

Analysis of influencing factors and risk prediction model of postoperative pathological types of appendicitis

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Abstract

Aim: The influencing factors of postoperative pathological types (Including chronic appendicitis, acute simple appendicitis, acute suppurative appendicitis, acute gangrenous appendicitis) of appendicitis patients were analyzed, and a risk prediction model was constructed. **Materials and Methods:** This study retrospectively analyzed the impact of baseline clinical features and preoperative serological results on the pathological classification of postoperative appendicitis in 295 patients who underwent appendectomy from September 2019 to September 2023 at the Seventh Affiliated Hospital of Sun Yat-sen University, and constructed a risk prediction model. **Results:** For chronic and acute appendicitis, primary attack (HR = 2.778, 95% CI = 1.260–6.198; p = 0.011), white blood cell count (WBC) ($\geq 9.76 \times 10^9/L$) (HR = 2.425, 95% CI = 1.113–5.281; p = 0.026), and lymphocyte-to-neutrophil ratio (LNR) ($< 32.51\%$) (HR = 0.259, 95% CI = 0.113–0.590; p = 0.001) are predictors; for acute simple and complicated appendicitis, WBC ($\geq 11.45 \times 10^9/L$) (HR = 2.745, 95% CI = 1.114–6.762; p = 0.028), LNR ($\geq 24.54\%$) (HR = 0.164, 95% CI = 0.069–0.393, p < 0.001) and CRP ($\geq 21\text{mg/L}$) (HR = 2.508, 95% CI = 1.038–6.063; p = 0.041) may be predictors while; for acute suppurative and acute gangrenous appendicitis, abdominal pain time (≥ 18 hours) (HR = 5.010, 95% CI = 1.688–14.867; p = 0.004), hyponatremia (HR = 3.445, 95% CI = 1.234–9.674; p = 0.018), WBC ($\geq 16.40 \times 10^9/L$) (HR = 2.731, 95% CI = 1.701–6.946; p = 0.035), LNR ($< 11.09\%$) (HR = 3.222, 95% CI = 1.163–8.926; p = 0.024) and CRP ($> 27.54\text{mg/L}$) (HR = 3.605, 95% CI = 1.513–8.586; p = 0.004) are predictors. **Conclusion:** The primary attack, abdominal pain time, WBC, LNR, CRP and hyponatremia conditions may be of great help in indicating the extent of appendicitis inflammation and in determining clinical decisions.

Keywords Surgery; Appendicitis; Pathological classification of appendicitis; Influence factors; Risk prediction model

1 Introduction

Appendicitis is not only one of the most common acute abdominal diseases in the emergency department, it is also one of the most routine emergency operations ^[1–2]. Surgery is still one of the cornerstone treatments for appendicitis ^[3]. According to the literature ^[4], about 17–20% of patients have perforation at the time of diagnosis, thus expeditious diagnosis and timely treatment is the key to the treatment of appendicitis ^[5].

Traditionally, the most used methods to diagnose appendicitis are physical examination and laboratory tests combined with imaging findings like B-mode ultrasound or CT [6]. In addition, some doctors use different scoring systems to help with diagnoses such as Alvarado and RIPASA [7–8]. Unfortunately, none of these results can predict the postoperative pathological pattern of appendicitis before surgery.

Previously, a large number of studies have reported that some preoperative inflammatory indicators are highly correlated with the degree of inflammation [9–21]. However, the prognosis of postoperative pathology of appendicitis is still inconclusive. In this study, we analyzed the factors influencing the postoperative pathology of appendicitis according to the preoperative serological results of said patients, and established a risk prediction model to classify patients before surgery, so as to identify its pathological classification based on easily available laboratory test results.

2 Materials and Methods

The study has been approved by the institutional review board, and it abides by the revised Declaration of Helsinki and the requirements of good clinical practice.

We retrospectively evaluated patients who underwent appendectomy for histologically diagnosed appendicitis from September 2019 to September 2023 at the Seventh Affiliated Hospital of Sun Yat-sen University. Inclusion criteria are as follows: (a) patients undergoing appendectomy; (b) Age ≥ 18 years old; (c) Integral material; (d) No contraindications to surgery. The exclusion criteria are as follows: (a) Patients treated conservatively or treated with ERAT (Endoscopic Retrograde Appendicitis Therapy); (b) Age < 18 years old; (c) Conservative treatment; (d) Incomplete information.

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 Informed consent for this retrospective analysis was waived, and which has been approved by the Medical Ethics Committee of the Seventh Affiliated Hospital of Sun Yat-sen University.

This study has been registered with the Chinese Clinical Trial Registry (registration number: ChiCTR2500109521).

2.1 Follow-up

The clinical features (including age, sex, primary attack, abdominal pain time, history of abdominal operation, smoking and drinking status, and BMI), preoperative examination results (including WBC, percentage of neutrophils, percentage of lymphocytes, CRP, electrolyte levels, Hhponatremia, blood type and fecalith), and postoperative pathological type [including chronic appendicitis and acute appendicitis (acute simple appendicitis, acute suppurative appendicitis and gangrenous appendicitis)] of the patients were collected.

All patients were discharged safely, and ICU transfer rates and mortality were 0%.

2.2 Surgical Techniques

Patients were divided into 2 groups according to whether the postoperative pathology was acute appendicitis, and further divided into 2 groups according to whether the postoperative pathology in the acute appendicitis group was acute simple appendicitis, and finally divided into another 2 groups according to the pathological types in the non-acute simple appendicitis group (acute suppurative appendicitis or acute gangrenous appendicitis).

All the surgeons employed are with extensive clinical experience and all patients with appendicitis underwent laparoscopic surgery. In addition, the conversion rate to laparotomy was 0%.

2.3 Statistical Analysis

All statistical analyses were performed with IBM SPSS statistics 25.0 and PRISM software. The prediction model diagram used R Programming Language. ROC curves of 3 groups were performed to determine the optimal cut-off values of body mass index (BMI), white blood cell count (WBC), lymphocyte-to-neutrophil ratio (LNR) and C-reactive protein (CRP). Chi-square test was used to detect the baseline characteristics of the six groups of patients. Logistic regression was used for univariate and multi-factor analysis of bivariate variables. Finally, R Programming Language was used to establish three risk prediction models for independent risk factors.

3 Results

3.1 Patient Screening Process

Details of the patients screening are shown in Fig. 1. Finally, we selected 295 patients who underwent appendectomy from 360 patients diagnosed with appendicitis, including 54 patients with chronic appendicitis, 241 patients with acute appendicitis (comprising of 43 patients with acute simple appendicitis, 163 patients with acute suppurative appendicitis, and 35 patients with acute gangrenous appendicitis).

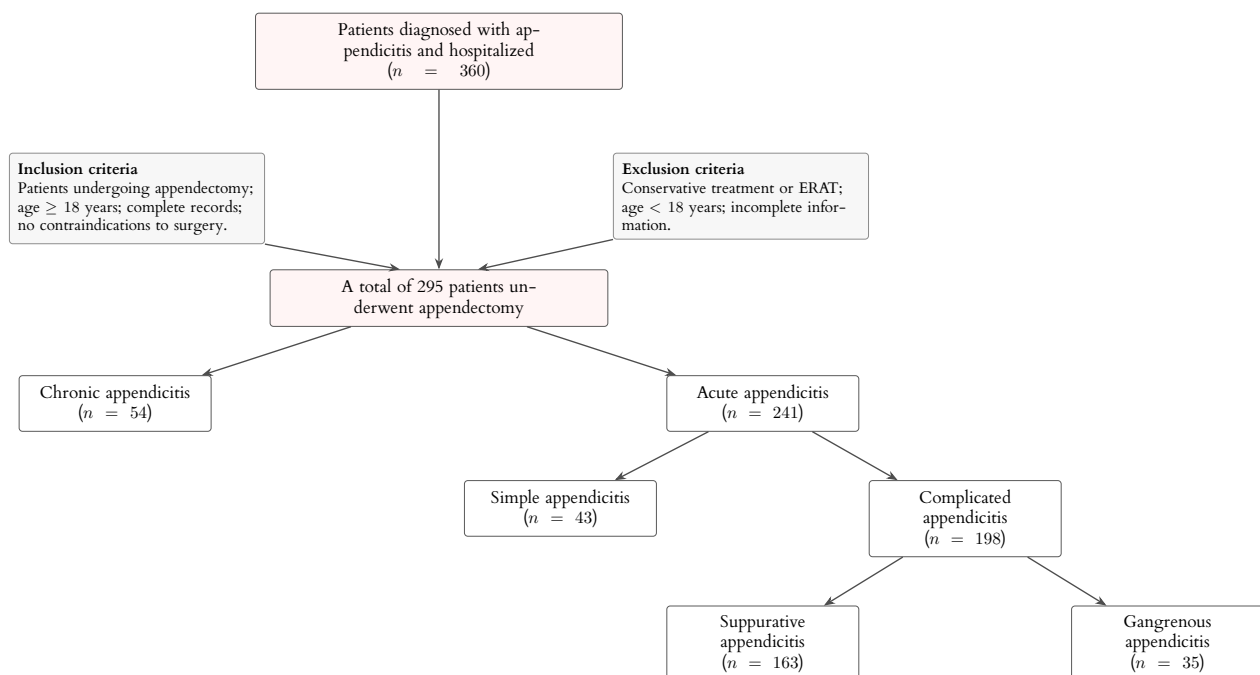
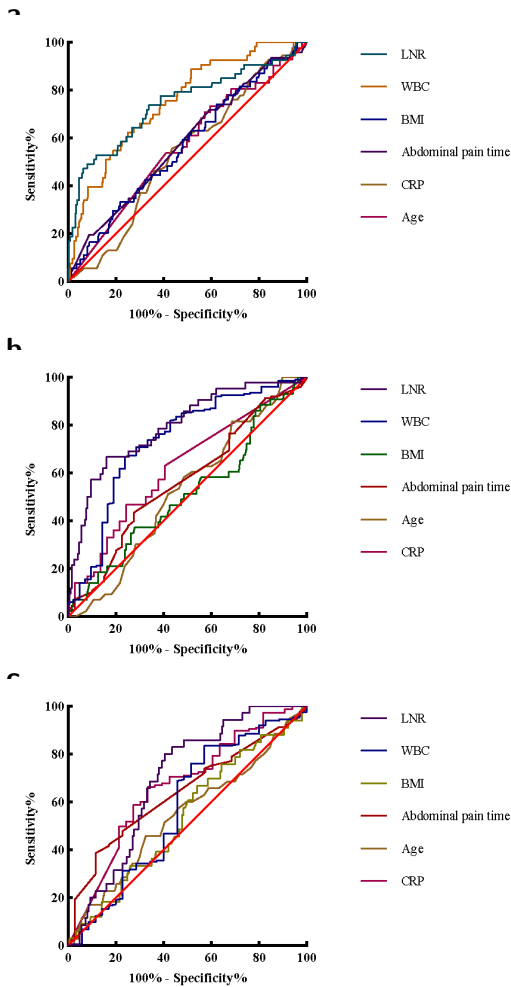


Figure 1: Flow chart of patient selection.

3.2 ROC Curve

Fig. 2 shows the ROC curve of patients with appendicitis. Fig. 2(a) shows the relationship between continuous variables for acute and chronic appendicitis, in which age ($p = 0.401$, $AUC = 0.531$), BMI ($p = 0.134$, $AUC = 0.565$), APT ($p = 0.095$, $AUC = 0.578$), WBC ($p < 0.001$, $AUC = 0.751$), LNR ($p < 0.001$, $AUC = 0.742$), and CRP ($p = 0.198$, $AUC = 0.563$), and their best cut-off values are 35 years old, 24.65kg/m^2 , 23 hours, $9.76 \times 10^9/\text{L}$, 32.51%, and 24.32mg/L respectively. Among them, LNR ($p < 0.001$, $AUC = 0.742$) and WBC ($p < 0.001$, $AUC = 0.751$) are most closely related to postoperative complications of appendicitis; Fig. 2(b) shows the relationship between continuous variables for acute simple and complicated appendicitis. in which age ($p = 0.608$, $AUC = 0.525$), BMI ($p = 0.825$, $AUC = 0.511$), APT ($p = 0.203$, $AUC = 0.050$), WBC ($p < 0.001$, $AUC = 0.732$), LNR ($p < 0.001$, $AUC = 0.793$) and CRP ($p = 0.022$, $AUC = 0.620$), and their best cut-off values are 45 years old, 25.27kg/m^2 , 23 hours, $11.45 \times 10^9/\text{L}$, 24.54%, and 21.29mg/L

**a.** Area under ROC of acute and chronic appendicitis

Variable	Area	Std. Error	p value	95% CI	
				Lower	Upper
Age	0.537	0.041	0.401	0.457	0.616
Abdominal pain time	0.578	0.047	0.095	0.487	0.669
BMI	0.565	0.043	0.134	0.481	0.650
WBC	0.751	0.035	<0.001	0.682	0.821
LNR	0.742	0.043	<0.001	0.673	0.826
CRP	0.563	0.049	0.198	0.467	0.660

b. Area under ROC of acute simple appendicitis and acute complicated appendicitis

Variable	Area	Std. Error	p value	95% CI	
				Lower	Upper
Age	0.525	0.045	0.608	0.438	0.612
Abdominal pain time	0.564	0.050	0.203	0.467	0.661
BMI	0.511	0.050	0.825	0.413	0.609
WBC	0.732	0.046	<0.001	0.641	0.822
LNR	0.793	0.040	<0.001	0.715	0.970
CRP	0.620	0.050	0.022	0.523	0.717

c. Area under ROC of suppurative appendicitis and non-suppurative appendicitis

Variable	Area	Std. Error	p value	95% CI	
				Lower	Upper
Age	0.542	0.056	0.434	0.432	0.652
Abdominal pain time	0.640	0.047	0.001	0.548	0.731
BMI	0.535	0.054	0.526	0.428	0.641
WBC	0.575	0.059	0.164	0.458	0.691
LNR	0.691	0.042	<0.001	0.610	0.773
CRP	0.664	0.053	0.003	0.559	0.769

Figure 2: ROC curves and corresponding area-under-the-curve estimates. **a.** Acute and chronic appendicitis. **b.** Acute simple and acute complicated appendicitis. **c.** Acute suppurative and acute gangrenous appendicitis.

respectively. Among them, LNR ($p < 0.001$, $AUC = 0.793$), CRP ($p = 0.022$, $AUC = 0.620$) and WBC ($p < 0.001$, $AUC = 0.732$) are most closely related to postoperative complications of appendicitis; Fig. 2(c) shows the relationship between continuous variables for acute simple and complicated appendicitis. in which age ($p = 0.434$, $AUC = 0.542$), BMI ($p = 0.526$, $AUC = 0.535$), APT ($p = 0.001$, $AUC = 0.640$), WBC ($p = 0.164$, $AUC = 0.575$), LNR ($p < 0.001$, $AUC = 0.694$) and CRP ($p = 0.198$, $AUC = 0.563$), and their best cut-off values are 43 years old, 22.78kg/m^2 , 18 hours, $16.40 \times 10^9/\text{L}$, 11.09%, and 27.54mg/L respectively. Among them, LNR ($p < 0.001$, $AUC = 0.742$) and CRP ($p = 0.003$, $AUC = 0.664$) are most closely related to postoperative complications of appendicitis.

3.3 Population Baseline Characteristics for Acute and Chronic Appendicitis

For acute and chronic appendicitis, Table 1 showed that the ratio of primary attack ($p < 0.001$), lower WBC (< 0.001), higher LNR (< 0.001), electrolyte balance [(hyponatremia, $p = 0.038$), (hypokalemia, $p = 0.024$)] in chronic appendicitis group, the opposite is also true in acute appendicitis group.

Table 1: Clinical and pathological features of acute and chronic appendicitis patients

Variable		N (%)	Chronic appendicitis (%)	Acute appendicitis (%)	P value
Sex	Male	164 (55.6%)	26 (8.8%)	138 (46.8%)	0.223
	Female	131 (44.4%)	28 (9.5%)	103 (34.9%)	
Age (years old)	<35	135 (45.8%)	30 (10.2%)	105 (35.6%)	0.110
	≥35	160 (54.2%)	24 (8.1%)	136 (46.1%)	

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Table 1 continued

Variable		N (%)	Chronic appendicitis (%)	Acute appendicitis (%)	P value
Primary attack	Yes	248 (84.4%)	33 (11.2%)	215 (73.1%)	<0.001
	No	46 (15.6%)	20 (6.8%)	26 (8.8%)	
Abdominal pain time (hour)	<23	122 (41.4%)	21 (7.1%)	101 (34.2%)	0.684
	≥23	173 (59.6%)	33 (11.2%)	140 (47.5%)	
History of abdominal operation	Yes	25 (8.5%)	6 (2.0%)	19 (6.4%)	0.441
	No	270 (91.5%)	48 (16.3%)	222 (75.3%)	
Smoking	Yes	35 (11.9%)	6 (2.0%)	29 (9.8%)	0.850
	No	260 (88.1%)	48 (16.3%)	212 (71.9%)	
Drinking	Yes	29 (9.8%)	2 (0.7%)	27 (9.2%)	0.094
	No	266 (90.2%)	52 (17.6%)	214 (72.5%)	
BMI (kg/m ²)	<24.65	186 (64.6%)	40 (13.9%)	146 (50.7%)	0.106
	≥24.65	102 (35.4%)	14 (4.9%)	88 (30.6%)	
WBC (×10 ⁹ /L)	≤9.76	97 (32.9%)	35 (11.9%)	62 (21.0%)	<0.001
	>9.76	198 (67.1%)	19 (6.4%)	179 (60.7%)	
LNR	<32.51%	237 (80.9%)	25 (8.5%)	212 (72.4%)	<0.001
	≥32.51%	56 (19.1%)	28 (9.6%)	28 (9.6%)	
CRP (mg/L)	<24.32	158 (61.7%)	30 (11.7%)	128 (50.0%)	0.100
	≥24.32	98 (38.3%)	11 (4.3%)	87 (34.0%)	
Electrolyte (Na ⁺ , K ⁺)	Normal	255 (87.6%)	51 (17.5%)	204 (70.1%)	0.092
	Abnormal	36 (12.4%)	3 (1.0%)	33 (11.3%)	
Hyponatremia	Yes	18 (6.1%)	0 (0.0%)	18 (6.1%)	0.038
	No	277 (93.9%)	54 (18.3%)	223 (75.6%)	
Hypokalemia	Yes	21 (7.1%)	0 (0.0%)	21 (7.1%)	0.024
	No	274 (92.9%)	54 (18.3%)	220 (74.6%)	
Blood type (o-type blood)	Yes	95 (34.2%)	17 (6.1%)	78 (28.1%)	0.889
	No	183 (65.8%)	34 (12.2%)	149 (53.6%)	
Stercorolith	Yes	48 (16.3%)	7 (2.4%)	41 (13.9%)	0.466
	No	247 (83.7%)	47 (15.9%)	200 (67.8%)	

3.4 Univariate and Multivariate Analysis for Chronic and Acute Appendicitis

In Table 2, univariate and multivariate analyses shows that primary attack (HR = 2.778, 95% CI = 1.260–6.198; p = 0.011), WBC ($\geq 9.76 \times 10^9/L$) (HR = 2.425, 95% CI = 1.113–5.281; p = 0.026), LNR (< 32.51%) (HR = 0.259, 95% CI = 0.113–0.590; p = 0.001) are independent risk factors for acute appendicitis.

Table 2: Univariate and multivariate analyses of factors for acute and chronic appendicitis

Variable	Univariate		Multivariate	
	HR (95% CI)	P value	HR (95% CI)	P value
Sex (Male)	0.686 (0.379–1.241)	0.212		
Age (<35 years old)	1.619 (0.894–2.933)	0.112		
Primary attack (Yes)	5.012 (2.517–9.977)	<0.001	2.778 (1.260–6.198)	0.011
Abdominal pain time (<23 hours)	0.882 (0.482–1.614)	0.684		
History of abdominal operation (Yes)	0.685 (0.260–1.805)	0.444		
Smoking (Yes)	1.094 (0.430–2.782)	0.850		
Drinking (Yes)	3.280 (0.756–14.238)	0.113		
BMI (<24.65 kg/m ²)	1.722 (0.887–3.344)	0.108		
WBC ($<9.76 \times 10^9/L$)	5.318 (2.836–9.974)	<0.001	2.425 (1.113–5.281)	0.026
LNR (<32.51%)	0.118 (0.060–0.230)	<0.001	0.259 (0.113–0.590)	0.001
CRP (<24.32 mg/L)	1.854 (0.882–3.895)	0.103		
Electrolyte (Na ⁺ , K ⁺ , normal)	2.750 (0.811–9.325)	0.104		
Hyponatremia (Yes)		0.998		
Hypokalemia (Yes)		0.998		
Blood type (o-type blood)	1.047 (0.550–1.992)	0.889		
Stercorolith (Yes)	1.376 (0.581–3.260)	0.468		

3.5 Clinical Prediction Model for Chronic and Acute Appendicitis

Fig. 3a shows the established pathological types risk prediction model for chronic and acute appendicitis. The results shows That WBC, LNR and primary attack are all predictors for chronic and acute appendicitis.

3.6 Population Baseline Characteristics for Acute Simple and Complicated Appendicitis

The results in Table 3 represent baseline characteristics of patients with acute simple appendicitis and acute complicated appendicitis. The results show that the probability of $WBC \geq 11.45 \times 10^9/L$ ($p < 0.001$), $LNR < 24.54\%$ ($p < 0.001$), $CRP \geq 21.29$ ($p = 0.013$) and hyponatremia ($p = 0.040$) is higher in the acute complicated appendicitis group than in the acute appendicitis group.

Table 3: Clinical and pathological features of acute simple and non-simple appendicitis patients

Variable		N (%)	Simple appendicitis (%)	Suppurative appendicitis (%)	P value
Sex	Male	138 (57.3%)	21 (8.7%)	117 (48.5%)	0.218
	Female	103 (42.7%)	22 (9.1%)	81 (33.6%)	
Age (years old)	<45	171 (71.0%)	35 (14.5%)	136 (56.4%)	0.096
	≥ 45	70 (29.0%)	8 (3.3%)	62 (25.7%)	
Primary Attack	Yes	215 (89.2%)	37 (15.4%)	178 (73.9%)	0.460
	No	26 (10.8%)	6 (2.5%)	20 (8.3%)	
Abdominal pain time (hour)	<23	101 (41.9%)	14 (5.8%)	87 (36.1%)	0.170
	≥ 23	140 (58.1%)	29 (12.0%)	111 (46.1%)	
History of abdominal operation	Yes	19 (7.9%)	3 (1.2%)	16 (6.6%)	0.808
	No	222 (92.1%)	40 (16.6%)	182 (75.5%)	
Smoking	Yes	29 (12.0%)	6 (2.5%)	23 (9.5%)	0.669
	No	212 (88.0%)	37 (15.4%)	175 (72.6%)	
Drinking	Yes	27 (11.2%)	6 (2.5%)	21 (8.7%)	0.528
	No	214 (88.8%)	37 (15.4%)	177 (73.4%)	
BMI (kg/m^2)	<25.27	95 (40.8%)	18 (7.7%)	77 (33.0%)	0.872
	≥ 25.27	138 (59.2%)	25 (10.7%)	113 (48.5%)	
WBC ($\times 10^9/L$)	<11.45	100 (41.5%)	33 (13.7%)	67 (27.8%)	<0.001
	≥ 11.45	141 (58.5%)	10 (4.1%)	131 (54.4%)	
LNR	<24.54%	179 (74.6%)	14 (5.8%)	165 (68.8%)	<0.001
	$\geq 24.54\%$	61 (25.4%)	28 (11.7%)	33 (13.8%)	
CRP (mg/L)	<21.29	123 (57.2%)	28 (13.0%)	95 (44.2%)	0.013
	≥ 21.29	92 (42.8%)	9 (4.2%)	83 (38.6%)	
Electrolyte (Na ⁺ , K ⁺)	Normal	204 (86.1%)	40 (16.9%)	164 (69.2%)	0.058
	Abnormal	33 (13.9%)	2 (0.8%)	31 (13.1%)	
Hyponatremia	Yes	18 (7.5%)	0 (0.0%)	18 (7.5%)	0.040
	No	223 (92.5%)	43 (17.8%)	180 (74.7%)	
Hypokalemia	Yes	21 (8.7%)	2 (0.8%)	19 (7.9%)	0.297
	No	220 (91.3%)	41 (17.0%)	179 (74.3%)	
Blood type (o-type blood)	Yes	66 (32.7%)	8 (4.0%)	58 (28.7%)	0.173
	No	136 (67.3%)	27 (13.4%)	109 (54.0%)	
Stercorolith	Yes	41 (17.0%)	7 (2.9%)	34 (14.1%)	0.888
	No	200 (83.0%)	36 (14.9%)	164 (68.0%)	

3.7 Univariate and Multivariate Analysis for Acute Simple and Non-simple Appendicitis

The results of univariate and multivariate analysis in Table 4 show that $WBC (\geq 11.45 \times 10^9/L)$ (HR 2.745, 95%CI 1.114–6.762; $P=0.028$), $LNR (\geq 24.54\%)$ (HR 0.164, 95% CI 0.069–0.393, $P<0.001$) and $CRP (\geq 21mg/L)$ (HR 2.508, 95% CI 1.038–6.063; $P=0.041$) are independent risk factors for acute non-simple appendicitis.

Table 4: Univariate and multivariate analyses of factors for acute simple appendicitis and non-simple appendicitis

Variable	Univariate		Multivariate	
	HR (95% CI)	P value	HR (95% CI)	P value
Sex (Male)	0.661 (0.341–1.281)	0.220		
Age (<45 years old)	1.994 (0.874–4.550)	0.101		
Primary Attack (Yes)	1.443 (0.542–3.840)	0.462		
Abdominal pain time (<23 hours)	0.616 (0.307–1.236)	0.173		
History of abdominal operation (Yes)	1.172 (0.326–4.215)	0.808		
Smoking (Yes)	0.810 (0.308–2.129)	0.670		
Drinking (Yes)	0.732 (0.276–1.938)	0.530		
BMI (<25.27 kg/m^2)	1.057 (0.540–2.068)	0.872		

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Table 4 continued

Variable	Univariate		Multivariate	
	HR (95% CI)	P value	HR (95% CI)	P value
WBC ($<11.45 \times 10^9/L$)	6.452 (2.999-13.884)	<0.001	2.745 (1.114-6.762)	0.028
LNR ($<24.54\%$)	0.100 (0.048-0.210)	<0.001	0.164 (0.069-0.393)	<0.001
CRP (<21.29 mg/L)	2.718 (1.213-6.090)	0.015	2.508 (1.038-6.063)	0.041
Electrolyte (Na ⁺ , K ⁺ , normal)	3.780 (0.868-16.460)	0.076		
Hyponatremia (Yes)		0.998		
Hypokalemia (Yes)	2.176 (0.487-9.713)	0.308		
Blood type (o-type blood)	1.796 (0.767-4.205)	0.177		
Stercorolith (Yes)	1.066 (0.438-2.596)	0.888		

3.8 Clinical Prediction Model for Acute Simple and Complicated Appendicitis

Fig. 3b shows the established pathological types risk prediction model for acute simple and acute non-simple appendicitis. The results shows That WBC, LNR and CRP are all predictors for chronic and acute appendicitis.

3.9 Population Baseline Characteristics for Acute Suppurative and Gangrenous Appendicitis

Table 5 shows the clinical features of acute suppurative appendicitis and acute gangrenous appendicitis. In the gangrenous appendicitis group, the rate of abdominal pain time ≥ 18 hours ($p = 0.002$), WBC $\geq 16.40 \times 10^9/L$ ($p = 0.001$), LNR $< 11.09\%$ ($p < 0.001$), CRP > 27.54 ($p < 0.001$) and hyponatremia ($p = 0.013$) is higher than that of the suppurative appendicitis group.

Table 5: Clinical and pathological features of acute Suppurative and Gangrenous appendicitis patients

Variable		N (%)	Suppurative appendicitis (%)	Gangrenous appendicitis (%)	P value
Sex	Male	117 (59.1%)	96 (48.5%)	21 (10.6%)	0.904
	Female	81 (40.9%)	67 (33.8%)	14 (7.1%)	
Age (years old)	<43	129 (65.2%)	110 (55.6%)	19 (9.6%)	0.137
	≥ 43	69 (34.8%)	53 (26.8%)	16 (8.1%)	
Primary Attack	Yes	178 (89.9%)	148 (74.7%)	30 (15.2%)	0.365
	No	20 (10.1%)	15 (7.6%)	5 (2.5%)	
Abdominal pain time (hour)	<18	68 (34.3%)	64 (32.3%)	4 (2.0%)	0.002
	≥ 18	130 (65.7%)	99 (50.0%)	31 (15.7%)	
History of abdominal operation	Yes	16 (8.1%)	15 (7.6%)	1 (0.5%)	0.211
	No	182 (91.9%)	148 (74.7%)	34 (17.2%)	
Smoking	Yes	23 (11.6%)	20 (10.1%)	3 (1.5%)	0.536
	No	175 (88.4%)	143 (72.2%)	32 (16.2%)	
Drinking	Yes	21 (10.6%)	19 (9.6%)	2 (1.0%)	0.300
	No	177 (89.4%)	144 (72.7%)	33 (16.7%)	
BMI (kg/m ²)	<22.78	83 (43.7%)	72 (37.9%)	11 (5.8%)	0.187
	≥ 22.78	107 (56.3%)	85 (44.7%)	22 (11.6%)	
WBC ($\times 10^9/L$)	<16.40	156 (78.8%)	136 (68.7%)	20 (10.1%)	0.001
	≥ 16.40	43 (21.2%)	27 (13.6%)	15 (7.6%)	
LNR	$<11.09\%$	104 (52.5%)	97 (49.0%)	7 (3.5%)	<0.001
	$\geq 11.09\%$	94 (47.5%)	66 (33.3%)	28 (14.1%)	
CRP (mg/L)	<27.54	107 (60.1%)	96 (53.9%)	11 (6.2%)	<0.001
	≥ 27.54	71 (39.9%)	49 (27.5%)	22 (12.4%)	
Electrolyte (Na ⁺ , K ⁺)	Normal	164 (84.1%)	138 (70.8%)	26 (13.3%)	0.080
	Abnormal	31 (15.9%)	22 (11.3%)	9 (4.6%)	
Hyponatremia	Yes	18 (9.1%)	11 (5.6%)	7 (3.5%)	0.013
	No	180 (90.9%)	152 (76.8%)	28 (14.1%)	
Hypokalemia	Yes	19 (9.6%)	13 (6.6%)	6 (3.0%)	0.095
	No	179 (90.4%)	150 (75.8%)	29 (14.6%)	
Blood type (o-type blood)	Yes	58 (34.5%)	50 (29.8%)	8 (4.8%)	0.208
	No	110 (65.5%)	86 (51.2%)	24 (14.3%)	
Stercorolith	Yes	34 (17.2%)	26 (13.1%)	8 (4.0%)	0.326
	No	164 (82.8%)	137 (69.2%)	27 (13.6%)	

3.10 Univariate and Multivariate Analysis for Acute Suppurative and Gangrenous Appendicitis

In Table 6, for acute gangrenous appendicitis, the abdominal pain time (≥ 18 hours) (HR = 5.010, 95% CI = 1.688–14.867; $p = 0.004$) and hyponatremia (HR = 3.445, 95% CI = 1.234–9.674; $p = 0.018$) are risk factors, while WBC ($\geq 16.40 \times 10^9/L$) (HR = 2.731, 95% CI = 1.701–6.946; $p = 0.035$), LNR ($< 11.09\%$) (HR = 3.222, 95% CI = 1.163–8.926; $p = 0.024$) and CRP ($> 27.54 \text{ mg/L}$) (HR = 3.605, 95% CI = 1.513–8.586; $p = 0.004$) are independent risk factors.

Table 6: Univariate and multivariate analyses of factors for Suppurative appendicitis and Gangrenous appendicitis

Variable	Univariate		Multivariate	
	HR (95% CI)	P value	HR (95% CI)	P value
Sex (Male)	0.955 (0.454–2.012)	0.904		
Age (< 43 years old)	1.748 (0.833–3.668)	0.140		
Primary Attack (Yes)	0.608 (0.205–1.801)	0.369		
Abdominal pain time (< 18 hours)	5.010 (1.688–14.867)	0.004	2.707 (0.776–9.448)	0.118
History of abdominal operation (Yes)	0.290 (0.037–2.273)	0.239		
Smoking (Yes)	0.670 (0.188–2.393)	0.538		
Drinking (Yes)	0.459 (0.102–2.070)	0.311		
BMI ($< 22.78 \text{ kg/m}^2$)	1.694 (0.770–3.729)	0.190		
WBC ($< 16.40 \times 10^9/L$)	3.778 (1.720–8.295)	0.001	2.731 (1.071–6.964)	0.035
LNR ($< 11.09\%$)	5.897 (2.425–14.249)	< 0.001	3.222 (1.163–8.926)	0.024
CRP ($< 27.54 \text{ mg/L}$)	3.918 (1.758–8.733)	0.001	3.605 (1.513–8.586)	0.004
Electrolyte (Na ⁺ , K ⁺ , normal)	2.171 (0.899–5.243)	0.085		
Hyponatremia (Yes)	3.445 (1.234–9.674)	0.018	2.195 (0.633–7.612)	0.215
Hypokalemia (Yes)	2.387 (0.839–6.794)	0.103		
Blood type (o-type blood)	0.573 (0.240–1.372)	0.212		
Stercorolith (Yes)	1.561 (0.639–3.815)	0.328		

3.11 Clinical Prediction Model for Acute Suppurative and Gangrenous Appendicitis

Fig. 3c shows the established pathological types risk prediction model for acute suppurative and acute gangrenous appendicitis. The results shows That WBC, LNR, CRP and Hyponatremia are all predictors for chronic and acute appendicitis.

4 Discussion

In the study, univariate and multifactorial analyses of postoperative pathological patterns of appendicitis are performed using variables that are readily available before surgery. We found out through research that the primary attack, abdominal pain time, WBC, LNR, CRP and hyponatremia may be of great help in indicating the extent of appendicitis inflammation and in determining clinical decisions.

The outcome of patients undergoing surgical resection of appendicitis is usually good [22–23]. However, for different pathological types of appendicitis, because of the differences in the degree of inflammation, we exercise different measures, such as surgical methods, antibiotic types and so on. For our research, we used simple variables that were readily available before surgery to predict the pathological type of appendicitis, which not only helped us understand the degree of inflammation in the patients, but also assisted us in making decisions on the treatment of appendicitis, including surgical and conservative treatment. When explaining the severity of the disease to the patient, we have a more complete understanding of the condition of the patient, and even predict the operation time, intraoperative bleeding, postoperative conditions and so on.

Our retrospective analysis shows that WBC, LNR, CRP, and hyponatremia have predictive effects for pathological types of appendicitis. It can even be said that for the four pathological types, LNR has the greatest predictive effect. These values are very easy to obtain since it is a blood test away for suspected appendicitis patients [24–25]. To date, there have been numerous studies on the use of WBC, LNR, CRP, and hyponatremia in predicting the degree of inflammation of diseases, including appendicitis [18,26–29]. Even for hyponatremia, it is widely reported that it is closely associated with the severity of many diseases, in-

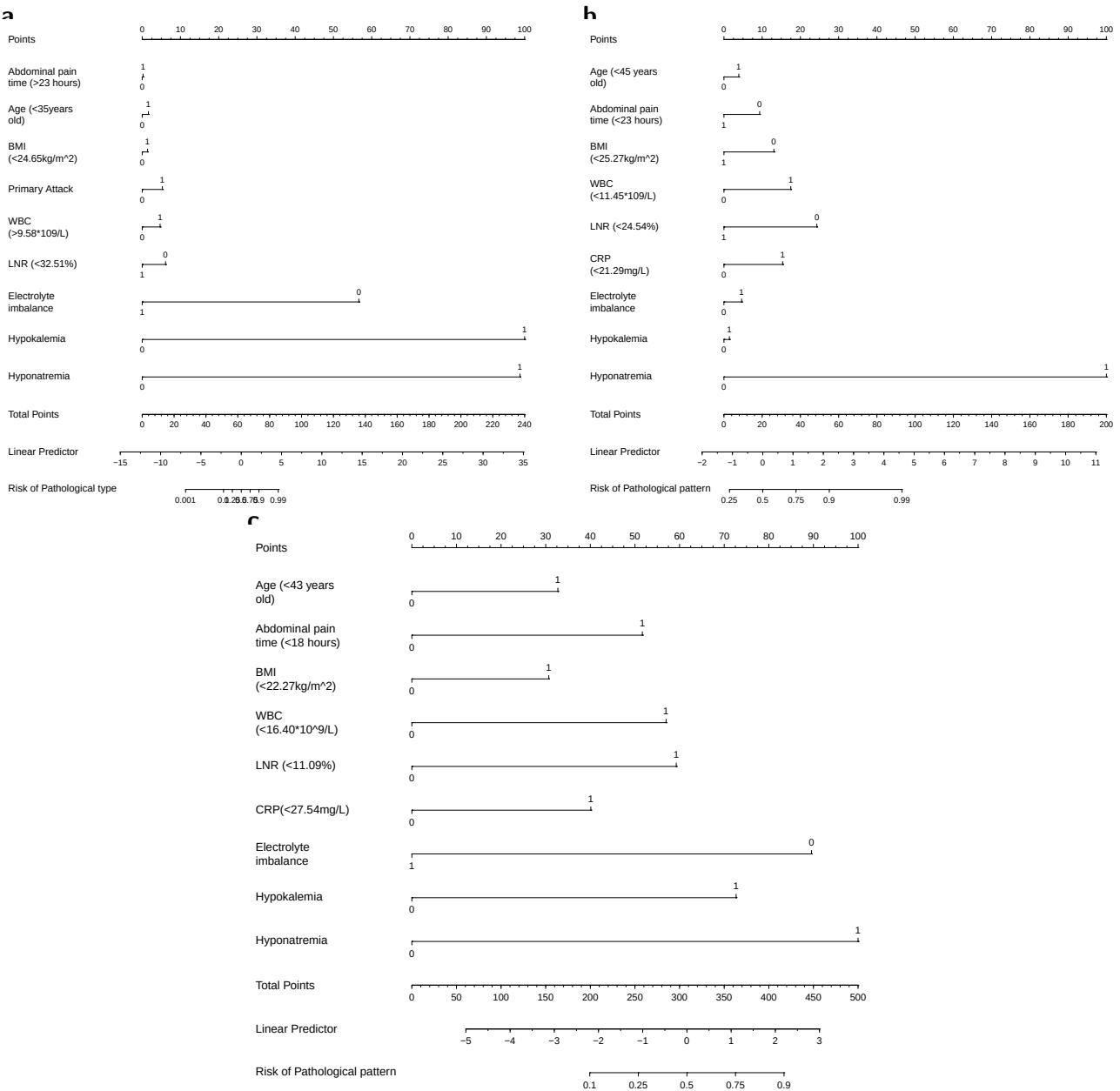


Figure 3: Pathological-type risk prediction models. **a**, Chronic versus acute appendicitis. **b**, Acute simple versus acute non-simple appendicitis. **c**, Acute suppurative versus acute gangrenous appendicitis.

cluding gangrenous cholecystitis, intestinal necrosis, and postoperative anastomotic fistula after colorectal surgery, increasing the incidence of perioperative complications, mortality and complicated appendicitis [30–38]. In addition, we have confirmed in another study that WBC, LNR, CRP, and hyponatremia are closely related to the occurrence of postoperative complications. Therefore, similar to the precision and individualized treatment of tumors, we should develop a personalized, precise treatment plan after carefully evaluating the conditions of appendicitis patients, and perhaps eventually WBC, LNR, CRP, and hyponatremia may be the target inspiring great confidence in the diagnosis, treatment, and prognosis of all appendicitis.

In our results, it is also shown that primary attack is an independent risk factor for acute appendicitis. It is well known that patients with appendicitis attacks can be treated conservatively and endoscopic retrograde appendicitis therapy (ERAT), which is a nonoperative and minimally invasive method of treatment, and research results show that conservative treatment is no less effective than surgical methods [39–45]. However, compared with complete appendectomy, there is risk of recurrence with conservative treatment,

and the rate of recurrence varies according to our experience with the presence or absence of fecalith in the appendix. A study has shown no correlation between fecalith and acute appendicitis [46]. However when a conservatively treated appendicitis patient recurs, the possibility of the inflammatory infiltrating cells transforming from neutrophils to macrophages is greatly increased [47–48], pathologically indicating an acute attack of chronic appendicitis. Therefore, when a patient with recurred appendicitis visits the clinic, we should diagnose as chronic appendicitis, without ruling out the possibility of severe appendicitis, so both laboratory and physical examination have to be considered for a comprehensive judgment.

Finally, our results also suggested the effect of abdominal pain time on acute suppurative appendicitis and acute gangrenous appendicitis. For a patient with severe inflammation such as acute suppurative appendicitis and acute gangrenous appendicitis, timely surgical treatment is the best treatment to control the inflammation and remove the lesion. The longer the inflammation progresses without effective control, the more likely it is for suppurative appendicitis to progress to acute gangrenous appendicitis. Many years ago, the authoritative international journal published the management concept of appendicitis time [49–50]. For appendicitis with severe inflammation, the abdominal pain duration is an important factor that we cannot ignore.

This study has some limitations, First, the number of patients included in the study was small; second, we are lacking in powerful and definitive RCT results; finally, data were obtained from a single center.

5 Conclusion

First attack, white blood cell count ($\geq 9.76 \times 10^9/L$) and LNR ($\geq 32.51\%$) were independent risk factors for acute appendicitis and chronic appendicitis. White blood cell count ($11.12 \times 10^9/L$), LNR ($< 24.54\%$) and CRP (≥ 21.29) were independent risk factors for acute simple appendicitis and acute complicated appendicitis. Electrolyte disturbance is a risk factor for acute suppurative appendicitis, while white blood cell count ($\geq 16.40 \times 10^9/L$), LNR ($< 11.09\%$) and CRP (≥ 27.54) are independent risk factors for acute suppurative appendicitis and acute gangrenous appendicitis.

Ethics Statement

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). Participate declaration: Every human participant agreed to this study, and this study was approved by the Medical Ethics Committee of the Seventh Affiliated Hospital of Sun Yat-sen University (No.KY-2023-133-02).

Clinical Trial Registration

The study was registered with the Chinese Clinical Trial Registry (ChiCTR2500109521).

Author Contributions

Authors' contributions: Hui-Long Guo, Zhi-Feng Mo, Mao-Lin Liu contributed equally to this study, and both conceptualized and designed the study, analyzed and interpreted the data, drafted the manuscript, and critically revised the manuscript for important intellectual content; Hui-Long Guo participated in data acquisition and statistical analysis and supervised the whole study and monitored the standard surgical operations; all the authors took part in the surgical treatment of appendicitis.

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Data Availability Statement

The original anonymous dataset is available on request from the corresponding author at liu-maolin@sysush.com.

Previous Presentation

The paper is not based on a previous communication to a society or meeting.

Conflict of Interest

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

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