

Development of a Simple Perioperative Risk Prediction Model for Postoperative Complications After Laparoscopic Appendectomy: A Single-Center Retrospective Study

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Abstract

Aim This study aimed to identify factors associated with postoperative complications after laparoscopic appendectomy and to develop a simple perioperative risk prediction model.

Materials and Methods We retrospectively reviewed 295 adult patients who underwent laparoscopic appendectomy for histologically confirmed appendicitis at the Seventh Affiliated Hospital of Sun Yat-sen University between September 2019 and September 2023. Patients were divided into complication and non-complication groups. Baseline characteristics, preoperative laboratory variables, and perioperative indicators were compared between groups. Receiver operating characteristic curve analysis was used to determine optimal cut-off values for continuous variables. Logistic regression analysis was performed to identify factors associated with postoperative complications, and a risk prediction model was constructed based on independent predictors.

Results Among the 295 patients, 61 developed postoperative complications, with an overall complication rate of 20.68%. In univariate analysis, age ≥ 38 years, abdominal pain duration ≥ 18 hours, operation time ≥ 73 minutes, intraoperative blood loss ≥ 8 mL, WBC $\geq 14.64 \times 10^9/L$, LNR $< 11.47\%$, CRP ≥ 23.67 mg/L, and electrolyte imbalance were associated with postoperative complications. In multivariate logistic regression analysis, operation time ≥ 73 minutes (OR = 2.249, 95% CI: 1.028–4.917, $P = 0.042$), LNR $< 11.47\%$ (OR = 2.558, 95% CI: 1.131–5.780, $P = 0.024$), CRP ≥ 23.67 mg/L (OR = 2.578, 95% CI: 1.159–5.735, $P = 0.020$), and electrolyte imbalance (OR = 4.654, 95% CI: 1.760–12.310, $P = 0.002$) remained independently associated with postoperative complications. Among the laboratory variables, CRP showed the highest discriminatory ability, with an area under the ROC curve of 0.720.

Conclusion Longer operation time, lower lymphocyte-to-neutrophil ratio, higher CRP level, and electrolyte imbalance were independently associated with postoperative complications after laparoscopic appendectomy. These routinely available clinical and perioperative indicators may help clinicians identify patients at increased risk of postoperative complications.

Keywords Appendicitis; Laparoscopic appendectomy; Postoperative complications; Logistic regression; Risk prediction model; C-reactive protein

Fund: This study was supported by the Guangdong Provincial Key Laboratory of Digestive Cancer Research (No. 2021B1212040006), the “735 Program” Project of Clinical Medical Research of the Seventh Affiliated Hospital of Sun Yat-sen University (No. ZSQY2025735), and related institutional research support.

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Medical Research, ISSN 2664-0333 (Print), ISSN 2664-0341 (Online). Published by Creative Publishing Co., Limited (CPCL®). <https://mrhk.cc>, <https://cpcl.hk>, Email: cpcl@cpcl.hk.

1 Introduction

Appendicitis is one of the most common acute abdominal conditions in emergency surgery, with an estimated lifetime risk of approximately 7%–8% (1,2). Although non-operative treatment with antibiotics has been evaluated in selected patients with uncomplicated appendicitis, appendectomy remains a cornerstone of treatment, especially when complicated disease or treatment failure is suspected (3–15).

Despite the low mortality associated with appendectomy, postoperative complications remain clinically relevant, with reported rates ranging from approximately 5% to 28% in previous studies (16–20). Early recognition of patients at higher risk may help surgeons optimize perioperative management, postoperative monitoring, antibiotic strategies, and drainage decisions.

Several studies have suggested that inflammatory markers, surgical timing, operative approach, and appendicitis severity are associated with postoperative outcomes (20–24). However, risk stratification tools based on routinely available clinical and laboratory variables remain limited. Therefore, this study analyzed clinical characteristics, preoperative serological variables, and perioperative indicators in adult patients undergoing laparoscopic appendectomy and constructed a simple perioperative model to estimate the risk of postoperative complications.

2 Materials and Methods

2.1 Patients

The study was conducted in accordance with the Declaration of Helsinki and the requirements of good clinical practice. This retrospective study was approved by the Medical Ethics Committee of the Seventh Affiliated Hospital of Sun Yat-sen University (No. KY-2023-133-02), and the requirement for individual informed consent was waived.

We retrospectively evaluated adult patients who underwent appendectomy for histologically diagnosed appendicitis at the Seventh Affiliated Hospital of Sun Yat-sen University from September 2019 to September 2023. The inclusion criteria were as follows: (1) patients undergoing appendectomy; (2) age ≥ 18 years; (3) complete clinical information; and (4) no contraindications to surgery. The exclusion criteria were as follows: (1) conservative treatment or endoscopic retrograde appendicitis therapy; (2) age < 18 years; and (3) incomplete clinical information.

2.2 Data collection and outcome

Clinical characteristics, including age, sex, primary attack, duration of abdominal pain, history of abdominal surgery, smoking, drinking, and body mass index, were collected. Preoperative examination results included WBC count, percentage of neutrophils, percentage of lymphocytes, CRP, electrolyte status, blood type, and fecalith. Perioperative variables included operation time and intraoperative blood loss. The lymphocyte-to-neutrophil ratio (LNR) was calculated from the lymphocyte and neutrophil percentages. Postoperative complications and complication types were collected from the medical records.

Patients were divided into a complication group and a non-complication group according to whether postoperative complications occurred. All patients were discharged safely. No patient was transferred to the intensive care unit, and no death occurred.

2.3 Surgical technique

All included patients underwent laparoscopic appendectomy. The conversion rate to open surgery was 0%. The operations were performed by surgeons with clinical experience in laparoscopic appendectomy.

2.4 Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 25.0 and GraphPad Prism. The risk prediction model diagram was generated using R software. Receiver operating characteristic curve analysis was used to determine optimal cut-off values for continuous variables, including age, BMI, duration of abdominal pain, operation time, intraoperative blood loss, WBC, LNR, and CRP. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Logistic regression was used for univariate and multivariate analyses. Effect estimates are presented as odds ratios (ORs) with 95% confidence intervals (CIs). A two-sided P value <0.05 was considered statistically significant.

3 Results

3.1 Patient selection

A total of 360 patients diagnosed with appendicitis were screened. After applying the inclusion and exclusion criteria, 295 patients who underwent appendectomy were included. Among them, 61 patients developed postoperative complications and 234 did not, yielding an overall complication rate of 20.68%.

3.2 ROC curve analysis

ROC curve analysis was performed for continuous variables. The AUC values were 0.546 for age (P = 0.273), 0.553 for BMI (P = 0.214), 0.506 for duration of abdominal pain (P = 0.886), 0.617 for operation time (P = 0.005), 0.609 for intraoperative blood loss (P = 0.011), 0.584 for WBC (P = 0.046), 0.651 for LNR (P < 0.001), and 0.720 for CRP (P < 0.001). The optimal cut-off values were 38 years, 20.21 kg/m², 18 hours, 73 minutes, 8 mL, $14.64 \times 10^9/L$, 11.47%, and 23.67 mg/L, respectively. Among these variables, CRP showed the highest discriminatory ability for postoperative complications.

3.3 Baseline characteristics

The baseline characteristics of the patients are shown in Table 1. Sex (P = 0.980), primary attack (P = 0.857), history of abdominal operation (P = 0.263), smoking (P = 0.582), drinking (P = 0.630), BMI (P = 0.076), blood type (P = 0.795), and fecalith (P = 0.977) were not significantly different between groups. Patients in the complication group had higher age (P = 0.026), longer duration of abdominal pain (P = 0.008), longer operation time (P = 0.002), greater intraoperative blood loss (P = 0.023), higher WBC (P = 0.001), higher CRP (P < 0.001), and a higher rate of electrolyte imbalance (P < 0.001). In contrast, LNR was lower in the complication group than in the non-complication group (P < 0.001).

3.4 Univariate and multivariate analyses

The results of the univariate and multivariate logistic regression analyses are shown in Table 2. In univariate analysis, age ≥ 38 years, duration of abdominal pain ≥ 18 hours, operation time ≥ 73 minutes, intraoperative blood loss ≥ 8 mL, WBC $\geq 14.64 \times 10^9/L$, LNR < 11.47%, CRP ≥ 23.67 mg/L, and electrolyte imbalance were associated with postoperative complications. In multivariate analysis, operation time ≥ 73 minutes (OR = 2.249, 95% CI: 1.028–4.917, P = 0.042), LNR < 11.47% (OR = 2.558, 95% CI: 1.131–5.780, P = 0.024), CRP ≥ 23.67 mg/L (OR = 2.578, 95% CI: 1.159–5.735, P = 0.020), and electrolyte imbalance (OR = 4.654, 95% CI: 1.760–12.310, P = 0.002) remained independently associated with postoperative complications.

3.5 Clinical prediction model

A perioperative complication risk prediction model was constructed using the independent predictors identified in the multivariate logistic regression analysis. Because operation time is an intraoperative variable, the model should be interpreted as a perioperative risk stratification tool rather than a purely preoperative prediction model.

3.6 Types of complications

Complication types are summarized in Figure 4. No postoperative intestinal fistula occurred. A total of 65 complication events were recorded among 61 patients. Seroperitoneum was the most common event (42/65, 64.6%), followed by ileus (8/65, 12.3%), abdominal infection (4/65, 6.2%), pulmonary infection (4/65, 6.2%), hydrothorax (3/65, 4.6%), ventosity (2/65, 3.1%), arrhythmia (1/65, 1.5%), and hypochromic anemia (1/65, 1.5%).

4 Discussion

This single-center retrospective study evaluated clinical features, preoperative laboratory variables, and perioperative indicators associated with postoperative complications after laparoscopic appendectomy. The main finding was that longer operation time, lower LNR, higher CRP, and electrolyte imbalance were independently associated with postoperative complications. These variables are routinely available and may support perioperative risk stratification in patients with appendicitis.

Inflammatory markers are closely related to appendicitis severity and postoperative outcomes. WBC, LNR, and CRP are inexpensive and readily available indicators that reflect systemic inflammatory status (28–30). In this study, CRP showed the highest AUC among the evaluated continuous variables, suggesting that it may be particularly useful for identifying patients at increased risk. A lower LNR may reflect greater inflammatory burden and impaired immune balance, which could explain its association with postoperative complications.

Electrolyte imbalance was also independently associated with postoperative complications. Abnormal serum sodium or potassium may reflect dehydration, vomiting, systemic inflammatory stress, or delayed presentation. In clinical practice, electrolyte status is easy to assess and correct; therefore, it may be useful for perioperative optimization and postoperative monitoring.

Longer operation time was independently associated with postoperative complications. Operation time may reflect surgical difficulty, more severe local inflammation, adhesions, or complicated appendicitis. Although operation time cannot be used as a purely preoperative predictor, it can be incorporated into perioperative risk stratification to guide postoperative observation and management.

Age, duration of abdominal pain, intraoperative blood loss, and WBC were significant in univariate analysis but did not remain independent predictors in the multivariate model. These findings suggest that their effects may overlap with inflammatory burden and operative difficulty. Nevertheless, delayed presentation and older age remain clinically relevant and should be considered during perioperative assessment.

This study has several limitations. First, the sample size was relatively small, and the study was conducted at a single center. Second, the retrospective design may have introduced selection bias and information bias. Third, external validation was not performed. Fourth, the model did not include calibration analysis, decision curve analysis, or bootstrap internal validation. Fifth, surgeries were performed by different surgical teams, and the surgical learning curve was not fully considered. Future multicenter studies with larger sample sizes and external validation are needed to confirm the clinical utility of this model.

5 Conclusion

Longer operation time, lower LNR, higher CRP, and electrolyte imbalance were independently associated with postoperative complications after laparoscopic appendectomy. These routinely available clinical and perioperative indicators may help clinicians identify patients at increased risk and support individualized perioperative management. Further external validation is required before the model can be widely applied.

6 Declarations

Ethical approval This study was approved by the Medical Ethics Committee of the Seventh Affiliated Hospital of Sun Yat-sen University (No. KY-2023-133-02). Individual consent for this retrospective analysis was waived.

Funding This study was supported by the Guangdong Provincial Key Laboratory of Digestive Cancer Research (No. 2021B1212040006), the "735 Program" Project of Clinical Medical Research of the Seventh Affiliated Hospital of Sun Yat-sen University (No. ZSQY202573533), and the Pre-hospital Emergency Care Financial Reward-based Subsidy Fund (No. 00403000002).

Conflict of interest The authors declare that they have no conflict of interest related to this manuscript.

Data availability The original anonymous dataset is available on request from the corresponding author.

Table 1. Clinical and pathological features of appendicitis patients

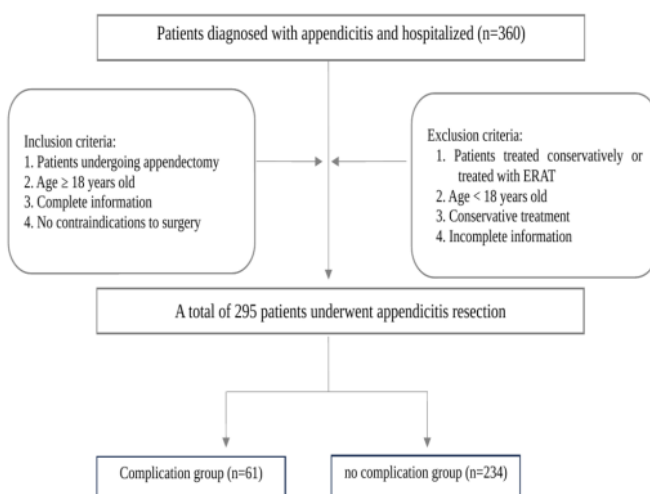
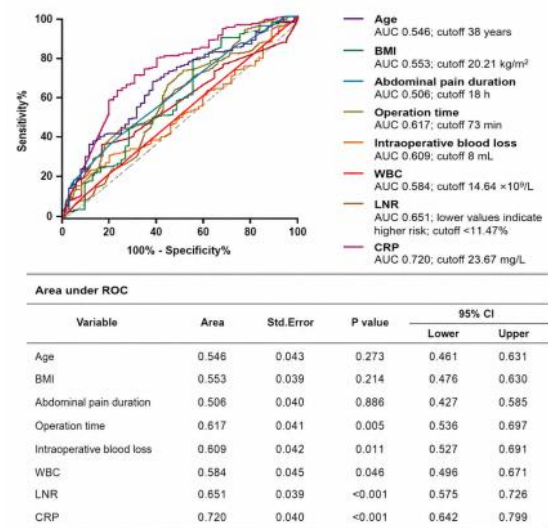
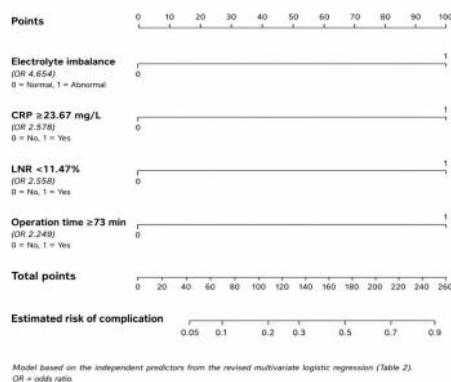
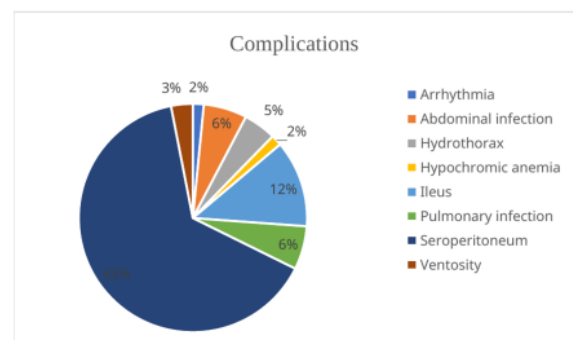
Variable	Category	N (%)	Complications Yes	Complications No	P value
N		295 (100%)	61 (20.68%)	234 (79.32%)	
Sex	Male	164 (55.6%)	34 (11.5%)	130 (44.1%)	0.980
	Female	131 (44.4%)	27 (9.2%)	104 (35.3%)	
Age (years)	<38	163 (55.3%)	26 (8.8%)	137 (46.4%)	0.026
	≥38	132 (44.7%)	35 (11.9%)	97 (32.9%)	
Primary attack	Yes	248 (84.4%)	51 (17.3%)	197 (67.0%)	0.857
	No	46 (15.6%)	10 (3.4%)	36 (12.2%)	
Abdominal pain duration (h)	<18	100 (33.9%)	12 (4.1%)	88 (29.8%)	0.008
	≥18	195 (66.1%)	49 (16.6%)	146 (49.5%)	
History of abdominal operation	Yes	25 (8.5%)	3 (4.9%)	22 (7.5%)	0.263
	No	270 (91.5%)	58 (19.7%)	212 (71.9%)	
Smoking	Yes	35 (11.9%)	6 (2.0%)	29 (9.8%)	0.582
	No	260 (88.1%)	55 (18.6%)	205 (69.5%)	
Drinking	Yes	29 (9.8%)	5 (1.7%)	24 (8.1%)	0.630
	No	266 (90.2%)	56 (19.0%)	210 (71.2%)	
BMI (kg/m ²)	<20.21	58 (20.1%)	7 (2.4%)	51 (17.7%)	0.076
	≥20.21	230 (79.9%)	52 (18.1%)	178 (61.8%)	
Operation time (min)	<73	199 (67.5%)	31 (10.5%)	168 (56.9%)	0.002
	≥73	96 (32.5%)	30 (10.2%)	66 (22.4%)	
Intraoperative blood loss (mL)	<8	208 (73.8%)	36 (12.8%)	172 (61.0%)	0.023
	≥8	74 (26.2%)	22 (12.8%)	52 (18.4%)	
WBC (× 10 ⁹ /L)	<14.64	213 (72.7%)	33 (11.3%)	180 (61.4%)	0.001
	≥14.64	80 (27.3%)	27 (9.2%)	53 (18.1%)	
LNR	<11.47%	116 (39.6%)	37 (12.6%)	79 (27.0%)	<0.001
	≥11.47%	177 (60.4%)	23 (7.8%)	154 (52.6%)	
CRP (mg/L)	<23.67	156 (60.9%)	17 (6.6%)	139 (54.3%)	<0.001
	≥23.67	100 (39.1%)	38 (14.8%)	62 (24.2%)	
Electrolyte (Na ⁺ , K ⁺)	Normal	255 (87.6%)	42 (14.4%)	213 (73.2%)	<0.001
	Abnormal	36 (12.4%)	19 (6.5%)	17 (5.8%)	
Blood type (O-type blood)	Yes	95 (34.2%)	21 (7.6%)	74 (26.6%)	0.795
	No	183 (65.8%)	38 (13.7%)	145 (52.2%)	
Fecalith	Yes	48 (16.3%)	10 (3.4%)	38 (12.9%)	0.977
	No	247 (83.7%)	51 (17.3%)	196 (66.4%)	

Note: Percentages are calculated from the total cohort unless otherwise indicated.

Table 2. Univariate and multivariate logistic regression analyses of factors associated with postoperative complications

Variable	Univariate OR (95% CI)	P value	Multivariate OR (95% CI)	P value
Sex (male vs female)	0.981 (0.556-1.733)	0.949		
Age (≥ 38 vs <38 years)	1.901 (1.075-3.363)	0.027	1.918 (0.915-4.024)	0.085
Primary attack (yes vs no)	0.932 (0.434-2.004)	0.857		
Abdominal pain duration (≥ 18 vs <18 h)	2.461 (1.241-4.880)	0.010	1.660 (0.665-4.143)	0.277
History of abdominal operation (yes vs no)	0.486 (0.138-1.714)	0.262		
Smoking (yes vs no)	0.749 (0.285-1.973)	0.559		
Drinking (yes vs no)	0.764 (0.270-2.165)	0.613		
BMI (≥ 20.21 vs <20.21 kg/m ²)	2.128 (0.911-4.971)	0.081		
Operation time (≥ 73 vs <73 min)	2.479 (1.388-4.426)	0.002	2.249 (1.028-4.917)	0.042
Intraoperative blood loss (≥ 8 vs <8 mL)	2.037 (1.100-3.770)	0.024	1.130 (0.481-2.654)	0.778
WBC (≥ 14.64 vs $<14.64 \times 10^9/L$)	2.788 (1.535-5.062)	0.001	2.210 (0.955-5.110)	0.064
LNR ($<11.47\%$ vs $\geq 11.47\%$)	3.145 (1.745-5.650)	<0.001	2.558 (1.131-5.780)	0.024
CRP (≥ 23.67 vs <23.67 mg/L)	5.011 (2.628-9.556)	<0.001	2.578 (1.159-5.735)	0.020
Electrolyte imbalance (abnormal vs normal)	5.678 (2.726-11.826)	<0.001	4.654 (1.760-12.310)	0.002
Blood type (O-type vs non-O-type)	1.083 (0.593-1.977)	0.796		
Fecalith (yes vs no)	1.011 (0.472-2.167)	0.978		

Note: OR, odds ratio; CI, confidence interval. The LNR effect estimate was inverted from the original protective direction to express the clinically clearer risk direction, namely LNR $<11.47\%$ versus LNR $\geq 11.47\%$.

**Fig 1. Flow chart of patient selection****Figure 2. ROC curves and AUC values for continuous variables.****Figure 3. Perioperative complication risk prediction model.****Fig 4. Classification of complications and percentage of total complications.**

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