, 45120, 45123–45135, 45397,

45402, 45550, and 45395. Patients who underwent colorectal surgery without colon or rectal resection, patients younger than 18 years, and patients who had preoperative ventilator dependency were excluded from the study. Postoperative ventilator dependency was defined as the need for ventilator support for more than 48 hours. Variables in the study were defined according to original variables of NSQIP and the International Classification of Diseases, 9th Revision, clinical modifications (ICD-9-CM) codes which are listed in Table 1. The rates of postoperative ventilator dependency according to surgical diagnosis and the procedure type were examined. Risk-adjusted analysis was performed to identify predictors of ventilator dependency.

Statistical Analysis

Statistical analysis was performed using the SPSS® software, Version 22 (SPSS Inc., Chicago, IL). Multivariate analysis using logistic regression was used to estimate the association between perioperative factors and postoperative ventilator dependency, as well as to compare ventilator dependency between different surgical procedures and pathologic conditions. P values less than 0.05 were considered statistically significant. For each variable, the adjusted odds ratio (AOR) with a 95 per cent confidence interval (CI) was calculated to estimate the relative risk associated with ventilator dependency. Adjustments were made for all variables of the study.

TABLE 2. Demographics and Perioperative Factors of Patients Underwent Colon and Rectal Resection

Variables		Patients Without Ventilator Dependency (211,149)	Patients with Ventilator Dependency (8,567)	P Value	
Age	Mean ± SD (year)	61 ± 15	68 ± 14	<0.01	
	Median (year)	62	69	–	
Sex	Female	101,023 (47.9%)	4,357 (50.9%)	0.03	
Admission	Emergency admission	24,619 (11.7%)	4,979 (58.1%)	<0.01	
Race	White	165,943 (86.2%)	6,562 (83.6%)	<0.01	
	Black or African American	18,943 (9.8%)	1,036 (13.2%)	<0.01	
	Asian	5,523 (2.9%)	159 (2%)	<0.01	
	Other	2,098 (1.1%)	89 (1.1%)	<0.01	
	Comorbidity	Hypertension	101,193 (47.9%)	5,807 (67.8%)	<0.01
	Smoking	38,832 (18.4%)	2,078 (24.3%)	<0.01	
	Diabetes mellitus	29,790 (14.1%)	2,159 (25.2%)	<0.01	
	Dyspnea	18,321 (8.7%)	2,109 (24.6%)	<0.01	
	Steroid use	15,726 (7.4%)	1,186 (13.8%)	<0.01	
	COPD	11,080 (5.2%)	1,693 (19.8%)	<0.01	
	Dependency before surgery*	10,452 (5%)	2,613 (30.7%)	<0.01	
	Disseminated cancer	10,581 (5%)	637 (7.4%)	<0.01	
	Weight loss	10,496 (5%)	676 (7.9%)	<0.01	
	Ascites	2,348 (1.1%)	597 (7%)	<0.01	
	Congestive heart failure	1,852 (0.9%)	541 (6.3%)	<0.01	
	Renal failure need for dialysis	1,799 (0.9%)	460 (5.4%)	<0.01	
	Preoperative pneumonia†	443 (0.4%)	251 (4.5%)	<0.01	
Surgical approach	Laparoscopic	83,253 (39.4%)	873 (10.2%)	<0.01	
	Open	127,896 (60.6%)	7,694 (89.8%)	<0.01	
Procedure	Partial colectomy	129,775 (61.5%)	6,359 (74.2%)	<0.01	
	Anterior resection	38,687 (18.3%)	644 (7.5%)	<0.01	
	Proctectomy	16,424 (7.8%)	239 (2.8%)	<0.01	
	Stoma closure	13,042 (6.2%)	150 (1.8%)	<0.01	
	Total colectomy	12,868 (6.1%)	1,151 (13.4%)	<0.01	
	Pelvic exenteration	353 (0.2%)	24 (0.3%)	0.01	
	Other factors	ASA score more than two	105,464 (50%)	7,773 (90.9%)	<0.01
		Preoperative sepsis‡	19,389 (9.2%)	4,733 (55.3%)	<0.01
	Airway trauma (during intubation)	173 (0.2%)	18 (0.5%)	<0.01	
	Anesthesia length, mean ±SD (minute)	223 ± 103	238 ± 124	<0.01	
	White blood cell count, mean ± SD (cells × 10 ⁹ /L)	8.1 ± 4.1	12.3 ± 8.3	<0.01	
	Serum albumin level, mean ± SD (g/dL)	3.72 ± 0.70	2.96 ± 0.86	<0.01	
	Hematocrit, mean ± SD	37.8 ± 5.6	35.3 ± 6.8	<0.01	
	BMI, mean ± SD	27.9 ± 6.7	29 ± 8.8	<0.01	
	Number of intraoperative packed cell transfusion (mean)	0	1	<0.01	

SD, Standard deviation; COPD, Chronic obstructive pulmonary disease.

* Partially or complete dependency before surgery.

y Presence at the time of operation.

z Preoperative sepsis, septic shock, and systemic inflammatory response syndrome.

Results

We sampled 219,716 patients who underwent colorectal resection from 2005 to 2013. The median age of patients was 62 years. The majority of the patients were white (86.1%) and female (52%). The most common comorbidities included hypertension (48.7%) and diabetes mellitus (14.5%). Demographic data of patients are reported in Table 2.

Of all patients who underwent colorectal resection, 8567 (3.9%) had postoperative ventilator dependency. Median hospitalization length for patients with or without ventilator dependency were 22 and 6 days, respectively (CI: 13.58–14.75, $P < 0.01$). The unadjusted mortality rate in patients with and without postoperative ventilator dependency was 27.7 per cent and 1.8 per cent, respectively. After adjusting for comorbidities, the risk of mortality was four times greater in patients with ventilator dependency (AOR: 4.02, CI: 3.52–4.59, $P < 0.01$).

The risk-adjusted analysis for factors associated with postoperative ventilator dependency is reported in Table 3. Among, preoperative factors, the ASA score of three or greater was the strongest predictor of ventilator dependency (AOR: 2.52, $P < 0.01$). Among preoperative laboratory biochemical parameters, serum albumin was reversely associated with ventilator dependency (AOR: 0.67, $P < 0.01$). Moreover, intraoperative factor of the amount of products transfused was associated with postoperative ventilator dependency (AOR: 1.21, $P < 0.01$). Moreover, intraoperative factor of the amount of products transfused was associated with postoperative ventilator dependency (AOR: 1.21, $P < 0.01$).

TABLE 3. Risk-Adjusted Analyze of Factors Associated with Postoperative Ventilator Dependency in Colon and Rectal Surgery Patients

	Variables	AOR	95% CI	P Value	
Gender	Male	1.16	1.06–1.27	<0.01	
Age	Age	1.015	1.011–1.019	<0.01	
Admission	Emergency	2.16	1.92–2.43	<0.01	
Surgical approach	Open	1.65	1.41–1.93	<0.01	
Comorbidity	Dependency before surgery*	1.95	1.76–2.17	<0.01	
	Dyspnea	1.46	1.30–1.63	<0.01	
	Preoperative pneumonia†	1.43	1.10–1.85	<0.01	
	Chronic obstructive pulmonary disease	1.39	1.21–1.58	<0.01	
	Smoking	1.33	1.19–1.49	<0.01	
	Congestive heart failure	1.30	1.05–1.61	0.01	
	Ascites	1.24	1.04–1.48	0.01	
	Dialysis	1.24	1.002–1.54	0.04	
	Hypertension	1.23	1.11–1.37	<0.01	
	Bleeding disorders	1.22	1.07–1.38	<0.01	
	Diabetes mellitus	1.07	0.96–1.20	0.21	
	Weight loss	1.06	0.91–1.24	0.42	
	Steroid use	0.95	0.82–1.10	0.55	
	Disseminated cancer	0.87	0.73–1.04	0.14	
	Other factors	ASA score more than two	2.52	2.17–2.92	<0.01
		Preoperative sepsis‡	2.14	1.90–2.41	<0.01
		BMI	1.012	1.006–1.18	<0.01
Serum albumin level		0.67	0.63–0.72	<0.01	
Intraoperative transfusion		1.21	1.17–1.25	<0.01	
Airway trauma (during intubation)		2.17	1.12–4.21	0.02	
Anesthesia length		1.003	1.002–1.003	<0.01	
Hematocrit		1.02	1.01–1.03	<0.01	
White blood cell count		1	0.99–1.01	0.44	

* Partially or complete dependency before surgery.

y Presence at the time of operation.

z Preoperative sepsis, septic shock, and systemic inflammatory response syndrome.

Overall rate of ventilator dependency after colorectal surgery was 3.9 per cent. However, the rate of ventilator dependency varied depending on the indication for surgery and the procedure type. Among indications for colorectal resection, patients with acute mesenteric ischemia had the highest rate of ventilator dependency (25.9%), followed by patients with colorectal perforation (23.8%). In addition, among colorectal procedures patients who underwent total colectomy had the highest rate of ventilator dependency (8.2%) followed by pelvic exenteration (6.4%) (Table 4). Risk-adjusted analysis of ventilator dependency by the procedure type and the indication for surgery is reported in Table 4. Among all indications for operation, patients who had lower gastrointestinal bleeding (AOR: 77.44, $P < 0.01$), colorectal perforation (AOR: 28.31, $P < 0.01$), and acute mesenteric ischemia (AOR: 14.80, $P < 0.01$) had a significantly increased risk of postoperative ventilator dependency. Among colorectal procedures, patients who underwent total colectomy had the highest risk of ventilator dependency (1.58, $P = 0.04$). Also, colonic procedures (including total colectomy and partial colectomy) had a higher risk of ventilator dependency compared with rectal procedures (including pelvic exenteration, anterior resection, and proctectomy) (AOR: 1.26, CI: 1.09–1.46, $P < 0.01$).

Overall, 29 per cent of patients with ventilator dependency had unplanned reintubation. Among patients with ventilator dependency, 16.9 per cent had a report of pneumonia, 8.7 per cent had a report of sepsis, 4.9 per cent had a report of acute renal failure, 3.3 per cent had a report of myocardial infarction, 3.2 per cent had a report of cardiac arrest, and 1.5 per cent had a report of pulmonary embolism before the ventilator dependency complication. Ventilator-associated pneumonia developed in 24 per cent of patients who experienced the complication of ventilator dependency.

Finally, risk-adjusted analysis revealed a statistically significant association between BMI and postoperative ventilator dependency (AOR: 1.01, $P < 0.01$), which really only reached clinical significance with a BMI greater than 40 (AOR: 41.45, $P < 0.01$). Figure 1 illustrates the rate of ventilator dependency according to BMI.

TABLE 4. Risk-Adjusted Analysis of Ventilator Dependency by Type of the Procedure and Indication of Surgery

	Variables	Rate of Ventilator Dependency (%)	AOR	95% CI	P Value
Indication of surgery	Rectal prolapse*	0.5	–	–	–
	Acute mesenteric ischemia	25.9	14.80	2.40–90.99	<0.01
	Perforation of colon or rectum	23.8	28.31	4.52–177.35	<0.01
	Acute generalized peritonitis	19.2	12.36	1.40–108.72	0.02
	Lower gastrointestinal bleeding	13.3	77.44	5.18–1156	<0.01
	Obstruction	7.3	9.21	1.95–43.51	<0.01
	Diverticulitis	4.6	7.94	1.20–52.34	0.03
	Fistula†	4.1	3.07	0.56–16.85	0.19
	Diverticulosis	4.1	2	0.24–16.36	0.51
	Cancer (noncolorectal)	3.3	6.88	1.44–32.87	0.01
	Colorectal cancer	2.1	4.69	1.14–19.22	0.03
	Ulcerative colitis	2.1	6.89	1.04–45.65	0.04
	Closure of colostomy	1.5	4.72	0.72–30.77	0.10
	Crohn's disease	1.2	10.36	1.39–81.38	0.02
	Benign colorectal tumor	1.1	4.35	0.65–29.04	0.12
	Procedures	Colostomy closure*	1.1	–	–
Total colectomy		8.2	1.58	1.001–2.53	0.04
Pelvic exenteration		6.4	1.36	0.04–2.89	0.34
Partial colectomy		4.7	1.15	0.82–1.62	0.40
Anterior resection		1.6	1.03	0.66–1.63	0.86
Proctectomy		1.4	0.36	0.18–1	0.05

* The reference group in multivariate analyzes.

† Includes colorectal fistula to bowel, skin, vagina, and bladder.

Discussion

Postoperative ventilator dependency in patients who underwent colorectal resection is associated with poor prognosis, significant mortality, and an increase in hospitalization length. We emphasize previous studies relating ventilator dependency with poor prognosis.⁵⁻⁷ Although this study and the previously published studies found multiple risk factors for ventilator dependency, only a limited number of risk factors are reducible. Further clinical trials with a focus on reducible predictors of ventilator dependency, such as operative approach (open vs laparoscopic) and preoperative low hematocrit, are needed.

Although postoperative ventilator dependency is not a common complication after colorectal surgery, the complication rate varied broadly depending on the diagnosis. This study found the overall rate of 3.9 per cent for ventilator dependency after colorectal procedures, which is in line with the previously reported rate of 5.7 per cent by Kirchoff.³ Surprisingly, we have found that although the rate of ventilator dependency is less than 1 per cent in some colorectal procedures, such as rectal prolapse, the rate is higher than 19 per cent (which is higher than elective cardiac procedures⁵) in patients who were admitted with acute mesenteric ischemia, acute generalized peritonitis, or colorectal perforation. We conclude that the indication for surgery is one of the most important factors which can significantly affect the risk of postoperative ventilator dependency.

Numerous factors are associated with postoperative ventilator dependency in colorectal surgery. We have found 22 predictors of ventilator dependency in colorectal surgery. We confirm previous studies reporting preoperative renal failure, prolonged operation time, congestive heart failure, low serum albumin and hematocrit levels, and chronic respiratory disease as predictors of ventilator dependency.^{5,6,8} Also, our results show that ASA classification and functional health status of patients can be used to predict the risk of ventilator dependency in colorectal patients. However, several risk factors introduced in our study and previously published studies are not adaptable. Further clinical trials are needed to evaluate whether controlling modifiable risk factors, such as low hematocrit and serum albumin level, and using the laparoscopic approach can decrease the rate of ventilator dependency.

Our study results demonstrate that patients undergoing different colorectal procedures have different rates of ventilator dependency. The highest risk of ventilator dependency is associated with total colectomy. In addition, compared with rectal procedures, colon procedures have a higher risk of postoperative ventilator dependency. This may be explained by the lower rate of respiratory complications with lower abdominal incisions compared with upper abdominal incisions after gastrointestinal surgery.⁹ However, there is limited published data in this regard and further studies are needed to compare postoperative ventilator dependency in colonic procedures and rectal procedures between two homogenous groups of patients.

The use of laparoscopic techniques in colorectal surgery may decrease the ventilator dependency risk in colorectal surgery patients. Our study results show that compared with open surgery, laparoscopic approach is associated with a 40 per cent lower risk of ventilator dependency in colorectal surgery. The lower rates of respiratory complication after laparoscopic colorectal surgery compared with the open procedures have been previously reported.^{3,10} As previously mentioned, critically ill patients undergoing emergency abdominal surgery often have prolonged ventilation time, however it is difficult to quantify the precise benefit of laparoscopy in these situations. Although some published articles report the feasibility of laparoscopic surgery in abdominal emergencies, such as peritonitis and perforated viscus,¹¹⁻¹³ further studies are required to compare benefits and disadvantages of laparoscopic surgery in abdominal emergencies.

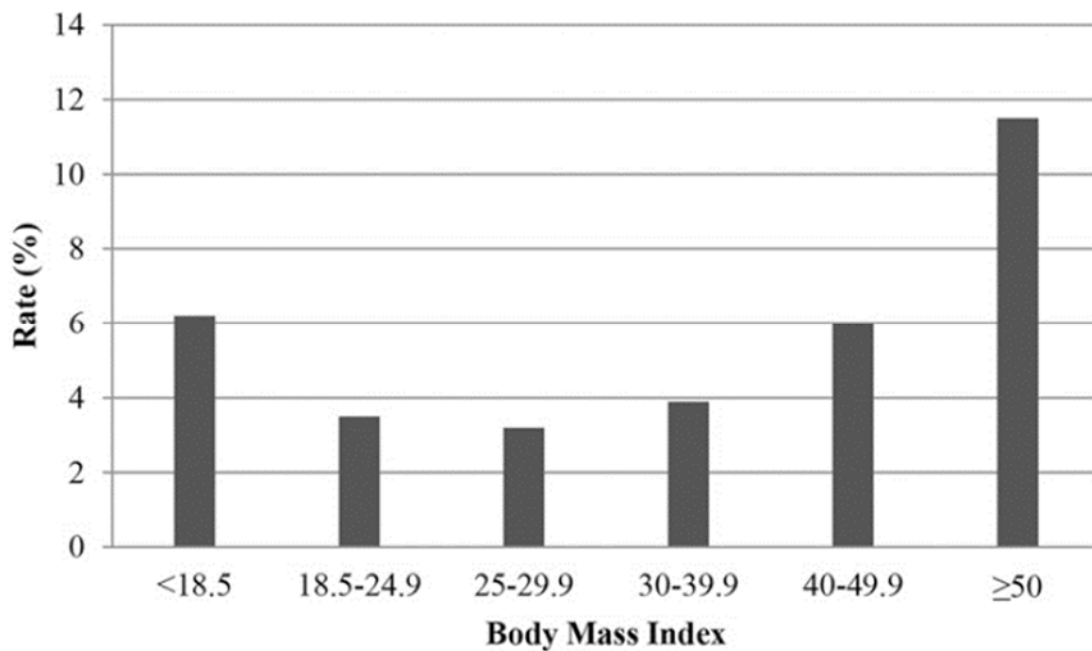


FIG. 1. Rate of postoperative ventilator dependency by BMI in colorectal surgery.

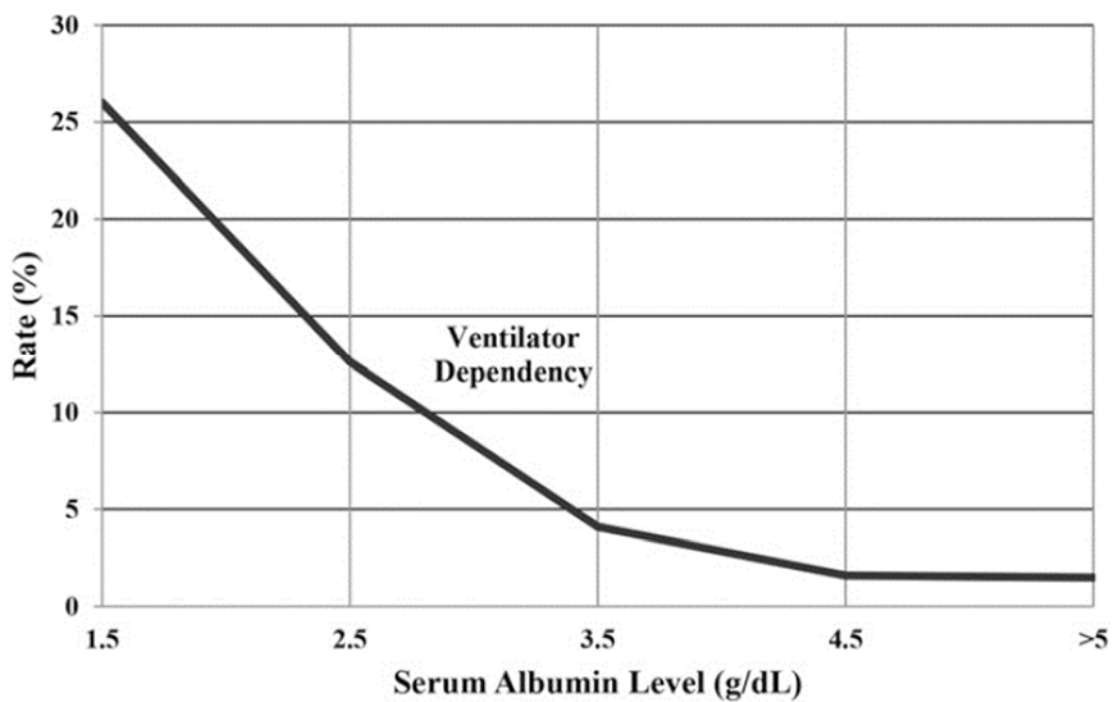


FIG. 2. Associations between serum albumin level and postoperative ventilator dependency in colorectal surgery.

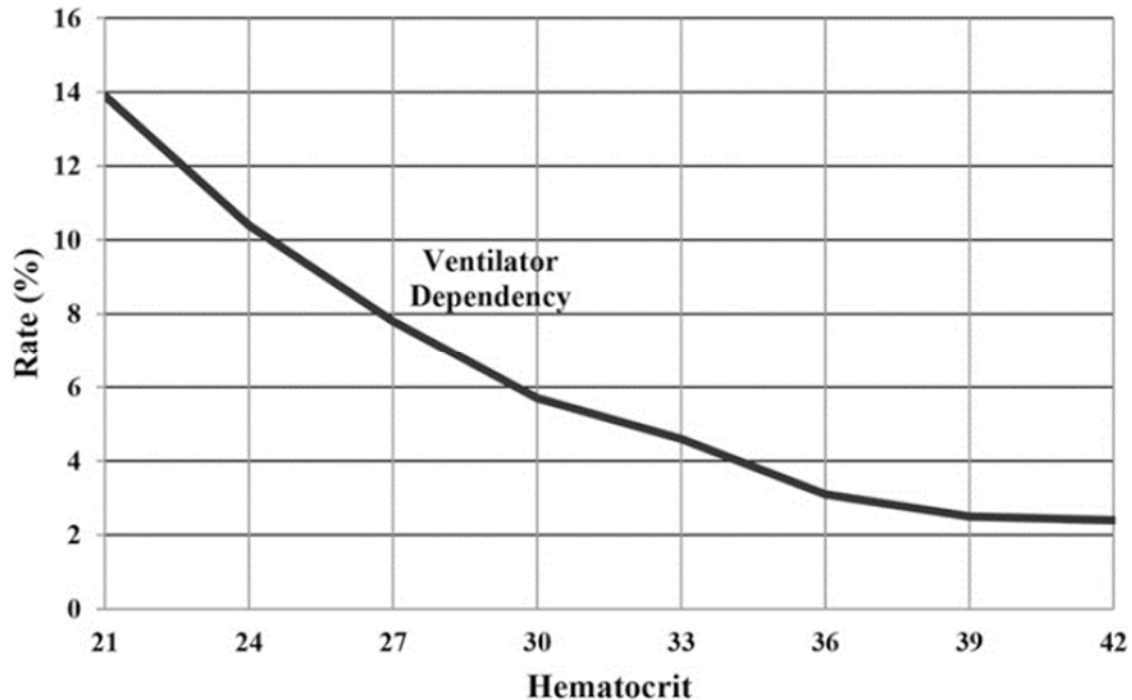


FIG. 3. Associations between hematocrit and postoperative ventilator dependency in colorectal surgery.

Our study shows that low serum albumin level (Figure 2) and hematocrit are associated with a higher risk of postoperative ventilator dependency. Serum albumin level has been introduced as a reliable mortality and morbidity predictor in colorectal surgery.¹⁴⁻¹⁶ Also, a number of previous studies have reported higher postoperative mortality, morbidity, and respiratory complications in anemic patients.^{5, 17-20} Considering the reversible nature of these two risk factors, further studies should be considered to distinguish whether correcting serum albumin and hematocrit levels before operation can decrease the rate of ventilator dependency.

Postoperative pneumonia was the most common complication reported before ventilator dependency complication. Also, postoperative myocardial infarction, pulmonary embolism, and sepsis were frequently reported before ventilator dependency. The limited information regarding the reason for ventilator dependency and the retrospective nature of our study make any conclusion on this topic difficult. However, it seems that postoperative pneumonia is associated with ventilator dependency. In addition, we have found that 24 per cent of patients with ventilator dependency developed pneumonia during the postoperative course. Ventilator-associated pneumonia has an incidence of 8 to 28 per cent in patients with prolonged mechanical ventilation and has been reported as a serious complication with a mortality rate as high as 76 per cent.²¹ Such patients may benefit from early tracheostomy and empiric antibiotic treatment.^{8, 22}

Study Limitations

This study is a large retrospective review extracted from the NSQIP and is subject to selection bias. Variables such as the diverse hospital settings and surgeons' expertise may affect the study results. Patients in this study were both very heterogeneous with regards to demographic data and primary diagnoses. Because of the restriction of the database, we did not have information of length of ventilator dependency and reasons for ventilator dependency of the patients which may have altered outcomes. Patients cannot be tracked beyond 30 days from the date of surgery,

therefore long-term outcomes are inaccessible. In addition, coding errors may exist with the use of ICD-9 codes.²³ Despite these limitations, this study is one of the first to report on the postoperative ventilator dependency after colorectal resection procedures.

Conclusion

Ventilator dependency is a serious complication with significant mortality in colorectal surgery patients. Although the overall rate of ventilator dependency after colorectal procedures is 3.9 per cent, in presence of acute mesenteric ischemia, colorectal perforation, obstruction, and peritonitis, the rate of ventilator dependency rises to more than 19 per cent. Overall, colon procedures have a higher risk of ventilator dependency compared with rectal procedures. From a procedure perspective, the highest risk of ventilator dependency is seen after total colectomy. The ASA classification and functional health status of patients before surgery can also be used to predict the risk of ventilator dependency. The use of laparoscopy in colorectal surgery may decrease the risk of ventilator dependency. Low serum albumin level and hematocrit levels seem to increase the risk of postoperative ventilator dependency in colorectal surgery. Considering the modifiable nature of these two risk factors, it may be beneficial to further investigate whether correcting these values preoperatively ultimately leads to decreasing the rate of ventilator dependency.

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