To close or not to close? Wound management in emergent colorectal surgery, an EAST multicenter prospective cohort study

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AUTHORS/CONTRIBUTORS

Cristina B. Feather, Scott Rehrig, Rebecca Allen, Nadine Barth, Emmalee M. Kugler, Daniel C. Cullinane, Carolyne R. Falank, Bishwajit Bhattacharya, Adrian A. Maung, CSL Behring, Grant/Travel fee, Researcher/Travel, Sharon Gautschy. Sirivan Seng, Asanthi Ratnasekera, Gary Alan Bass, Dale Butler, Illumix Surgical/Gale Sun Technologies, Consulting fee/Stock, Consultant, Sharon Gautschy. Jose L. Pascual, Court proceedings, Legal Expert Testimony, Expert Testimony, Sharon Gautschy. Daniel Srikureja, Nolan Winicki, Jennifer Lynde, Brittany Nowak, Faris Azar, Lauren A. Thompson, Jeffry Nahmias, Morgan Manasa, Ronald Tesoriero, Sandhya B. Kumar, Morgan Collom, Michelle Kincaid, Kimberly Sperwer, Ariel P. Santos, J. Robert Klune have nothing to disclose, and Justin Turcotte, AART/RWJ Health Equity Innovations Fund Grant/CareFirst Sustainability Grant, Grant, Principal Investigator, Sharon Gautschy.

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Cristina B. Feather, MD, MHS, Scott Rehrig, MD, Rebecca Allen, MD, Nadine Barth, MD, Emmalee M. Kugler, BS, Daniel C. Cullinane, MD, Carolyne R. Falank, PhD, Bishwajit Bhattacharya, MD, Adrian A. Maung, MD, Sirivan Seng, MD, Asanthi Ratnasekera, DO, Gary Alan Bass, MD, BSc, MSc, MBA, PhD, FEBS(Em Surg), Dale Butler, MD, MBA, Jose L. Pascual, MD, PhD, Daniel Srikureja, MD, Nolan Winicki, MS, Jennifer Lynde, DO, Brittany Nowak, MD, Faris Azar, MD, Lauren A. Thompson, DO, Jeffry Nahmias, MD, MHPE, Morgan Manasa, MD, Ronald Tesoriero, MD, FACS, Sandhya B. Kumar, MD, FACS, Morgan Collom, DO, Michelle Kincaid, MD, Kimberly Sperwer, DO, Ariel P. Santos, MD, MPH, FRCSC, FACS, FCCM, J. Robert Klune, MD, MBA, *and* **Justin Turcotte, PhD, MBA**, *Annapolis, Maryland*

BACKGROUND: This study aimed to determine the clinical impact of wound management technique on surgical site infection (SSI), hospital length of stay (LOS), and mortality in emergent colorectal surgery.

METHODS: A prospective observational study (2021–2023) of urgent or emergent colorectal surgery patients at 15 institutions was conducted. Pediatric patients and traumatic colorectal injuries were excluded. Patients were classified by wound closure technique: skin closed (SC), skin loosely closed (SLC), or skin open (SO). Primary outcomes were SSI, hospital LOS, and in-hospital mortality rates. Multivariable regression was used to assess the effect of wound closure on outcomes after controlling for demographics, patient characteristics, intensive care unit admission, vasopressor use, procedure details, and wound class. A priori power analysis indicated that 138 patients per group were required to detect a 10% difference in mortality rates.

RESULTS: In total, 557 patients were included (SC, n = 262; SLC, n = 124; SO, n = 171). Statistically significant differences in body mass index, race/ethnicity, American Society of Anesthesiologist scores, EBL, intensive care unit admission, vasopressor therapy, procedure details, and wound class were observed across groups. Overall, average LOS was 16.9 ± 16.4 days, and rates of in-hospital mortality and SSI were 7.9% and 18.5%, respectively, with the lowest rates observed in the SC group. After risk adjustment, SO was associated with increased risk of mortality (OR, 3.003; $p = 0.028$) in comparison with the SC group. Skin loosely closed was associated with increased risk of superficial SSI (OR, 3.439; $p = 0.014$), after risk adjustment.

CONCLUSION: When compared with the SC group, the SO group was associated with mortality but comparable when considering all other outcomes, while the SLC was associated with increased superficial SSI. Complete skin closure may be a viable wound management technique in emergent colorectal surgery. (*J Trauma Acute Care Surg.* 2024;97: 73–81. Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.)

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KEY WORDS: Colorectal surgery; emergency general surgery; wound management; skin closure; surgical site infection.

Surgical site infections (SSIs) have a significant impact on both patients and health care systems, as the most common hospital-acquired infections in surgical patients account for more than 3 billion dollars in direct costs.[1–3] Because of such clinical and financial impacts, SSIs serve as an important quality measure, with reporting required, and reimbursement dependent on these outcomes.[4] In 2006, implementation of the Surgical Care Improvement Program was initiated with the aim of providing a bundled intervention to significantly reduce SSIs and improve the quality of care for surgical patients over the 5 years of implementation.[5] Surgical Care Improvement Program measures focused on mitigating well-known risk factors of SSI, such as contamination, temperature regulation, and glucose control.[6] However, many risk factors cannot be modified, specifically patient characteristics and procedure indications. Colorectal surgery carries a higher risk of SSI, with reported SSI incidences ranging from 5% to 30%.[1,7] More importantly, indication for operation can further influence the risk of SSI, as emergent procedures have increased contamination rates, metabolic derangements, hemodynamic changes, and longer operative times.[8–10] Surgical Care Improvement Program measures were accepted as practice guidelines but retired as reportable measures after 2015, as the literature showed a plateau in the incidence of SSI but did not show a significant reduction of SSI among surgical patients.[11,12]

Building on mitigation efforts established by Surgical Care Improvement Program, the Centers for Disease Control and Prevention established updated guidelines for preventing

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From the Anne Arundel Medical Center and Doctors Community Medical Center (C.B.F., S.R., R.A., J.R.K., J.T.), Luminis Health, Annapolis, Maryland; Cooper University Hospital (N.B., E.M.K.), Camden, New Jersey; Maine Medical Center (D.C.C., C.R.F.), Portland, Maine; Yale New Haven Hospital (B.B., A.A.M.), New Haven, Connecticut; Crozer Chester Medical Center (S.S., A.R.), Upland; Hospital of the University of Pennsylvania (G.A.B., J.L.P.), Philadelphia, Pennsylvania; University of Texas Southwestern Medical Center (D.B.), Dallas, Texas; Loma Linda University Medical Center (D.S., N.W.), Loma Linda, California; Jackson Memorial Hospital (J.L., B.N.), University of Miami, Miami, Florida; St. Mary's Medical Center (F.A., L.A.T.), Florida Atlantic University, West Palm Beach, Florida; University of California at Irvine Health (J.N., M.M.), Orange; Zuckerberg San Francisco General Hospital (R.T., S.B.K.), UCSF, San Francisco, California; Medical City Plano (M.C.), Envision Health, Plano, Texas; OhioHealth Grant Medical Center (M.K., K.S.), Columbus, Ohio; and Texas Tech University Health Science Center (A.P.S.), Lubbock, Texas.
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Address for correspondence: Cristina B. Feather, MD, MHS, Anne Arundel Medical Center and Doctors Community Medical Center, Luminis Health, Annapolis, MD; email: cfeather@luminishealth.org, cbfeather7@gmail.com.

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TABLE 1. Demographics and Clinical Presentation by Wound Closure Type

Patient Characteristic, Avg. ± SD or n (%)	All Patients (n = 557)	SC (n = 262)	SLC (n = 124)	SO (n = 171)	*p*
Demographics					
Age, y	58.5 ± 17.4	57.9 ± 17.3	61.3 ± 16.7	57.5 ± 17.9	0.141
Female	261 (46.9)	117 (44.7)	66 (53.2)	78 (45.6)	0.268
Race/ethnicity					
White	375 (67.3)	169 (64.5)	95 (76.6)	111 (64.9)	**0.044**
Black/African American	144 (25.9)	71 (27.1)	20 (16.1)	53 (31.0)	**0.013**
Asian	15 (2.7)	8 (3.1)	6 (4.8)	1 (0.6)	0.053*
Native Hawaiian or other Pacific Islander	3 (0.5)	2 (0.8)	0 (0.0)	1 (0.6)	1.000*
Other	26 (4.7)	14 (5.3)	4 (3.2)	8 (4.7)	0.654
Hispanic ethnicity**	61 (11.7)	41 (16.1)	8 (6.6)	12 (8.2)	**0.008**
Past medical history					
Diabetes mellitus	107 (19.2)	47 (17.9)	23 (18.5)	37 (21.6)	0.620
Liver disease	28 (5.0)	12 (4.6)	5 (4.0)	11 (6.4)	0.584
Chronic kidney disease	68 (12.2)	33 (12.6)	11 (8.9)	24 (14.0)	0.395
Chronic steroid use	26 (4.7)	7 (2.7)	10 (8.1)	9 (5.3)	0.058
Congestive heart failure	42 (7.5)	15 (5.7)	11 (8.9)	16 (9.4)	0.307
Myocardial infarction	31 (5.6)	8 (3.1)	8 (6.5)	15 (8.8)	**0.036**
Chronic pulmonary disease	72 (12.9)	33 (12.6)	15 (12.1)	24 (14.0)	0.866
Peripheral vascular disease	31 (5.6)	16 (6.1)	8 (6.5)	7 (4.1)	0.596
Stroke	38 (6.8)	18 (6.9)	7 (5.6)	13 (7.6)	0.805
Chronic anticoagulation or dual antiplatelet therapy	67 (12.0)	37 (14.1)	13 (10.5)	17 (9.9)	0.355
Rheumatic or connective tissue disorder	17 (3.1)	9 (3.4)	5 (4.0)	3 (1.8)	0.471
Cancer	121 (21.7)	71 (27.1)	24 (19.4)	26 (15.2)	**0.010**
Chemotherapy	33 (5.9)	20 (7.6)	6 (4.8)	7 (4.1)	
Current smoker	61 (11.0)	26 (9.9)	13 (10.5)	22 (12.9)	0.621
Prior abdominal surgery	156 (28.0)	72 (27.5)	36 (29.0)	48 (28.1)	0.951
ASA ≥3	166 (32.0)	58 (23.5)	34 (28.3)	74 (48.7)	**<0.001**
Malnourished†	143 (31.8)	59 (27.7)	35 (33.0)	49 (37.4)	0.163
BMI, kg/m^2	28.3 ± 7.9	27.1 ± 7.3	28.2 ± 6.7	30.2 ± 9.0	**<0.001**
Surgery/hospitalization details					
Procedure location(s)					
Right colon	207 (37.2)	113 (43.1)	31 (25.0)	63 (36.8)	**0.003**
Left colon	331 (59.4)	146 (55.7)	83 (66.9)	102 (59.6)	0.111
Rectum	45 (8.1)	16 (6.1)	11 (8.9)	18 (10.5)	0.240
Other	79 (14.2)	38 (14.5)	16 (12.9)	25 (14.6)	0.898
Wound class					
Clean	25 (4.5)	21 (8.0)	2 (1.6)	2 (1.2)	**<0.001**
Clean contaminated	169 (30.3)	119 (45.4)	26 (21.0)	24 (14.0)	**<0.001**
Contaminated	117 (21.0)	52 (19.8)	21 (16.9)	44 (25.7)	0.153
Dirty/infected	246 (44.2)	70 (26.7)	75 (60.5)	101 (59.1)	**<0.001**
Estimated blood loss >500 mL	88 (15.8)	41 (15.6)	9 (7.3)	38 (22.2)	**0.002**
Prophylactic antibiotics	520 (93.5)	242 (92.7)	118 (95.2)	160 (93.6)	0.661
Intraoperative vasopressor therapy	273 (49.0)	102 (38.9)	57 (46.0)	114 (66.7)	**<0.001**
Stoma created	353 (63.4)	144 (55.0)	84 (67.7)	125 (73.1)	**<0.001**
Intraoperative hypothermia	139 (25.0)	65 (24.8)	22 (17.7)	52 (30.4)	**0.046**
ICU admission	288 (52.0)	109 (42.1)	53 (42.7)	126 (73.7)	**<0.001**
Damage-control surgery	114 (20.5)	23 (8.8)	17 (13.7)	74 (43.5)	**<0.001**

*Fisher's exact test was performed (assumptions of χ^2 not met).
**Ethnicity data were recorded in 521 patients.
†Albumin <3. Albumin was recorded in 450 patients.
p Values <0.05 in bold.
One-way analysis of variance was performed to compare continuous measures across groups; χ^2 was performed to compare categorical measures.
ICU, intensive care unit.

SSI in 2017.[4] Currently, a combination of best practice recommendations and a surveillance system of risk-adjusted SSI rates are used to avoid and reduce SSI among surgery patients.[3] Elements of this risk-adjusted score include patient-specific clinical factors, infection present at the time of surgery, and closure techniques, making management of skin closure in colorectal procedures a critical decision for the operating surgeon.[3]

Previous studies have also suggested that management of skin closure according to patient risk factors can decrease the rate of SSI.[9,13–15] However, the clinical and economic burden of different wound management strategies remains largely unexplored. Retrospective studies on wound management strategies in colon surgery for trauma or EGS cases reveal that patients with colonic injuries managed with open skin compared with closed skin incisions had longer hospital stays, more postoperative visits, and longer time to last outpatient follow-up compared with those with closed incisions.[16,17]

It is widely accepted in the surgical community that certain risk factors, such as contaminated wounds, the presence of shock, emergent procedures, and colorectal surgery, increase the likelihood of SSI.[3,13,15] Consequently, managing the skin incision differently in these circumstances has become frequent. Some advocate to not close high-risk incisions to prevent infections and avoid adverse quality metrics. In contrast, others continue to close skin incisions with close follow-up in hopes of reducing the clinical burden on the patient. However, the question of the clinical impact of wound management strategy in emergent nontraumatic colorectal surgery patients remains unanswered. The purpose of this study is to determine the clinical impact of wound management techniques on SSI, hospital length of stay (LOS), and mortality in emergent colorectal surgery. We hypothesize that there will be no difference in SSI, LOS, or mortality among patients with variable wound management techniques.

PATIENTS AND METHODS

This study was approved by the Eastern Association for the Surgery of Trauma Multi-Institutional Trials Committee. It was deemed exempt under 45 CFR § 46.104(d)(4) and received a waiver of informed consent by the Western Institutional Review Board. Before the initiation of the study, local institutional review board exemption was obtained at all participating sites. A prospective observational study of adult patients undergoing urgent or emergent colorectal surgery from March 1, 2021, to March 1, 2023, was conducted at 15 institutions. Patients younger than 18 years at the time of surgery, pregnant women, prisoners, and those undergoing elective surgery or surgeries for traumatic colorectal injuries were excluded. This study was performed in alignment with the Equator Network's STROBE guidelines for cohort studies.[18]

Independent Variables

Patients were classified by wound closure technique: skin closed (SC), skin loosely closed (SLC), or skin open (SO). Skin closed was defined as primary closure with staples or suture at fascial closure, SLC was defined as skin closed incompletely to allow for packing or drainage at fascial closure, and SO was defined as no portion of the skin being closed at fascial closure. Additional covariates assessed included demographics (including age, body mass index [BMI], sex, and patient-reported race/ethnicity), past medical history (including comorbidities, history of anticoagulation use, smoking status, BMI, American Society of Anesthesiologist [ASA] score, and history of prior abdominal surgery), surgical details (including procedure location, wound class, and estimated blood loss), antibiotic prophylaxis, intraoperative vasopressor therapy, stoma creation, intraoperative hypothermia, intensive care unit (ICU) admission, and damage control surgery. Damage control surgery was defined as multiple operations prior to fascial and skin closure. A complete list of variables evaluated is presented in Table 1.

Outcomes

The primary outcomes of interest were SSI, hospital LOS days, and in-hospital mortality. Surgical site infection was defined as the occurrence of a superficial, deep-incisional, or organ/space infection within 30 days of surgery, based on Centers for Disease Control definitions. Secondary outcomes included enteric fistula, fascial dehiscence, home discharge, unplanned return to the operating room (OR), and 30-day unplanned readmission rates.

Statistical Analysis

Univariable analyses were performed to compare patient characteristics and outcomes across the SC, SLC, and SO groups. One-way analysis of variance and χ^2 tests were performed to compare continuous and categorical measures, respectively, across groups. Fisher's exact test was performed when the χ^2 assumptions were unmet. Post hoc pairwise comparisons were Bonferroni adjusted. Multivariable linear and logistic regression models were constructed to assess the relationship between closure type and outcomes after adjusting for age, sex, race (white vs. other), BMI, ASA ≥3, history of myocardial infarction, history of cancer, procedure location (right colon vs. other), wound class (1/2 vs. 3/4), EBL>500 ml, ICU admission, damage control surgery, intraoperative vasopressor therapy, intraoperative hypothermia, and stoma creation. All demographic variables were used as covariates in the multivariable models. Given the large number of past medical history and surgical/hospitalization detail variables assessed, only those that demonstrated statistically significant differences across closure technique groups were included as covariates. Odds ratios (β value for the hospital LOS linear regression model) and 95% confidence intervals were calculated to present the odds of each outcome for patients with SLC or SO in relation to the SC reference group. The details of each model constructed are presented in Supplemental Digital Content 1, Appendix (http://links.lww.com/TA/D657). Univariable subgroup analyses comparing outcomes of SC and SLC closed patients with or without placement of a negative pressure wound vacuum (NPWV) and of SO patients with or without delayed primary closure (DPC) were performed. A priori power analysis was performed based on previously published mortality rates of 15% after nonelective colorectal surgery.[18] At $\alpha = 0.05$ and 80% power, 138 patients per group were deemed necessary to detect a 10% point difference in mortality rates between groups. All statistical analyses were

TABLE 2. Outcomes by Wound Closure Type

Outcome Measure, Avg. ± SD or n (%)	All Patients (n = 557)	SC (n = 262)	SLC (n = 124)	SO (n = 171)	*p*
Any SSI	103 (18.5)	36 (13.7)$_a$	26 (21.0)$_{a,b}$	41 (24.0)$_b$	**0.020**
Superficial SSI	33 (5.9)	11 (4.2)$_a$	15 (12.1)$_b$	7 (4.1)$_a$	**0.004**
Deep SSI	13 (2.3)	4 (1.5)	1 (0.8)	8 (4.7)	0.068*
Organ/space SSI	70 (12.6)	30 (11.5)$_a$	10 (8.1)$_a$	30 (17.5)$_a$	**0.040**
Enteric fistula	9 (1.6)	1 (0.4)	3 (2.4)	5 (2.9)	0.056*
Fascial dehiscence	24 (4.3)	6 (2.3)	6 (4.8)	12 (7.0)	0.050
In-hospital mortality	44 (7.9)	7 (2.7)$_a$	6 (4.8)$_a$	31 (18.1)$_b$	**<0.001**
Home discharge**	343 (66.9)	185 (72.5)$_a$	85 (72.0)$_a$	73 (52.1)$_b$	**<0.001**
Hospital LOS, d	16.9 ± 16.4	14.5 ± 12.0$_a$	16.4 ± 15.5$_a$	21.0 ± 21.3$_b$	**<0.001**
Unplanned return to OR	49 (8.8)	18 (6.9)	9 (7.3)	22 (12.9)	0.078
30-d Unplanned readmission	90 (16.2)	37 (14.1)	21 (16.9)	32 (18.7)	0.431
Follow-up time, d	51.3 ± 73.5	50.5 ± 74.3	55.2 ± 67.4	49.7 ± 76.9	0.798

*Fisher's exact test was performed (assumptions of χ^2 not met).
**Excludes in-hospital mortalities (n = 513).
p Values <0.05 in bold.
One-way analysis of variance was performed to compare continuous measures across groups; χ^2 was performed to compare categorical measures.
Subscripts describe post hoc Bonferroni adjusted differences between groups. Different letters represent statistically significant differences between groups.

performed in SPSS v. 26 (IBM Inc., Armonk, NY). Statistical significance was assessed at $p < 0.05$.

RESULTS

Patient and Procedure Characteristics

In total, 557 patients were included in the study (SC, n = 262; SLC, n = 124; SO, n = 171). On average, patients were 58.5 ± 17.4 years old and had a BMI of 28.3 ± 7.9 kg/m^2. Approximately 47% of patients were female, 67% were of White race, and 12% were of Hispanic ethnicity; significant differences in BMI and race/ethnicity distributions existed across groups. The most prevalent comorbidities were malnourishment (defined as albumin <3.0) in 31.8% of patients, cancer (21.7%), and diabetes mellitus (19.2%). Twenty-eight percent of patients had a history of prior abdominal surgery, and 32% had an ASA score of ≥3. A trend toward higher ASA scores in the SO group (SC, 23.5%; SLC, 28.3%; SO, 48.7%; $p < 0.001$) was observed (Table 1).

Surgeries were most commonly performed on the left colon (59.4%), followed by the right colon (37.2%), other locations (14.2%), and rectum (8.1%). Rates of right colon procedures were significantly different across groups and were most commonly performed in SC patients (SC, 43.1%; SLC, 25.0%; SO, 36.8%; $p = 0.003$). The most common wound classification was dirty/infected (type IV, 44.2% of patients), followed by clean contaminated (type II), contaminated (type III), and clean (type I) in 30.3%, 21.0%, and 4.5% of patients, respectively. Significant differences in rates of clean, clean contaminated, and dirty/infected wound classifications were observed between groups (all $p < 0.001$), with a trend toward higher rates of dirty/infected wounds in the SLC and SO groups. Overall, 15.8% of patients had an EBL of >500 mL, and rates ranged from 7.3% in the SLC group to 22.2% in the SO group ($p = 0.002$). Significant differences in rates of intraoperative vasopressor therapy ($p < 0.001$), stoma creation ($p < 0.001$), intraoperative hypothermia ($p = 0.046$), ICU admission ($p < 0.001$), and damage control surgery ($p < 0.001$) were also observed across groups. For each of these measures, a trend toward higher rates among SO patients was observed (Table 1).

Unadjusted Outcomes

Overall, 103 of 557 patients (18.5%) experienced an SSI, with a significant difference in rates observed across groups ($p = 0.020$). The lowest SSI rate (13.7%) occurred in the SC group, which was significantly lower than the rate of 24.0% in the SO group ($p < 0.0167$) but statistically similar to that of the SLC group (21.0%). Surgical site infection rates were statistically similar between the SLC and SO groups. The overall rates of superficial, deep, and organ/space SSIs were 5.9%, 2.3%, and 12.6%, respectively. Superficial SSI rates were significantly different across groups ($p = 0.004$) and significantly higher rates in the SLC group (12.1%) compared with the SC (4.2%) or SO groups (4.1%). The average LOS was 16.9 ± 16.4 days on average. Patients in the SO group required longer hospitalizations (21.0 ± 21.3 days) than those in the SC (14.5 ± 12.0 days) and SLC groups (16.4 ± 15.5 days) ($p < 0.0167$). Furthermore, patients with SO had higher rates of in-hospital mortality (18.1%) than those with SC (2.7%) or SLC (4.8%) ($p < 0.0167$) (Table 2).

Of the secondary outcomes examined, only significant differences in rates of home discharge existed across groups ($p < 0.001$). Compared with SC and SLC patients, SO patients were less likely to be discharged home (SC, 72.5%; SLC, 72.0%; SO, 52.1%; $p < 0.0167$). No significant differences in rates of enteric fistula, fascial dehiscence, unplanned return to OR, or 30-day unplanned readmissions were observed. Overall average follow-up time was 51.3 ± 73.5 days and was similar across groups (Table 2).

Risk-Adjusted Outcomes

In comparison with patients with SC, those with SO were at increased risk of in-hospital mortality (OR, 3.003; $p = 0.028$), after controlling for demographics, past medical history, and surgical/hospitalization details. Patients with SLC were at increased risk for superficial SSI (OR, 3.439; $p = 0.014$) only after controlling for these factors. No significant relationships between closure type and any deep SSI, organ/space SSI, enteric fistula, fascial dehiscence, home discharge, hospital length of stay, unplanned return to the OR, or 30-day unplanned readmission were observed in the risk-adjusted models (Table 3).

Subgroup Analysis SC and SLC

A total of 386 patients had either SC or SLC. Of this group, 90.9% (n = 351) did not have a subsequent NPWV applied within 24 hours, while 9% (n = 35) did have an NPWV applied. Patients with NPWV had significantly shorter follow-up times compared with patients without NPWV (38.5 ± 32.6 days vs. 53.3 ± 74.6 days, $p = 0.036$).

No significant relationships between NPWV use and any SSI, superficial SSI, deep SSI, organ/space SSI, enteric fistula, hospital LOS, home discharge, unplanned return to the OR, or 30-day unplanned readmission were observed (Table 4).

Subgroup Analysis SO

A total of 171 patients had their skin left open. Of this group, 66.7% (n = 114) did not have a DPC, while 33.3% (n = 57) did undergo DPC. No significant relationships between DPC use and any SSI, superficial SSI, deep SSI, organ/space SSI, enteric fistula, hospital LOS, home discharge, unplanned return to the OR, 30-day unplanned readmission, or follow-up time were observed (Table 5).

DISCUSSION

The decision to close skin or not is challenging for surgeons as they try to balance concerns for adverse quality outcomes with

TABLE 3. Risk-Adjusted Outcomes by Wound Closure Type in Relation to SC Reference

Wound Closure	Odds Ratio	Odds Ratio 95% CI	*p*
Outcome: any SSI			
SLC	1.427	0.742–2.745	0.287
SO	1.875	0.989–3.557	0.054
Outcome: superficial SSI			
SLC	3.439	1.289–9.172	**0.014**
SO	1.086	0.325–3.625	0.893
Outcome: deep SSI			
SLC	0.374	0.034–4.149	0.423
SO	1.933	0.336–11.120	0.460
Outcome: organ/space SSI			
SLC	0.567	0.241–1.334	0.194
SO	1.509	0.748–3.043	0.250
Outcome: enteric fistula			
SLC	9.732	0.603–156.950	0.109
SO	1.765	0.134–23.252	0.666
Outcome: fascial dehiscence			
SLC	2.663	0.763–9.291	0.124
SO	2.828	0.886–9.030	0.079
Outcome: in-hospital mortality			
SLC	1.094	0.274–4.379	0.899
SO	3.003	1.125–8.019	**0.028**
Outcome: home discharge*			
SLC	1.408	0.740–2.677	0.297
SO	0.722	0.392–1.329	0.295
Outcome: hospital LOS days (β)			
SLC	0.511	−3.062 to 4.084	0.779
SO	−0.970	−4.543 to 2.603	0.594
Outcome: unplanned return to OR			
SLC	1.150	0.451–2.935	0.770
SO	1.168	0.495–2.756	0.724
Outcome: 30-d unplanned readmission			
SLC	1.522	0.785–2.952	0.213
SO	1.580	0.816–3.061	0.175

*Excludes in-hospital mortalities.

p Values <0.05 in bold.

Controlling for age, sex, race (white vs. other), BMI, ASA ≥3, history of myocardial infarction, history of cancer, procedure location (right colon vs. other), wound class (1/2 vs. 3/4), EBL >500 mL, ICU admission, damage-control surgery, intraoperative vasopressor therapy, intraoperative hypothermia, and stoma creation.

ICU, intensive care unit.

TABLE 4. Negative Pressure Wound Vacuum Versus No NPWV in SC and SLC Patients

Outcome Measure, Avg. ± SD or n (%)	No NPWV (n = 351)	NPWV (n = 35)	*p*
Any SSI	57 (16.2)	5 (14.3)	0.764
Superficial SSI	23 (6.6)	3 (8.6)	0.719*
Deep SSI	3 (0.9)	2 (5.7)	0.067*
Organ/space SSI	36 (10.3)	4 (11.4)	0.773*
Enteric fistula	4 (1.1)	0 (0.0)	1.000*
Fascial dehiscence	12 (3.4)	0 (0.0)	0.612*
In-hospital mortality	11 (3.1)	2 (5.7)	0.333*
Home discharge**	251 (72.5)	19 (57.6)	0.070
Hospital LOS, d	15.2 ± 13.6	14.3 ± 8.5	0.726
Unplanned return to OR	24 (6.8)	3 (8.6)	0.725*
30-d Unplanned readmission	50 (14.2)	8 (22.9)	0.174
Follow-up time, d	53.3 ± 74.6	38.5 ± 32.6	**0.036**

*Fisher's exact test performed (assumptions of χ^2 not met).
**Excludes in-hospital mortalities (n = 379).
p Values <0.05 in bold.

patient centric care. Our multi-institutional, prospective observational data suggest that complete skin closure is a viable wound management option in patients who undergo urgent or emergent colorectal surgery for nontraumatic indications. Surgical site infection, LOS, fascial dehiscence, and in-hospital mortality among patients with SC were favorable compared with SO in the unadjusted analyses. After adjusting for significant differences between groups, SO was associated with increased risk of mortality when compared with SC. These findings demonstrate the multitude of factors influencing closure technique selection and outcomes and highlight the importance of risk stratification when attempting to identify which patients would benefit from leaving skin open. In addition, the results bring into question the utilization of the SLC technique in this patient population, as superficial skin infections were higher in the SLC group compared with SC and SO. This large multicenter study also demonstrated no relationship between wound management technique and other clinically important outcomes after risk adjustment, including overall SSI rates, deep and organ space SSI, fascial dehiscence, home discharge, hospital length of stay, readmission, unplanned return to OR, and total follow-up time.

Throughout the last century, generations of surgeons have debated the best management of wounds after emergency abdominal surgery.[9,19,20] Traditional dogma in colon surgeries, where the peritoneum is heavily contaminated, has been to leave the skin open to avoid the possibility of SSI.[19,21] Today, proponents of SO management techniques use a variety of protocols, including the application of dressings changed daily or vacuum-assisted closure devices, followed by wound closure under anesthesia several days later. Theoretically, delaying primary wound closure may decrease bacterial burden via irrigation and dressing changes and increase wound strength via increased oxygen levels, blood flow, protein synthesis, and tissue remodeling.[20] Interestingly, our subgroup analysis of the 157 patients with SO technique shows no significant difference in clinical outcomes for patients who underwent DPC compared with those who did not.

Over the last decade, several meta-analyses of recent randomized controlled trials of SO versus SC techniques for

TABLE 5. Delayed Primary Closure Versus No DPC in SO Patients

Outcome Measure, Avg. ± SD or n (%)	No DPC (n = 114)	DPC (n = 57)	*p*
Any SSI	25 (21.9)	16 (28.1)	0.375
Superficial SSI	3 (2.6)	4 (7.0)	0.224*
Deep SSI	3 (2.6)	5 (8.8)	0.119*
Organ/space SSI	21 (18.4)	9 (15.8)	0.670
Enteric fistula	5 (4.4)	0 (0.0)	0.171*
Fascial dehiscence	10 (8.8)	2 (3.5)	0.341*
In-hospital mortality	20 (17.5)	11 (19.3)	0.779
Home discharge**	49 (52.1)	24 (52.2)	0.996
Hospital LOS, d	21.9 ± 24.0	19.2 ± 14.6	0.450
Unplanned return to OR	18 (15.8)	4 (7.0)	0.106
30-d Unplanned readmission	18 (15.8)	14 (24.6)	0.166
Follow-up time, d	50.6 ± 78.4	47.6 ± 74.4	0.813

*Fisher's exact test performed (assumptions of χ^2 not met).
**Excludes in-hospital mortalities (n = 140).
p Values <0.05 in bold.

contaminated and dirty abdominal operations have been performed. No meta-analysis demonstrated a clear benefit of one technique over another because of high bias levels, small participant numbers, heterogeneity, and discordant results between fixed and random effects models.[22–24]

Focus on SSI remains steadfast for the consequences for the patient and the financial implications on the healthcare system. The measurement of LOS as a health system metric began in the 1980s with the introduction of the diagnosis-related group payments model by the Centers for Medicare and Medicaid Services, which introduced fixed-rate payments to hospitals. Before introducing the diagnosis-related group payment model, hospitals were reimbursed using a days-of-care model.[25] Since then, Centers for Medicare and Medicaid Services has increasingly implemented financial disincentive programs such as the Hospital-Acquired Condition Reduction Program and Hospital Value-Based Purchasing to attempt to control health care costs by holding back reimbursements to low-performing hospitals.[26] In response, health care systems have increased pressure on surgeons to control SSI rates. Surgeons have naturally responded by preferentially adopting open wound care management techniques for high-risk cases to avoid penalties. While potentially decreasing the risk of SSI, the net effect of these policies has shown some indications of added clinical burden by increasing LOS via more prolonged hospitalizations, more unplanned operations, increased consumption of nondurable medical supplies, decreased patient quality of life, increased readmissions, and increased overall costs.[27–29]

Interestingly, after adjusting for confounding variables, our data did not show a significant relationship between leaving skin open and increasing length of stay, with comparable length of stay data among all wound management techniques. However, the absence of a difference in length of stay among wound management type highlights the importance of looking at other clinical factors or wound management decisions that may be contributing to financial and clinical implications to the patient and health care system. Further investigation regarding subsequent management decisions along the path to complete wound healing will be important to better describe how to best mitigate risk with consideration of patient-centered outcomes.

In support, our data show a relationship between the SO technique and increased LOS. Intuitively, the SO group may have experienced an increased hospital LOS because of the increased time required to manage more complex wounds. Beyond the direct effect of the increased time needed for open wound care, other factors theoretically contributing to the increased LOS in the SO group identified in our unadjusted analysis include an increased proportion of patients with ASA[3] 3 scores, dirty/infected wounds, higher operative blood loss, fascial dehiscence, and in-hospital mortality. Although many of these variables are included in our risk-adjusted analysis that supports continued findings of increased LOS in the SO group, further data on the critically ill patient population with a higher disease burden are needed to determine if this relationship persists.

As recent literature suggests a state of clinical equipoise, this study, with its large sample size and prospective multicenter design, aims to answer the question of the best wound management technique after emergency nontraumatic colorectal surgery. Clinically, surgeons should attempt to control for their own cognitive bias and exercise their best judgment to risk stratify the skin wound, considering variables such as higher ASA class, degree of peritoneal contamination, and procedure location to maximize the best possible outcome for the patient and mitigate the consequences of SSI to the healthcare system. However, the results of this study strongly support an SC technique as a reasonable option for wound management in nontraumatic emergency colorectal surgery.

CONCLUSION

Several limitations to this study should be considered. First, this is a prospective observational study, relying on the decision of the operating surgeon for wound management decisions. Although we attempted to control for confounding variables in our analysis, it is possible that additional unmeasured clinical and psychosocial factors such as insurance status and domicile status confounded our results. In addition, some covariates included in the models, such as ASA score, are inherently limited by their subjective nature and thus present the potential lack of inter-rater reliability. Further, the inclusion of multiple demographic and clinical covariates in the multivariable models was purposefully performed given the breadth of factors influencing closure types and outcomes. However, this may have led to model overfitting, particularly for outcomes with low occurrence rates. Second, although indication for surgery was limited to nontraumatic colorectal surgery, indications for procedure were not accounted for, introducing further bias for wound management by the operating surgeon. Given the multitude of factors that influence both closure technique selection and outcomes, the results of this study demonstrate the need for future randomized controlled trials to mitigate these sources of bias. Finally, we recognize that initial management of skin closure may be just one step to final wound healing. Although we did perform subgroup analysis for patients who received subsequent wound management strategies, namely, incisional VAC and DPC, the total number of patients in these groups was small. Further studies considering incisional VAC and DPC in this patient population could prove beneficial to boosting the surgeon's algorithm for decision making in nontraumatic emergent colorectal surgery.

AUTHORSHIP

C.B.F., J.T., and J.R.K. contributed to the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision. S.R. and R.A. contributed to the data collection, data analysis, data interpretation, writing, and critical revision. N.B., E.M.K., D.C.C., C.R.F., B.B., A.A.M., S.S., A.R., G.A.B., D.B., J.L.P., D.S., N.W., J.L., B.N., F.A., L.A.T., J.N., M.M., R.T., S.B.K., M.C., M.K., K.S., and A.P.S. contributed to data collection and manuscript editing.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D658).

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