Appendicitis Prognostic Score: A Preoperative Scoring System to Help Determine Surgical Timing for Appendectomy

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Abstract

Background: Several factors are considered to be associated with increased postoperative complications after appendectomies, yet whether high-risk patients benefit from a shorter waiting time for surgery remains unclear. This study aimed to propose an appendicitis prognostic score (APS) for predicting surgical outcome and assessing the influence of surgical delay on postoperative complications.

Methods: From 2013 to 2019 patients diagnosed with acute appendicitis requiring an emergent appendectomy were divided into training (2013-2018) and validation groups (2019). The APS was developed from preoperative characteristics related to a perforated appendicitis in the training group, then correlated with postoperative complications (surgical site infection, intra-abdominal abscess and ileus) and verified by the validation group. The effects of surgical delay on postoperative complications was evaluated between high and low APS subgroups.

Results: APS criteria included age >45, body temperature >37.5°C, heart rate >95bpm, breathing rate >20/min, diastolic blood pressure <75mmHg, and abdominal pain duration 24-48h and >48h, with a maximum of 8 points. A high APS (≥ 4 points) was significantly associated with an increased complication rate in the validation group ($p=0.016$). Further analysis of the training group showed that patients with ≥ 4 points had a higher overall complication (21.85% vs. 11.27%, $p=0.006$) and surgical site infection rate (11.92% vs. 4.69%, $p=0.011$) if surgical delay exceeded 12 hours.

Conclusion: The APS is a practical metric for predicting postoperative complications. It is recommended that patients with an APS score ≥ 4 undergo an appendectomy within 12 hours to avoid an increased risk of overall complications and surgical site infection.

Background

Acute appendicitis is one of the most common causes of an acute abdomen and usually requires emergent surgery. Before computed tomography (CT) became popular, appendicitis was mostly diagnosed based on symptoms, physical examination and laboratory findings. Alvarado et al. [1] published a scoring system that helped surgeons decide whether to observe or operate on patients with suspected appendicitis. CT is now helpful for distinguishing appendicitis from mimicking diseases, such as diverticulitis or ileitis, and for identifying certain features suggestive of a perforated appendicitis.

Although antibiotic treatment may be effective in select patients, appendectomy is still the only way to prevent recurrent appendicitis. There has been dispute over the impact of surgical delay on outcomes for years. Some studies claimed that a prolonged waiting time for surgery increased the risk of complications such as surgical site infection [2–4], while other studies disagreed [5–7]. Several factors (i.e., age, obesity, leukocytosis, symptom duration) have been proposed to be associated with an increased risk of postoperative complications [8–10]. If those patients at a high-risk for complication benefit from a shorter waiting time for surgery remains unclear. The purpose of this study is to identify patients who may be potentially affected by surgical delay.

A perforated appendix is thought to put patients at a greater risk of postoperative complications [7, 11, 12]. By collecting comprehensive clinical characteristics and perioperative medical data, we created a new scoring system based on preoperative factors related to a perforated appendix. Then we evaluated the association

between the scoring system and postoperative complications (surgical site infection, intra-abdominal abscess, and ileus). The efficacy of the scoring system was verified with a separate cohort. Furthermore, we aimed to use the scoring system to assess the influence of surgical delay on postoperative complications. Our scoring system can play an important role in reducing postoperative complications by optimizing the time to the operating room (OR) for select vulnerable patients, particularly since the coronavirus disease 2019 (COVID-19) became pandemic and created challenges in the management of surgical emergencies.

Methods

Patients and Data Collection

We retrospectively analyzed the outcomes of patients who were diagnosed with acute appendicitis at a single tertiary medical center from 2013 to 2019. This study was approved by the Research Ethics Committee Office at National Taiwan University Hospital, Taipei, Taiwan (Institutional Review Board number: 202010066RINB). Patients who had visited our emergency room (ER) and underwent an emergent appendectomy were included in this study. Those who received conservative treatment first or had an elective appendectomy were excluded. Patients accidentally found to have appendicitis mixed with neoplastic lesions (i.e., adenocarcinoma, carcinoid, pseudomyxoma) or other conditions that required a combined surgery with other specialists (i.e., urologists, obstetricians, gynecologists) were excluded. Patients with no emergency room record or an unclear history were also excluded.

Emergency room records included basic arrival information, clinical history, laboratory values and imaging findings. Arrival information included body temperature, pulse rate, respiratory rate and blood pressure upon arrival at the ER. Empiric intravenous antibiotics were administered to all patients as soon as they were diagnosed with acute appendicitis either by clinical or imaging findings. Perioperative data included the time of ER arrival, time of surgery start, operative time, operative method, operative findings, pathology reports, hospital stay and postoperative complications. Abdominal pain duration, being an important indicator in the study, was defined as the time from symptom onset to ER arrival. To minimize recall bias we reviewed the history record from the ER note, admission note and nursing note. Cases with discordant descriptions were excluded. Time to surgery was defined as the time from ER arrival to surgery start.

Disease Severity and Surgical Outcomes

A perforated appendix was defined as a ruptured and abscessed appendix. Gangrenous change was not defined as perforated appendicitis because the appendiceal wall remained intact and there was evidence that treating gangrenous appendicitis as nonperforated disease did not affect surgical outcome [13]. Disease severity was based on intraoperative findings. However, once turbid ascites was mentioned in the operative note the pathology report was reviewed to rule out a microperforation.

Postoperative complications included surgical site infection, intra-abdominal abscess formation, paralytic ileus, and internal bleeding. Patients with surgical site infections required wet dressings or a special sterile dressing on their wounds with oral or intra-venous antibiotic administration. An intra-abdominal abscess was confirmed on computed tomography when patients reappeared to the ER complaining of a fever or abdominal pain after discharge. Paralytic ileus was diagnosed if the patient required short-term nasogastric tube decompression or an

intravenous injection of prokinetics during recovery. Postoperative internal bleeding required emergent surgical intervention or transarterial embolization.

Data analysis and statistics

All patients were assigned into a training (2013–2018) or validation group (2019) based on the year of encounter. The training group was used to design the scoring system and the validation group was used to verify its efficacy. In the training group the clinical characteristics of patients with perforated and nonperforated appendicitis were compared using a Chi-square or Fisher's exact test for categorical variables and an independent Student's t-test for continuous variables. Preoperative factors were selected and analyzed with univariate and multivariate logistic regression models to identify factors associated with a perforated appendix.

For those significant factors that were continuous variables a cut point was set to transform that factor into a categorical variable. The appropriate cut-off value was determined based on the optimal combination of sensitivity and specificity from the receiver operating characteristic (ROC) curve. The new categorical factors were reanalyzed using univariate and multivariate logistic regression to reconfirm significance. The β coefficients that were obtained from the multivariate logistic regression were used to measure the score of each parameter (significant factor). With cut points and scores we developed a scoring system called the Appendicitis Prognostic Score (APS).

The postoperative complications were the primary end-point in the study. The relationships between preoperative factors, APS and postoperative complications were then evaluated using univariate and multivariate logistic regression models. The efficacy of APS was verified by comparing overall complications between high (≥ 4 points) and low (< 4 points) scores in the validation group using the Chi-square test. The effect of surgical delay on postoperative complications was compared between subgroups of high and low APS using the Chi-square test. All statistical analysis was performed with SAS version 9.4 (SAS Institute Inc, Cary, NC). Statistical significance was defined as $P < 0.05$.

Results

From 2013 to 2019 a total of 1986 patients coded for acute appendicitis with the ICD-9 (before 2016) and ICD-10 (2016-) classification were cared for at our institution, of whom 1559 were included in this study. The study flowchart is shown in Fig. 1.

Development of the APS

The baseline demographic and clinical characteristics of patients with or without a perforated appendix are shown in Table 1. The perforation rate was 29.8%, which was similar to other studies.[6, 7] There were significant differences in age, body temperature, heart rate, systolic and diastolic pressure when arriving ER, abdominal pain duration, operative time, the use of laparoscopic surgery, Neutrophil-Lymphocyte Ratio (NLR), Platelet-Lymphocyte Ratio (PLR), hospital stay, overall complications, intra-abdominal abscess formation and paralytic ileus between groups. Surgical site infection was higher in patients with a perforated appendix (8.52% vs. 5.85%) but did not reach statistical significance. Notably, no specific difference was seen in BMI, time to surgery or WBC count between groups.

Table 1
Baseline Demographics and Clinical Characteristics

	All Patients (n = 1339)	Non- Perforated (n = 940)	Perforated (n = 399)	P
Age (Mean, SD)	38.21 (19.33)	37.27 (17.83)	40.41 (22.34)	0.013 ^a
Sex (n, %)				0.255 ^b
Women	636 (47.5%)	456 (48.51%)	180 (45.11%)	
Men	703 (52.5%)	484 (51.49%)	219 (54.89%)	
Body Mass Index (BMI) (Mean, SD)	22.86 (4.60)	22.96 (4.12)	22.62 (5.57)	0.270 ^a
Body temperature at triage (Mean, SD)	37.34 (0.80)	37.21 (0.72)	37.64 (0.91)	< 0.001 ^a
Heart rate at triage (Mean, SD)	93.45 (19.09)	90.54 (16.77)	100.29 (22.24)	< 0.001 ^a
Breathing rate at triage (Mean, SD)	19.20 (11.35)	18.67 (1.89)	20.47 (20.55)	0.082 ^a
Systolic blood pressure at triage (Mean, SD)	124.25 (20.32)	124.99 (19.78)	122.50 (21.47)	0.049 ^a
Diastolic blood pressure at triage (Mean, SD)	75.41 (22.05)	76.40 (24.44)	73.05 (14.68)	0.002 ^a
Pain score (VAS) (Mean, SD)	5.98 (1.81)	6.01 (1.72)	5.92 (2.02)	0.409 ^a
Abdominal pain duration (n, %)				< 0.001 ^b
< 24h	706 (52.73%)	576 (61.28%)	130 (32.58%)	
24-48h	273 (20.39%)	183 (19.47%)	90 (22.56%)	
> 48h	360 (26.89%)	181 (19.26%)	179 (44.86%)	
Diagnostic tool				1.000 ^c
Physical examination	2 (0.15%)	2 (0.22%)	0 (0%)	
CT	1311 (98.94%)	919 (98.82%)	392 (99.24%)	
Ultrasound	10 (0.75%)	7 (0.75%)	3 (0.76%)	
MRI	2 (0.15%)	2 (0.22%)	0 (0%)	
Diagnostic time (ER->Exam) (h) (Mean, SD)	3.87 (2.79)	3.95 (2.84)	3.67 (2.66)	0.106 ^a
Time to surgery (ER->OR) (h) (Mean, SD)	14.97 (10.44)	14.60 (9.62)	15.81 (12.06)	0.096 ^a
Operative time (min) (Mean, SD)	70.91 (32.42)	63.33 (25.51)	87.97 (39.18)	< 0.001 ^a
Operative method (n, %)				0.004 ^b

	All Patients (n = 1339)	Non- Perforated (n = 940)	Perforated (n = 399)	P
Laparoscopic	1321 (98.8%)	934 (99.36%)	387 (97.48%)	
Open	16 (1.20%)	6 (0.64%)	10 (2.52%)	
WBC (Mean, SD)	13.79 (4.48)	13.63 (4.35)	14.15 (4.77)	0.062 ^a
Neutrophil-Lymphocyte Ratio (NLR) (Mean, SD)	10.49 (7.86)	9.72 (7.66)	12.30 (8.05)	< 0.001 ^a
Platelet-Lymphocyte Ratio (PLR) (Mean, SD)	27.66 (20.08)	25.87 (19.59)	31.86 (20.6)	< 0.001 ^a
Hospital stay in days (Mean, SD)	3.70 (3.45)	2.76 (1.58)	5.92 (5.22)	< 0.001 ^a
Complication (n, %)	139 (10.39%)	65 (6.91%)	74 (18.59%)	< .0001 ^b
Surgical site infection	89 (6.65%)	55 (5.85%)	34 (8.52%)	0.073 ^b
Intra-abdominal abscess	30 (2.24%)	7 (0.74%)	23 (5.76%)	< .0001 ^b
Paralytic ileus	23 (1.72%)	3 (0.32%)	20 (5.01%)	< .0001 ^b
Internal bleeding	2 (0.15%)	1 (0.11%)	1 (0.25%)	0.507 ^c
a. Estimated by independent t test. b. Estimated by chi-square test. c. Estimated by Fisher's exact test (Non-parameter statistic).				

Table 2
Univariate and Multivariate Logistic Regression Models for Perforated Appendicitis

	Univariate Model		Multivariate Model		
(A) Preoperative factors	OR (95% CI)	P	β	OR (95% CI)	P
Age	1.01 (1.001,1.01)	0.007		1.01 (1.01,1.02)	< 0.001
Sex	1.15 (0.91,1.45)	0.255			
Body mass index (BMI)	0.98 (0.96,1.01)	0.214			
Body temperature at triage	1.98 (1.70,2.31)	< 0.001		1.33 (1.10,1.60)	0.004
Heart rate at triage	1.03 (1.02,1.03)	< 0.001		1.01 (1.01,1.02)	0.001
Breath rate at triage	1.14 (1.08,1.21)	< 0.001		1.12 (1.05,1.19)	0.001
Systolic blood pressure at triage	0.99 (0.99,1.00)	0.042		1.003 (0.99,1.01)	0.589
Diastolic blood pressure at triage	0.99 (0.98,0.99)	0.001		0.98 (0.97,0.995)	0.009
Pain score (VAS)	0.97 (0.91,1.04)	0.378			
Time to surgery ($\leq$ 12hr, > 12hr)	1.02 (0.79,1.31)	0.901			
WBC	1.03 (1.00,1.05)	0.053			
Neutrophil-Lymphocyte Ratio (NLR)	1.04 (1.03,1.06)	< 0.001		1.02 (0.98,1.06)	0.341
Platelet-Lymphocyte Ratio (PLR)	1.01 (1.01,1.02)	< 0.001		1.01 (0.99,1.02)	0.387
Abdominal pain duration					
< 24h	Ref			Ref	
24-48h	2.18 (1.59,2.99)	< 0.001	0.6574	1.93 (1.38,2.70)	< 0.001
> 48h	4.38 (3.31,5.80)	< 0.001	1.3580	3.89 (2.88,5.25)	< 0.001
(B) With cut points	OR (95% CI)	P	β	OR (95% CI)	P
Age > 45	1.89 (1.49,2.40)	< 0.001	0.7573	2.13 (1.62,2.81)	< 0.001
Body temperature > 37.5 (°C)	2.94 (2.30,3.75)	< 0.001	0.6304	1.88 (1.41,2.49)	< 0.001
Heart rate > 95 (bpm)	2.30 (1.81,2.92)	< 0.001	0.5430	1.72 (1.29,2.29)	< 0.001

	Univariate Model		Multivariate Model		
Breathing rate > 20 (/min)	2.22 (1.53,3.22)	< 0.001	0.7435	2.1 (1.39,3.18)	< 0.001
Diastolic blood pressure < 75 (mmHg)	1.59 (1.26,2.02)	< 0.001	0.6050	1.83 (1.41,2.38)	< 0.001

Of the clinical characteristics listed in Table 1, preoperative factors were selected and further evaluation for a perforated appendicitis was performed (Table 2A). On multivariate analysis, age, body temperature (BT), heart rate (HR), breath rate (BR), diastolic blood pressure (DBP) and abdominal pain duration 24–48h and > 48h had an independent statistically significant relationship with a perforated appendix. A ROC curve was obtained to identify the optimal cut-off value as follows: Age > 45, BT > 37.5°C, HR > 95bpm, BR > 20/min and DBP < 75mmHg. Univariate and multivariate analysis with the cut points mentioned above showed that all categorized factors were significantly associated with perforated appendicitis (Table 2B). Point values in the APS were assigned based on the β coefficient of each significant factor (Table 3).

Table 3
Parameters in the Appendicitis Prognostic Score

Parameters	Original ^a	Point
Age > 45	1.39	1
Body temperature > 37.5 (°C)	1.16	1
Heart rate > 95 (bpm)	1.00	1
Breathing rate > 20 (/min)	1.37	1
Diastolic blood pressure < 75 (mmHg)	1.11	1
Abdominal pain duration 24–48 (h)	1.21	1
Abdominal pain duration > 48 (h)	2.50	3
a. Original = β / 0.5430		

Table 4
Logistic Regression Models for Postoperative Complications

	Overall Complications		Surgical Site Infection		Intra-abdominal Abscess		Paralytic Ileus	
(A) Multivariate Regression	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Age	1.02 (1.01,1.03)	0.001	1.02 (1.005,1.03)	0.006	NS		NS	
Sex	NS		NS		NS		3.10 (1.30,7.43)	0.011
BMI	NS		NS		NS		NS	
Body temperature at triage	0.92 (0.71,1.18)	0.503	NS		NS		NS	
Heart rate at triage	1.01 (1.001,1.03)	0.027	NS		1.02 (0.998,1.04)	0.073	1.03 (1.01,1.04)	0.003
Breath rate at triage	NS		0.91 (0.80,1.02)	0.098	NS		NS	
Systolic blood pressure at triage	NS		1.01 (0.997,1.01)	0.180	NS		NS	
Diastolic blood pressure at triage	NS		NS		NS		NS	
Pain score (VAS)	NS		NS		NS		NS	
Abdominal pain duration	NS		NS		NS		NS	
< 24h	Reference		Reference		Reference		Reference	
24-48h	1.50 (0.94,2.41)	0.090	1.77 (1.05,2.99)	0.034	1.75 (0.39,7.91)	0.468	1.84 (0.69,4.90)	0.221
> 48h	1.79 (1.17,2.76)	0.008	1.24 (0.43,2.12)	0.424	6.80 (2.21,20.97)	0.001	1.88 (0.76,4.63)	0.170
Time to surgery ($\leq$ 12hr, $>$ 12hr)	NS		NS		NS		NS	
WBC	NS		NS		NS		NS	
Neutrophil-Lymphocyte Ratio (NLR)	1.03 (1.01,1.05)	0.014	NS		NS		1.00 (0.93,1.08)	0.997

	Overall Complications		Surgical Site Infection		Intra-abdominal Abscess		Paralytic Ileus	
Platelet-Lymphocyte Ratio (PLR)	NS		NS		NS		1.01 (0.98,1.04)	0.406
	Overall Complications		Surgical Site Infection		Intra-abdominal Abscess		Paralytic Ileus	
(B) Univariate Regression	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Appendicitis prognostic score (APS)	1.21 (1.10,1.34)	< 0.001	1.06 (0.94,1.19)	0.328	1.75 (1.37,2.23)	< 0.001	1.26 (1.03,1.54)	0.022
NS: No significance in univariate logistic regression								

Relationship between APS and Postoperative Complications

Preoperative factors were further evaluated for their association with overall complications, surgical site infection, intra-abdominal abscess formation and paralytic ileus (Table 4A). On multivariate analysis, age, HR, symptom duration > 48h and NLR were significantly related to overall complications. Age and symptom duration 24–48h were significantly related to surgical site infection. Symptom duration > 48h was significantly related to an intra-abdominal abscess. Sex and HR were significantly related to paralytic ileus. In contrast, there was no significant association between time to surgery and any kind of complication. No lab-specific factors (WBC, NLR, PLR) were related to specific complications (surgical site infection, intra-abdominal abscess and paralytic ileus).

Of those significant factors, age, HR and symptom duration 24–48h and > 48h were parameters of the APS. Univariate analysis revealed that APS was associated with overall complications ($p < 0.001$), intra-abdominal abscess formation ($p < 0.001$) and paralytic ileus ($p = 0.022$) (Table 4B). The validation group consisted of 220 patients and the overall complication rate was 8.18%. Patients with $APS \geq 4$ had a higher overall complication rate than patients with $APS < 4$ (14.93% vs. 5.23%, $p = 0.016$) (Table 5).

Table 5
Verification of Appendicitis Prognostic Score (APS) in Validation Group

Score	All Patients (n = 220)	Overall complications (n = 18)	P
≥ 4	67	10 (14.93%)	0.016
< 4	153	8 (5.23%)	

Impact of the APS on Surgical Delay

Based on the validation group results we further divided the training group into two subgroups: APS score ≥ 4 and APS score < 4 (Table 6). After omitting patients with missing time data there were 364 and 771 patients in the score ≥ 4 and score < 4 subgroups, respectively. In the score ≥ 4 subgroup, patients with a time to surgery > 12h had a significantly higher overall incidence of complications (21.85% vs. 11.27%, $p = 0.006$) and surgical site infections (11.92% vs. 4.69%, $p = 0.011$) than patients with a time to surgery of ≤ 12 h. The intra-abdominal abscess and paralytic ileus rates were higher (5.3% vs. 2.82%, 5.3% vs. 3.29%) but did not reach statistical

significance. In the score < 4 subgroup there was no significant difference in overall complications or any specific complication regardless of ≤ 12 h or > 12h until surgery.

Table 6
Association of Appendicitis Prognostic Score (APS) and Time to Surgery in Postoperative Complications

APS	Score ≥ 4 (364)			Score < 4 (771)		
Time to surgery	≤ 12 h (213)	> 12h (151)	P	≤ 12 h (396)	> 12h (375)	P
Overall complications	24 (11.27%)	33 (21.85%)	0.006	39 (9.87%)	31 (8.27%)	0.438
Surgical site infection	10 (4.69%)	18 (11.92%)	0.011	31 (7.83%)	24 (6.4%)	0.441
Intra-abdominal abscess	6 (2.82%)	8 (5.3%)	0.225	2 (0.51%)	3 (0.8%)	0.610
Paralytic ileus	7 (3.29%)	8 (5.3%)	0.342	6 (1.52%)	5 (1.33%)	0.832

Discussion

The treatment of nonperforated appendicitis differs from perforated appendicitis. Laparoscopic appendectomy is a safe procedure for nonperforated appendicitis, whereas conservative treatment may be successful in select patients even though some patients may eventually still need an appendectomy due to the considerable recurrence rate [14–16]. When dealing with perforated appendicitis, a small randomized controlled trial revealed that surgery was still feasible for patients with an appendiceal abscess [17], while other studies suggested that patients may benefit from antibiotics or drainage prior to surgery [18]. CT may be useful at differentiating between perforated from nonperforated appendicitis [19–21], but the relationship between these CT findings and postoperative complications is unclear. A few studies proposed a score or grading system for predicting surgical outcomes but most required intraoperative findings [22–24], which means that the systems were unable to help reverse these complications. The APS was developed using only preoperative factors and was shown to be associated with postoperative complications, intra-abdominal abscess formation and paralytic ileus. Looking into this result in terms of the parameters of the APS, all preoperative factors have been thoroughly analyzed for their relationship with postoperative complications in this study (Table 4A). Age was associated with overall complications and surgical site infection, while HR was associated with overall complications and paralytic ileus, respectively. Meanwhile, abdominal pain duration was found to be associated with overall complications, surgical site infection and intra-abdominal abscess formation.

There was wide disagreement about how time to surgery influences surgical outcome [2–7, 25–28], but few studies use a prognostic scoring system to identify patients who may be potentially affected by surgical delay. In our study, when focusing on patients with APS ≥ 4 a surgical delay of > 12h significantly increased overall complications and surgical site infection rate despite the fact that all of the patients in our study received preoperative intravenous antibiotics. BT, HR, and BR are criteria for systemic inflammatory response syndrome (SIRS), implying that patients with a high APS before surgery may be predisposed to disease progression from a localized to systemic infection. We hypothesized that the presence of SIRS/sepsis may be associated with postoperative complications. Boomer et al. [7] echoed our hypothesis, showing that the incidence of sepsis was significantly higher in the surgical site infection group than among those who did not develop a surgical site infection. Low DBP could be due to the loss of arterial elasticity through the aging process or vessel dilatation from the use of antihypertensive medications. Low DBP in middle aged and older patients was found to increase

all-cause mortality [29]. Jawad et al. [26] also believed that older age and a higher Charlson Comorbidity Index were related to appendicitis progression and worse outcomes. We therefore presumed that age and low DBP in the APS represented a chronically ill status, which may influence postoperative recovery. It is suggested that CT imaging may be a good tool for predicting the severity of a “locally-inflamed appendix”, but APS discloses the severity of “systemic progression” that may contribute to increased complications if we delay surgical intervention.

Of the studies that worked to predict postoperative complications [8–10, 22–24], our scoring system has several advantages. First, the efficacy of the APS was validated by a separate cohort of patients. Second, the APS is a simple and practical scoring system. It is composed of mainly objective numbers and should be applicable to any other medical institution. It can be assessed by a medical student or nurse since all one needs is a history and vital signs. Physical examination findings (peritoneal sign, muscle guarding, RLQ tenderness, etc.) may be discrepant when performed by different physicians. Although C-reactive protein (CRP) was required in some scoring systems, it was not included in our scoring system because not every medical institution (including our hospital) routinely checks this laboratory value. Most importantly, the APS can be calculated immediately once the patient is diagnosed with acute appendicitis. In the era of the COVID-19 pandemic, it is more important than ever to accurately prioritize emergent surgeries in order to preserve our medical resources, including hospital staff and operation room schedules. Our study suggests that patients with $APS < 4$ are safe for surgical delay $> 12h$ under administration of intravenous antibiotics. On the other hand, a recent study reported that prolonged time to consultation due to COVID-19 quarantine may increase rates of severe peritonitis and intra-abdominal abscess formation [30]. Since abdominal pain duration is a major factor in the calculation of APS, the APS can be helpful for surgeons to arrange surgery in an appropriate time frame to avoid an increased risk of overall complications and surgical site infection.

There are several limitations to this study. First, it was a single-institute retrospective study and the external cohort was set up by separate year. Although in the validation group we observed a higher proportion of complications at increased APS scores, the small number of cases used to verify this metric permitted only overall complications to reach statistical significance. Further multi-institution prospective studies or big data analysis may help confirm the impact of the APS on surgical delay. Second, although most preoperative characteristics were concrete data, recall bias was inevitable when recording abdominal pain duration. To limit this impact symptom duration was triple checked from the ER record, admission note and nursing note. Cases with discordant descriptions were excluded. Third, the operator’s surgical experience may be an important risk factor for postoperative complications but was not measurable in our score system [31]. Resident participation in the surgery and patient care should be considered in a future study.

Conclusion

In conclusion, the appendicitis prognostic score (APS) is a practical scoring system for predicting postoperative complications, and serves to select high-risk patients that may suffer from consequences of delayed surgery. Patients with an $APS \geq 4$ are indicated for an appendectomy within 12h to avoid an increased risk of overall complications and surgical site infection.

Abbreviations

APS: Appendicitis prognostic score; CT: Computed tomography; OR: Operation room; ER: Emergency room; ROC curve: Receiver operating characteristic curve; NLR: Neutrophil-lymphocyte ratio; PLR: Platelet-lymphocyte ratio; BT: Body temperature; HR: Heart rate; BR: Breath rate; DBP: Diastolic blood pressure; SIRS: Systemic inflammatory response syndrome; BMI: Body mass index

Declarations

Ethics approval and consent to participate:

This study was approved by the Research Ethics Committee Office at National Taiwan University Hospital, Taipei, Taiwan (Institutional Review Board number: 202010066RINB).

Consent for publication:

Not applicable

Availability of data and materials:

The dataset described in the manuscript is available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

LaiSL contributed to study conception design, data acquisition and article drafting. LinBR contributed to study conception design, data interpretation and critical revision. ChangCH contributed to data analysis and interpretation. LeePC, HoCM, WuJM and LaiHS contributed to data interpretation and critical revision. All authors read and approved the final manuscript.

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Figures

Figure 1

Study flow chart.