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The impact of complications on prolonged length of hospital stay after resection in colorectal cancer: A retrospective study of Taiwanese patients

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Abstract

Objectives: To assess the impact of minor, major and individual complications on prolonged length of hospital stay in patients with colorectal cancer (CRC) after surgery using multivariate models.

Methods: This was a retrospective review of data from patients who underwent surgery for stage I–III CRC at two medical centres in southern Taiwan between 2005–2010. Information was derived from four databases. Multivariate logistic regression methods were used to assess the impact of complications on prolonged length of stay (PLOS) and prolonged postoperative length of stay (PPOLOS).

Results: Of 1658 study patients, 251 (15.1%) experienced minor or major postsurgical complications during hospitalizations. Minor and major complications were significantly associated with PLOS (minor, odds ratio [OR] 3.59; major, OR 8.82) and with PPOLOS (minor, OR 5.55; major, OR 10.00). Intestinal obstruction, anastomosis leakage, abdominal abscess and bleeding produced the greatest impact.

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Conclusions: Minor and major complications were stronger predictors of prolonged hospital stay than preoperative demographic and disease parameters. Compared with the PLOS model, the PPOLOS model better predicted risk of prolonged hospital stay. Optimal surgical and medical care have major roles in surgical CRC patients.

Keywords
Complications, prolonged length of stay (PLOS), prolonged postoperative length of stay (PPOLOS), colorectal cancer, Taiwan

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Introduction

The World Health Organization (WHO) reported that worldwide, 1.4 million new cases of colorectal cancer (CRC) were diagnosed in 2012 and 0.69 million patients died of this disease.[1] In the USA and Europe, CRC ranks as the third most common cancer.[2,3] Moreover, as a result of ageing populations and changing life styles, the numbers of new patients are expected to increase in developed[4,5] and developing nations.[6,7] Surgery is the primary treatment for CRC,[8] and in Taiwan in 2010, of 10 674 new cases of CRC, 65.73% underwent surgery, which was an increase compared with previous years.[9] One possible explanation for the increase in the incidence of CRC cases in Taiwan is the changing pattern in life style, particularly the increased consumption of a 'Western' fast food diet.[10,11] Another factor may be the implementation of a cancer screening programme in 2004 by the Taiwan National Health Promotion Bureau, which has resulted in the identification of more early stage cancers.[12]

Several outcome measures such as 30-day unplanned hospital readmission, 30-day morbidity and mortality and prolonged hospital stays for surgical cancer care, have been proposed as important indicators of short-term outcome quality.[13] Among these indicators, prolonged hospital stay not only delays discharge and results in increased use of medical resources and higher costs, but it also predicts greater risk for readmission[14,15] and short-term mortality.[14,16] Given scarce medical resources and an environment of medical cost containment, prolonged hospital stay is attracting increasing attention in many healthcare systems worldwide. For example, in the USA and some European countries, several initiatives have been proposed to improve the quality and length of hospital stay.[17,18]

Hospital length of stay is commonly measured in two forms, prolonged length of stay (PLOS) and prolonged postoperative length of stay (PPOLOS). Healthcare executives and policy makers tend to focus on PLOS because of concerns related to utilization efficiency, whereas surgeons or medical staff tend to focus on PPOLOS because of concerns related to quality of care.[19] Studies derived from administrative claims have generally used PLOS because of a lack of information on dates of surgery.[20–23] Studies derived from medical chart review data have used mixed methods that have varied according to the study objectives.[24,25]

The identification of risk factors associated with hospital length of stay may play an important role in understanding how to reduce resource consumption and enhance quality of care. Previous studies have shown that prolonged hospital stay is associated with patient demographic and clinical characteristics, provider characteristics, intraoperative factors, and postoperative

complications.[18,20,22,23,26] Patient demographic and clinical characteristics include age,[18,20,26] sex,[15] American Society of Anesthesiologists (ASA) classification,[20,26] comorbidity,[18] and serum albumin level.[20,24] Intraoperative variables include operation time,[26] transfusion use,[20] and provider services volume.[18,22] In addition, postoperative complications have a significant impact on prolonged hospital stays, but studies assessing their influence have tended to focus on aggregated complications rather than on each individual complication.[23,26] Moreover, risk factors and their association with complications regarding PLOS and PPOLOS have not been well elucidated.

With the exception of one Japanese study,[27] which had a small sample size and did not use multivariate analytical methods, hospital length of stay and associated risk factors have been under-investigated in Asian populations. To the best of our knowledge this present study is the first to explore the impact of minor and major complications on both PLOS and PPOLOS following surgery for CRC in Taiwanese patients using multivariate logistic regression.

Patients and methods

Patient population

This retrospective study used data from patients who underwent surgery for CRC at two medical centres, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan and E-DA Hospital, Kaohsiung, Taiwan, in southern Taiwan between January 2005 and December 2010. Information was gathered from four databases. The first data source was hospital inpatient claims data, from which patients diagnosed with CRC who underwent surgery during the study period were identified. Variables derived from the data source included admission and discharge dates, diagnosis and procedure codes. The second data source was patients' medical charts, which provided information on patient demographic and operation-related characteristics (e.g. preoperative supplementary treatment procedures, comorbidity, hospitalization procedures for ongoing surgery, complications and post-surgical treatment procedures). An experienced senior disease coder (H.L.) obtained clinical information about the patients from the medical charts based on an instrument constructed for this study that was validated by two clinicians (J.Y., H.P.). The third data source was the 2012 Taiwan National Cancer Registry database, which contains cancer-related information, including cancer stage and date of recurrence. The fourth data source was the Taiwan Central Statistics Office (death registry database), from which survival status was established. Personal identification numbers were used to merge the four datasets. Patients were eligible for the study if they had been newly diagnosed with primary CRC (i.e. International Classification of Diseases, 9th Revision, Clinical Modification diagnosis codes 153–154 and procedure codes 45.7x, 45.8, 48.4x–48.6x) between January 2005 and December 2010 and were admitted to hospital for colorectal surgery. Patients who only received ostomies or had American Joint Committee on Cancer (AJCC) stages 0, IV, or unknown were excluded.

The study was approved by the Internal Research Boards (IRB) of both hospitals (registration numbers: KMUH-IRB-2011 0449 and EMRP-101-074) and because this was a retrospective study based on data from four databases, patient informed consent was not required.

Study outcomes

Outcomes of interests were PLOS and PPOLOS. In common with other outcome studies in CRC, hospital length of stay was determined as the duration greater than the

upper-quartile for all cases.[18,20,22,24,26,28] Therefore, in this study PLOS was defined as 20 days or longer between admission and discharge and PPOLOS was defined as 14 days or longer between operation and discharge or death.

Surgical complications were evaluated using definitions used in previous studies and were separated into major and minor categories.[20,29] Conditions that were identified before surgery were regarded as comorbidities. To validate the accuracy of the information, some complications were evaluated by combining imaging data with laboratory analyses.

Statistical analyses

For the descriptive analysis, demographic, disease-related and treatment-related characteristics by type of complication (i.e. none, minor, and major) were evaluated using χ^2-test for categorical variables and *t*-test for continuous variables. Multivariate logistic regression adjusted for confounding variables was used to assess the association between complications and the likelihood of PLOS or PPOLOS. The models were adjusted for demographic (i.e. age at onset,[30] sex, and body mass index), disease-related (i.e. Charlson comorbidity score,[31] ASA classification, ileus on admission, location of tumour, AJCC stage,[32] tumour grade,[32] lymphatic involvement, creatinine and haemoglobin values) and treatment-related variables (i.e. operation time and operation approach).

Model goodness-of-fit was examined by the Hosmer–Lemeshow test (*P*-value)[33] and the Cox and Snell measure (R^2).[34] Data analyses were performed using IBM SPSS software (version 19.0 for Windows®; IBM Corp, Armonk, NY, USA) and Stata 13 statistical software (Stata Corp., College Station, Texas, USA, 2013). A *P*-value < 0.05 was considered to indicate statistical significance.

Results

Using patients' claims data from January 2005 to December 2010, 1948 patients with newly diagnosed primary CRC who were admitted for surgery were identified. Patients who only received ostomies ($n = 56$, 2.9%), had AJCC stages 0, IV or unknown ($n = 228$, 11.7%) or were without discharged dates ($n = 6$, 0.3%) were excluded from the study; the remaining 1658 patients were included in the final analysis.

A summary of patient demographic, disease-related, and treatment-related characteristics and outcomes is shown in Table 1. By comparison with non-prolonged stay patients, PLOS and PPOLOS patients were more likely to be older, have ASA scores of III–IV, AJCC stages II and III and higher Charlson comorbidity scores. In addition, they had more minor and major surgical complications than non-prolonged stay patients, more ileus on admission and had more abnormal haemoglobin values and longer surgery times.

Types of surgical complication classified as minor or major are shown in Table 2. Of the 1658 study patients, 251 (15.1%) experienced minor or major postsurgical complications during hospitalization. The most frequent minor complication was urinary tract infection ($n = 67$, 4.0%), followed by intestinal obstruction ($n = 37$, 2.2%) and abdominal wound infection ($n = 35$, 2.1%). In terms of major complications, anastomosis leakage ($n = 31$, 1.9%) was the most common, followed by sepsis ($n = 28$, 1.7%) and abdominal abscess ($n = 23$, 1.4%).

The results of multivariate logistic regression analysis examining the impact of various factors on prolonged hospital stay with and without adjustment of confounding variables are shown in Table 3. Minor complications (odds ratio [OR] 3.59, 95% confidence interval [CI] 2.41, 5.36; $P < 0.001$) and major complications (OR 8.82, 95% CI 5.30, 14.67; $P < 0.001$) were significantly associated with PLOS.

Table 1. Patient characteristics and complications according to prolonged length of stay and prolonged postoperative length of stay ($n = 1658$).

	Prolonged hospital length of stay (PLOS) ($n = 1658$)			Prolonged postoperative length of stay (PPOLOS) ($n = 1658$)		
	No ($n = 1279$)	Yes ($n = 379$)	Statistical significance[a]	No ($n = 1266$)	Yes ($n = 392$)	Statistical significance[a]
Demographic characteristics						
Onset age, years	63.8 ± 12.5	68.4 ± 12.7	$P < 0.001$	63.9 ± 12.5	67.9 ± 12.9	$P < 0.001$
Onset age, years,						
<50	159 (12.5)	32 (8.5)	$P < 0.001$	155 (12.3)	36 (9.2)	$P < 0.001$
50–59	296 (23.2)	64 (16.9)		289 (22.9)	71 (18.2)	
60–69	351 (27.5)	86 (22.8)		347 (27.5)	90 (23.0)	
70–79	360 (28.2)	121 (32.0)		363 (28.7)	118 (30.2)	
≥80	110 (8.6)	75 (19.8)		109 (8.6)	76 (19.4)	
Men	729 (57.0)	224 (59.1)	NS	713 (56.3)	240 (61.2)	NS
BMI, kg/m^2	23.9 ± 3.6	23.6 ± 3.9	NS	23.8 ± 3.5	23.8 ± 4.0	NS
BMI, kg/m^2						
<18.5	69 (5.6)	30 (8.7)	NS	66 (5.4)	33 (9.1)	NS
18.5– <24	592 (47.8)	170 (49.4)		588 (48.2)	174 (48.1)	
24– <27	355 (28.7)	92 (26.7)		354 (29.0)	93 (25.7)	
≥27	223 (18.0)	52 (15.1)		213 (17.4)	62 (17.1)	
Disease-related characteristics						
ASA group						
I–II	722 (56.6)	146 (38.5)	$P < 0.001$	696 (55.2)	172 (43.9)	$P < 0.001$
III–IV	553 (43.4)	233 (61.5)		566 (44.8)	220 (56.1)	
Charlson score[31]						
0	522 (40.8)	102 (26.9)	$P < 0.001$	512 (40.4)	112 (28.6)	$P < 0.001$
1–2	583 (45.6)	167 (44.1)		574 (45.3)	176 (44.9)	
≥3	174 (13.6)	110 (29.0)		180 (14.2)	104 (26.5)	
Ileus on admission	172 (13.4)	102 (26.9)		173 (13.7)	101 (25.8)	$P < 0.001$
Location of tumour						
Colon	706 (55.6)	217 (58.0)	NS	727 (57.8)	196 (50.8)	$P = 0.014$
Rectum	563 (44.4)	157 (42.0)		530 (42.2)	190 (49.2)	
AJCC stage[32]						
I	252 (19.7)	53 (14.0)	$P = 0.015$	250 (19.7)	55 (14.0)	$P = 0.032$
II	493 (38.5)	171 (45.1)		494 (39.0)	170 (43.4)	
III	534 (41.8)	155 (40.9)		522 (41.2)	167 (42.6)	
Tumour grade[32]						
Well and moderately differentiated	1179 (92.8)	343 (90.7)	NS	1165 (92.6)	357 (91.5)	NS
Poorly and undifferentiated	91 (7.2)	35 (9.3)		93 (7.4)	33 (8.5)	
Lymphatic involvement	499 (39. 0)	140 (36.9)		482 (38.1)	157 (40.1)	NS
Creatinine, mg/dl	1.1 ± 1.0	1.5 ± 4.4	NS	1.1 ± 1.1	1.46 ± 4.2	NS
Creatinine[b]						
Normal	1024 (81.7)	262 (70.8)	$P < 0.001$	1002 (80.9)	284 (73.8)	$P = 0.002$
Abnormal	229 (18.3)	108 (29.2)		236 (19.1)	101 (26.2)	

(continued)

Table 1. Continued.

	Prolonged hospital length of stay (PLOS) ($n = 1658$)			Prolonged postoperative length of stay (PPOLOS) ($n = 1658$)		
	No ($n = 1279$)	Yes ($n = 379$)	Statistical significance[a]	No ($n = 1266$)	Yes ($n = 392$)	Statistical significance[a]
Haemoglobin, g/dl	12.3 ± 2.4	12.1 ± 8.1	NS	12.2 ± 2.5	12.3 ± 7.9	NS
Haemoglobin[c]						
Normal	696 (54.8)	158 (41.8)	$P < 0.001$	691 (54.9)	163 (41.8)	$P < 0.001$
Abnormal	575 (45.2)	220 (58.2)		568 (45.1)	227 (58.2)	
Treatment-related characteristics						
Operation time, min	199.5 ± 77.4	216.7 ± 84.4	$P < 0.001$	197.7 ± 75.9	222.2 ± 87.0	$P < 0.001$
Operation time, min						
≤190	688 (53.9)	168 (44.9)	$P = 0.002$	691 (54.7)	165 (42.6)	$P < 0.001$
>190	589 (46.1)	206 (55.1)		573 (45.3)	222 (57.4)	
Operation approach						
Open	1083 (84.7)	333 (87.9)	NS	1060 (83.7)	356 (90.8)	$P = 0.001$
Laparoscopic	196 (15.3)	46 (12.1)		206 (16.3)	36 (9.2)	
Selected outcomes						
Any complication	114 (8.9)	137 (36.1)	$P < 0.001$	102 (8.1)	149 (38.0)	$P < 0.001$
Any minor complication	84 (6.6)	84 (22.2)	$P < 0.001$	70 (5.5)	98 (25.0)	$P < 0.001$
Any major complication	33 (2.6)	74 (19.5)	$P < 0.001$	35 (2.8)	72 (18.4)	$P < 0.001$

Data are expressed as mean ± SD or *n* of patients (%).
The datasets for some of the characteristics are incomplete due to missing data.
[a]χ2-test for categorical variables and t-test for continuous variables.
[b]Creatinine: normal 0.7 to 1.2 mg/dl (men), 0.5 to 1.0 mg/dl (women).
[c]Haemoglobin: normal 13.4 to 17.2 g/dl (men), 11.1 to 15.1 g/dl (women).
BMI, body mass index; ASA, American Society of Anesthesiologists; AJCC, American Joint Committee on Cancer; NS, no significant between-group difference ($P \geq 0.05$).

Likewise, minor complications (OR 5.55, 95% CI 3.72, 8.27; $P < 0.001$) and major complications (OR 10.00, 95% CI 5.95, 16.83; $P < 0.001$) were significantly associated with PPOLOS. For severe comorbidity (comorbidity score ≥ 3) the OR was 1.95 (PLOS, 95% CI 1.30, 2.93; $P = 0.001$; PPOLOS, 95% CI 1.29, 2.94; $P = 0.002$). With the exception of ≥ 80 years (PPOLOS, OR 2.01, 95% CI 1.11, 3.64; $P = 0.022$), increasing age was not a predictor of prolonged hospital stay nor were AJCC values or the presence of ileus on admission. Operation time > 190 min was associated with prolonged hospital stay (PLOS, OR 1.42, 95% CI 1.07, 1.87; $P = 0.014$: PPOLOS, OR 1.77, 95% CI 1.34, 2.34; $P < 0.001$) as was abnormal haemoglobin (PPOLOS, OR 1.43, 95% CI 1.06, 1.92; $P = 0.018$).

In terms of goodness of fit, for the Hosmer–Lemeshow test,[33] the *P*-values were 0.208 and 0.573 for the PLOS and PPOLOS models, respectively. For the Cox and Snell test,[34] the R^2 values were 0.132 and 0.168 for the PLOS and PPOLOS models, respectively. The higher values for PPOLOS in both tests suggest that the PPOLOS multivariate regression model was a relatively better fit compared with the PLOS model.

Table 4 shows the distribution of individual surgical complications by PLOS and

Table 2. Numbers and percentage of patients by type of postsurgical complication.

Variable	*n* (%)
Total number of patients	1658
Any complication (patients)[a,b]	251 (15.1)
Any minor complication (patients)[c]	168 (10.1)
Urinary tract infection	67 (4.0)
Intestinal obstruction (prolonged ileus)	37 (2.2)
Abdominal wound infection	35 (2.1)
Gastrointestinal tract bleeding	26 (1.6)
Other minor complication (patients)	9 (0.5)
Urinary retention	6 (0.4)
Colitis/Enteritis	2 (0.1)
Atrial fibrillation	2 (0.1)
Any major complication (patients)[d]	107 (6.5)
Anastomosis leakage (patients)	31 (1.9)
Anastomosis leakage with surgical reintervention	23 (1.4)
Anastomotic leakage with radiological drainage	2 (0.1)
Anastomotic leakage with antibiotics therapy	7 (0.4)
Sepsis	28 (1.7)
Abdominal abscess (patients)	23 (1.4)
Abdominal abscess with antibiotics therapy	9 (0.5)
Abdominal abscess with radiological drainage	9 (0.5)
Abdominal abscess with surgical reintervention	6 (0.4)
Respiration failure	15 (0.9)
Pneumonia	14 (0.8)
Bleeding (patients)	14 (0.8)
Bleeding with surgical reintervention	9 (0.5)
Bleeding with blood transfusion after operation	5 (0.3)
Other major complication (patients)	33 (2.0)
Other Single organ failure	8 (0.5)
Cerebral vascular accident	8 (0.5)
Shock	6 (0.4)
Acute myocardial infarction	4 (0.2)
Intestinal obstruction with total parenteral nutrition	4 (0.2)
Disruption of operation wound	3 (0.2)
Pulmonary oedema	2 (0.1)
Multiple organ failure	1 (0.1)
Dehydration secondary to ileostomy output	1 (0.1)

Data are expressed as *n* (%).
[a]Patients may have had more than one complication.
[b]Patients with any complication: 251; total number of complications: 339.
[c]Patients with any minor complication: 168; number of complications: 175.
[d]Patients with any major complication: 107; number of complications: 164.

PPOLOS categories. The most common major complication, anastomosis leakage, occurred in 74.2% (23 of 31) of PLOS and 80.6% (25 of 31) of PPOLOS patients. The most common minor complication occurring in both groups was intestinal obstruction, which occurred in 56.8% (21 of 37) of PLOS and 75.7% (28 of 37) of PPOLOS patients.

Figures 1 and 2 show multivariate logistic regression results in terms of ORs for the effect of each complication on patient outcomes in the PLOS and the PPOLOS models, respectively. Compared with patients without intestinal obstruction, the OR for PLOS was 5.55 times (95% CI 2.59, 11.91; $P < 0.001$) greater for those with the complication. The OR for PPOLOS was 18.18 (95% CI 7.05, 46.89; $P < 0.001$) times greater for patients with intestinal obstruction than for those without. Compared with patients without anastomosis leakage, the OR for PLOS was 9.87 times (95% CI 4.08, 23.91; $P < 0.001$) greater for those with the complication. The OR for PPOLOS was 15.30 (95% CI 5.86, 39.95; $P < 0.001$) times greater for patients with anastomosis leakage than for those without the complication. Although pneumonia only affected 14 patients, it was not a significant predictor of PLOS (OR 3.17, 95% CI 0.82, 12.20),

Table 3. Predictors of prolonged length of stay (PLOS) and prolonged postoperative length of stay (PPOLOS) derived from multivariate models.

	PLOS		PLOS		PPOLOS		PPOLOS	
	Unadjusted		Adjusted		Unadjusted		Adjusted	
Variables	OR (95% CI)	Statistical significance	OR (95% CI)	Statistical significance	OR (95% CI)	Statistical significance	OR (95% CI)	Statistical significance
Constant			0.07	$P < 0.001$			0.06	$P < 0.001$
Demographic characteristics								
Onset age, years (<50)								
50–59	1.07 (0.67, 1.71)	NS	0.94 (0.55, 1.58)	NS	1.06 (0.68, 1.65)	NS	0.89 (0.53, 1.48)	NS
60–69	1.22 (0.78, 1.90)	NS	1.00 (0.60, 1.66)	NS	1.12 (0.73, 1.72)	NS	0.94 (0.57, 1.55)	NS
70–79	1.67 (1.08, 2.57)	$P = 0.02$	1.14 (0.68, 1.90)	NS	1.40 (0.92, 2.13)	NS	1.04 (0.63, 1.73)	NS
≥80	3.39 (2.10, 5.47)	$P < 0.001$	1.64 (0.90, 2.99)	NS	3.00 (1.88, 4.78)	$P < 0.001$	2.01 (1.11, 3.64)	$P = 0.022$
Sex (Male)								
Female	0.92 (0.73, 1.16)	NS	1.06 (0.80, 1.41)	NS	0.82 (0.65, 1.03)	NS	0.96 (0.72, 1.28)	NS
BMI, kg/m^2 (18.5– <24)								
<18.5	1.51 (0.95, 2.40)	NS	1.40 (0.83, 2.35)	NS	1.69 (1.08, 2.65)	0.023	1.68 (0.99, 2.84)	NS
24– <27	0.90 (0.68, 1.20)	NS	0.96 (0.69, 1.33)	NS	0.89 (0.67, 1.18)	NS	0.99 (0.71, 1.38)	NS
≥27	0.81 (0.57, 1.15)	NS	0.78 (0.53, 1.16)	NS	0.98 (0.71, 1.37)	NS	1.00 (0.68, 1.47)	NS
Disease-related characteristics								
ASA group (I–II)								
III–IV	2.08 (1.65, 2.64)	$P < 0.001$	1.35 (0.99, 1.85)	NS	1.57 (1.25, 1.98)	$P < 0.001$	1.05 (0.76, 1.44)	NS
Charlson score[31] (0)								
1–2	1.47 (1.12, 1.93)	$P = 0.006$	1.01 (0.73, 1.40)	NS	1.40 (1.08, 1.83)	$P = 0.013$	1.04 (0.75, 1.44)	NS
≥3	3.24 (2.35, 4.45)	$P < 0.001$	1.95 (1.30, 2.93)	$P = 0.001$	2.64 (1.92, 3.62)	$P < 0.001$	1.95 (1.29, 2.94)	$P = 0.002$
Ileus on admission (No)								
Yes	2.37 (1.79, 3.13)	$P < 0.001$	1.37 (0.96, 1.95)	NS	2.19 (1.66, 2.89)	$P < 0.001$	1.39 (0.97, 2.01)	NS
Location of tumour (Colon)								
Rectum	0.91 (0.72, 1.15)	NS	1.17 (0.88, 1.56)	NS	1.33 (1.06, 1.67)	0.015	1.71 (1.28, 2.28)	$P < 0.001$
AJCC stage[32] (I)								
II	1.65 (1.17, 2.33)	$P = 0.004$	1.53 (1.02, 2.30)	$P = 0.040$	1.56 (1.11, 2.20)	$P = 0.01$	1.45 (0.96, 2.18)	NS
III	1.38 (0.98, 1.95)	NS	1.64 (0.73, 3.72)	NS	1.45 (1.04, 2.04)	$P = 0.031$	1.36 (0.57, 3.25)	NS

(continued)

Table 3. Continued.

	PLOS		PLOS		PPOLOS		PPOLOS	
	Unadjusted		Adjusted		Unadjusted		Adjusted	
Variables	OR (95% CI)	Statistical significance	OR (95% CI)	Statistical significance	OR (95% CI)	Statistical significance	OR (95% CI)	Statistical significance
Tumour grade (Well/moderately differentiated)[32]								
Poor and undifferentiated	1.32 (0.88, 1.99)	NS	1.38 (0.85, 2.25)	NS	1.16 (0.77, 1.75)	NS	1.23 (0.75, 2.03)	NS
Lymphatic involvement (No)								
Yes	0.92 (0.72, 1.16)	NS	0.69 (0.32, 1.49)	NS	1.09 (0.86, 1.37)	NS	0.92 (0.41, 2.10)	NS
Creatinine (Normal)[a]								
Abnormal	1.84 (1.41, 2.40)	$P < 0.001$	1.22 (0.88, 1.68)	NS	1.51 (1.16, 1.97)	$P = 0.003$	1.07 (0.76, 1.49)	NS
Haemoglobin (Normal)[b]								
Abnormal	1.69 (1.34, 2.13)	$P < 0.001$	1.29 (0.96, 1.73)	NS	1.69 (1.35, 2.13)	$P < 0.001$	1.43 (1.06, 1.92)	$P = 0.018$
Treatment-related characteristics								
Operation time category (≤190 min)								
>190 min	1.43 (1.14, 1.81)	$P = 0.002$	1.42 (1.07, 1.87)	$P = 0.014$	1.62 (1.29, 2.04)	$P < 0.001$	1.77 (1.34, 2.34)	$P < 0.001$
Operation approach (Open)								
Laparoscopic	0.76 (0.54, 1.08)	NS	0.74 (0.49, 1.11)	NS	0.52 (0.36, 0.76)	$P = 0.001$	0.40 (0.25, 0.64)	$P < 0.001$
Outcome								
Complications (None)								
Minor	3.83 (2.68, 5.47)	$P < 0.001$	3.59 (2.41, 5.36)	$P < 0.001$	5.61 (3.94, 8.00)	$P < 0.001$	5.55 (3.72, 8.27)	$P < 0.001$
Major	10.38 (6.79, 15.88)	$P < 0.001$	8.82 (5.30, 14.67)	$P < 0.001$	9.51 (6.26, 14.47)	$P < 0.001$	10.00 (5.95, 16.83)	$P < 0.001$
Mortality (No)								
Yes	6.20 (2.06, 18.61)	$P = 0.001$	0.41 (0.10, 1.70)	NS	4.37 (1.51, 12.69)	$P = 0.007$	0.69 (0.15, 3.15)	NS
Cox and Snell (R^2)[34]			0.132				0.168	
Hosmer–Lemeshow (*P* value)[33]			0.208				0.573	

Models adjusted for demographic (i.e. age at onset, sex, and body mass index), disease-related (i.e. Charlson comorbidity score, ASA classification, ileus on admission, location of tumour, AJCC stage, tumour grade, lymphatic involvement, creatinine and haemoglobin values) and treatment-related variables (i.e. operation time and operation approach).
[a]Creatinine: normal 0.7 to 1.2 mg/dl (men), 0.5 to 1.0 mg/dl (women).
[b]Haemoglobin: normal 13.4 to 17.2 g/dl (men), 11.1 to 15.1 g/dl (women).
OR, odds ratio; CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiologists; AJCC, American Joint Committee on Cancer; NS, not statically significant ($P \geq 0.05$).

Table 4. Postsurgical complications related to prolonged length of stay (PLOS) and prolonged postoperative length of stay (PPOLOS).

	PLOS			PPOLOS		
	No	Yes	Statistical significance[a]	No	Yes	Statistical significance[a]
Any complication ($n = 251$)	114 (45.4)	137 (54.6)	$P < 0.001$	102 (40.6)	149 (59.4)	$P < 0.001$
Any minor complication ($n = 168$)	84 (50.0)	84 (50.0)	$P < 0.001$	70 (41.7)	98 (58.3)	$P < 0.001$
Urinary tract infection ($n = 67$)	35 (52.2)	32 (47.8)	$P < 0.001$	31 (46.3)	36 (53.7)	$P < 0.001$
Ileus/Intestinal obstruction ($n = 37$)	16 (43.2)	21 (56.8)	$P < 0.001$	9 (24.3)	28 (75.7)	$P < 0.001$
Abdominal wound infection ($n = 35$)	17 (48.6)	18 (51.4)	$P < 0.001$	10 (28.6)	25 (71.4)	$P < 0.001$
Gastrointestinal tract bleeding ($n = 26$)	11 (42.3)	15 (57.7)	$P < 0.001$	16 (61.5)	10 (38.5)	NS
Other minor complication ($n = 9$)	6 (66.7)	3 (33.3)	NS	5 (55.6)	4 (44.4)	NS
Any major complication ($n = 107$)	33 (30.8)	74 (69.2)	$P < 0.001$	35 (32.7)	72 (67.3)	$P < 0.001$
Anastomosis leakage ($n = 31$)	8 (25.8)	23 (74.2)	$P < 0.001$	6 (19.4)	25 (80.6)	$P < 0.001$
Sepsis ($n = 28$)	7 (25.0)	21 (75.0)	$P < 0.001$	10 (35.7)	18 (64.3)	$P < 0.001$
Abdominal abscess ($n = 23$)	4 (17.4)	19 (82.6)	$P < 0.001$	6 (26.1)	17 (73.9)	$P < 0.001$
Respiration failure ($n = 15$)	6 (40.0)	9 (60.0)	$P = 0.001$	8 (53.3)	7 (46.7)	$P = 0.035$
Pneumonia ($n = 14$)	5 (35.7)	9 (64.3)	$P < 0.001$	5 (35.7)	9 (64.3)	$P < 0.001$
Bleeding ($n = 14$)	5 (35.7)	9 (64.3)	$P < 0.001$	5 (35.7)	9 (64.3)	$P < 0.001$
Other major complication ($n = 33$)	11 (33.3)	22 (66.7)	$P < 0.001$	15 (45.5)	18 (54.5)	$P < 0.001$

Data are expressed as *n* (%).
[a] χ^2-test; NS, no statically significant between group difference ($P \geq 0.05$).

but it was statistically significant (OR 5.78, 95% CI 1.31, 25.55; $P = 0.021$) for PPOLOS.

Discussion

This present study showed that in a Taiwanese population of patients with CRC, minor and major complications were significantly associated with PLOS and PPOLOS. After adjustment for patient demographic and cancer characteristics and other treatment variables, the results indicated that compared with patients who had no complications following surgery, major complications had a greater impact on prolonged stay than minor complications. In addition, postsurgical complications had a greater impact on prolonged stay than preoperative parameters. For example, the likelihood of PPOLOS was 5.55 times greater with minor complications and 10.00

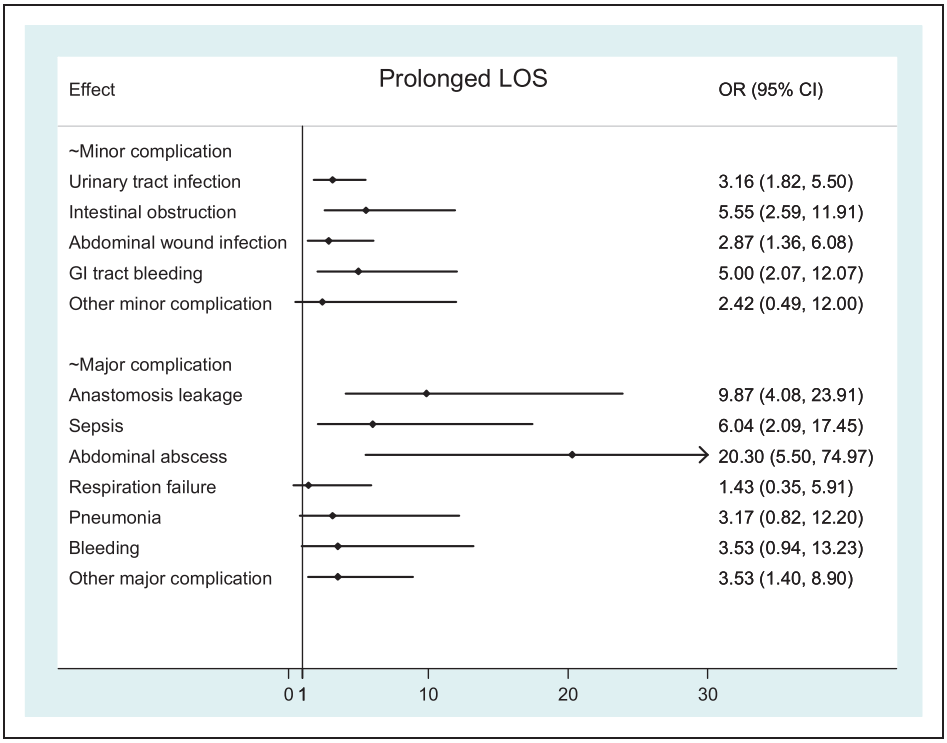

Figure 1. Forest plot of the multivariate logistic regression model used for predicting the effect of minor and major complications on prolonged length of stay (PLOS). The model was adjusted for patient, disease-related and treatment-related characteristics and death index hospitalization. Due to space limitation, variables with 95% confidence intervals > 30 times are presented with an arrowhead in the right tale (i.e. abdominal abscess).

times greater with major complications, whereas for severe comorbidity (comorbidity score ≥ 3) the OR was 1.95 and for $\geq$80 years of age the OR was 2.01. These results suggest that complications are more important than preoperative demographic and disease parameters in predicting prolonged hospital stay for CRC patients undergoing resection.

Although previous studies have reported the frequency of complications in patients with CRC, they have not been fully analysed as predictors of hospital stay.[25,27] For example, one study reported that that abdominal infection/abscess and wound infection were among the predictors of prolonged stay but the data were derived from a claims database and complications were confined to indications for reoperation.[23] By contrast, in this present study, the comprehensive analysis of the effect of complications on hospital stay has permitted both the assessment of surgical and non-surgical factors.

In agreement with previous research,[23] anastomosis leakage, abscess, and bleeding were found to be major postsurgical complications that affected hospital length of stay because they generally required reoperation during the index hospitalization. In addition, the results of this present study show that major and minor complications have a

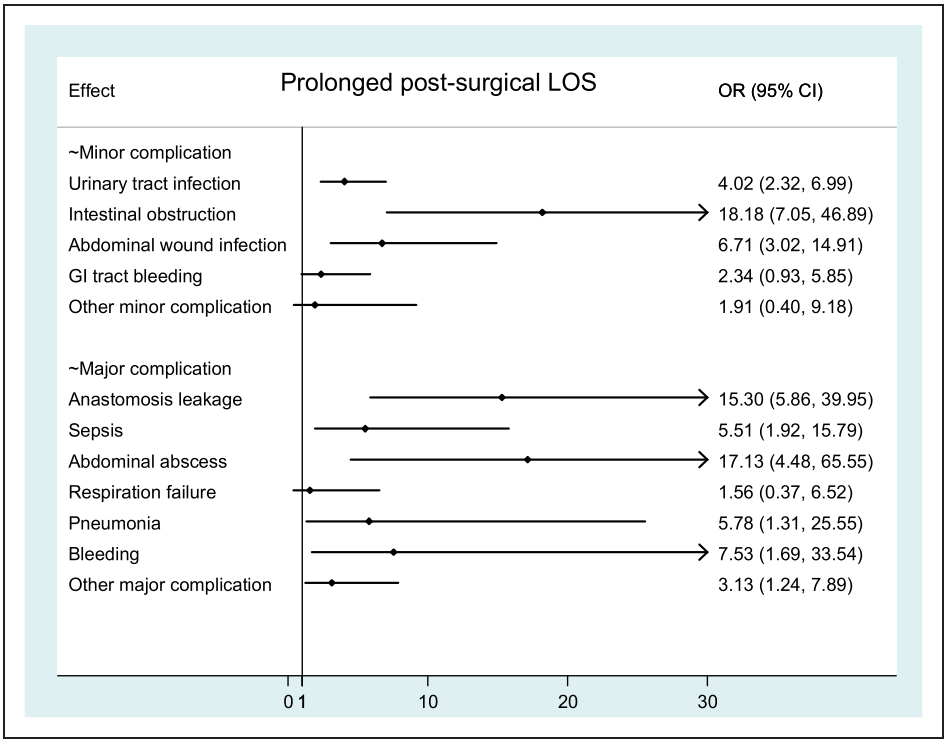

Figure 2. Forest plot of the multivariate logistic regression model used for predicting the effect of minor and major complications on prolonged postoperative length of stay (PPLOS). The model was adjusted for patient, disease-related and treatment-related characteristics and death index hospitalization. Due to space limitation, variables with 95% confidence intervals > 30 times are presented with an arrowhead in the right tale (i.e. intestinal obstruction, anastomosis leakage, abdominal abscess, and bleeding).

hierarchical impact on PLOS and PPOLOS. For example, surgical complications had a greater impact on prolonged stay than non-surgical complications.

The findings of this study show that surgical and medical care need to be at optimum levels for patients with CRC who require surgery. Indeed, some Western countries have tried different approaches to achieve this goal.[20,21,35] For instance, at one centre in the USA a strict postoperative protocol has been developed to fast-track the postoperative course for surgical patients[35] and has shown promising results in patients requiring colon resection.[18] In addition to postoperative management, the surgical approach may also affect hospital length of stay. One study found that low anterior resection had an impact on hospital stay in rectal cancer patients; primary anastomosis had the best outcome but anastomosis with de-functioning stoma was associated with prolonged hospital stay.[21] Successful policies and practices experienced elsewhere might serve as a benchmark for clinicians in Taiwan.

Statistical analyses in this study indicated that the PPOLOS model was better than the PLOS model for predicting prolonged hospital stay. Compared with PLOS, the PPOLOS generally showed higher probabilities for most complications, such as intestinal obstruction, abdominal leakage, and bleeding. Interestingly, pneumonia was not

a significant predictor in the PLOS model (OR 3.17) but was a good predictor (OR 5.78) in the PPOLOS model. To our knowledge, the selection of PLOS and PPOLOS in one study as outcome measures has not been previously adopted. Based on the present study findings, we believe that PPOLOS should be recommended if surgical data are to be analysed.

The study had some limitations. Some variables such as blood sampling and use of epidural or other anaesthetic techniques, which may have impacted on outcomes, were not recorded. Also, the study population was derived from only two medical centres in southern Taiwan and so the results cannot be generalized to the whole Taiwanese population.

In conclusion, the study found that individual minor and major complications had a hierarchical impact on PLOS and PPOLOS. Additionally, both minor and major complications were stronger predictors of hospital stay compared with preoperative characteristics. Unsurprisingly, major complications were more significantly correlated with prolonged stay than minor complications. Compared with the PLOS multivariate analysis model, the PPOLOS model was better at predicting risk of prolonged stay. The results of this study have implications for research, policy and clinical perspectives because they confirm that optimal surgical and medical care have important roles to play in the management of patients undergoing surgical treatment of CRC.

Declaration of conflicting interests

The authors declare that there are no conflicts of interest.

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