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Research article

Preoperative systemic and local inflammation are independent risk factors for difficult laparoscopic cholecystectomy after percutaneous transhepatic gallbladder drainage

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A R T I C L E I N F O

Keywords:
Acute cholecystitis
Laparoscopic cholecystectomy
Percutaneous transhepatic gallbladder drainage
Surgical difficulty

A B S T R A C T

Background: Laparoscopic cholecystectomy (LC) is required for acute cholecystitis patient with percutaneous transhepatic gallbladder drainage (PTGBD). However, it's unknown how to distinguishing the surgical difficulty for these patients.
Methods: Data of patients who underwent LC after PTGBD between 2016 and 2022 were collected. Patients were categorized into difficult and non-difficult operations based on operative time, blood loss, and surgical conversion. Performance of prediction model was evaluated by ROC, calibration, and decision curves.
Results: A total of 127 patients were analyzed, including 91 in non-difficult operation group and 36 in difficult operation group. Elevated CRP ($P = 0.011$), pericholecystic effusion ($P < 0.001$), and contact with stomach or duodenal ($P = 0.015$) were independent risk factors for difficult LC after PTGBD. A nomogram was developed according to these risk factors, and was well-calibrated and good at distinguishing difficult LC after PTGBD.
Conclusion: Preoperative elevated systemic and local inflammation indictors are predictors for difficult LC after PTGBD.

1. Introduction

Acute cholecystitis (AC) is acute gallbladder inflammation, with laparoscopic cholecystectomy (LC) as the standard treatment [1]. However, for patients with severe cholecystitis, with severe systemic inflammation, or with other serious comorbidities, immediate surgery may pose a life-threatening risk or lead to severe complications. For such high-risk patients, percutaneous transhepatic gallbladder drainage (PTGBD) is an alternative treatment to temporarily alleviate symptoms [2–4].

PTGBD is generally considered less invasive and with a lower risk of adverse events compared to cholecystectomy [1–5]. Although

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LC is the optimal choice for curative treatment of AC due to its high recurrence rate. However, given that elderly patients with AC often have additional comorbidities, PTGBD is frequently used as an interim treatment for those at high surgical risk before undergoing LC [6].

For patients requiring PTGBD, their LC procedures are more complex than those without PTGBD [7]. How to assess the surgical difficulty of LC in these patients is of significant value for reducing surgical risks and improving their prognosis. Previous researches have primarily focused on determining the optimal timing for subsequent LC after PTGBD [8,9]. However, the optimal timing for operation should be determined by a combination of various factors, rather than solely based on the timing of PTGBD treatment. For AC patients undergoing LC without PTGBD, various investigations have demonstrated that certain demographic, laboratory, and radiologic factors may lead to prolonged operating time or heightened risk of surgical conversion [10–15]. Nevertheless, for AC patients with PTGBD, preoperative assessment of the surgical difficulty for LC remains to be explored.

The ability to accurately identify an individual patient's risk for difficult operation based on preoperative information can result in more meaningful and accurate preoperative counseling, improved surgical scheduling and efficiency. On the other hand, risk stratification for LC after PTGBD increase patient safety by preassigning appropriate support staff and, if necessary, delaying surgery. Hence, the aim of our study is to identify the risk factors and establish a predictive model for difficult operation in patients undergoing LC after PTGBD.

2. Methods

2.1. Study population

The data of patients at Shanghai Tenth People's Hospital between January 2016 to July 2022 were collected. The study included patients diagnosed with cholecystitis who had PTGBD followed by LC. Patients were excluded from the study if they underwent additional procedures like hepatic cyst fenestration or choledochotomy, or if they had missing data on crucial parameters. All operations were performed by experienced hepatobiliary surgeons with over a decade of laparoscopic surgery experience.

2.2. Data collection

The following parameters were collected: (1) demographic characteristics [age, sex, body mass index (BMI), previous history of abdominal surgery, American Society of Anesthesiologists (ASA) score, and Charlson Comorbidity Index (CCI)], (2) laboratory data [C-reactive protein (CRP), white blood cells (WBC), hemoglobin, albumin, bilirubin, and alanine aminotransferase (ALT)], (3) radiographic data [maximum diameter of stone, multiple gallstone, gallstone in infundibulum, coarse gallbladder wall, pericholecystic effusion, distended gallbladder, contact between gallbladder and colon, contact between gallbladder and stomach or duodenum, thickness of gallbladder wall, gangrenous cholecystitis, pericholecystic abscess, hepatic abscess, biliary peritonitis, and emphysematous cholecystitis], (4) PTGBD- and surgery-related data [PTGBD tube removal before surgery, interval from PTGBD placement to LC surgery, duration of operation, surgical conversion, and blood loss], (5) prognosis data [postoperative hospitalization days, hospitalization costs, and postoperative complications].

Laboratory tests were conducted within 3 days prior to the operation. In our study, the elevated CRP is defined as CRP >8.2 mg/L, elevated WBC is defined as WBC $>9 \times 10^9$/L, abnormal PLT is defined as PLT $<100 \times 10^9$/L or PLT $>300 \times 10^9$/L. anemia is defined as hemoglobin <110 g/L, hypoalbuminemia is defined as albumin <35 g/L, jaundice is defined as bilirubin >26 μmol/L, elevated ALT is defined as ALT >40 U/L.

Computed tomogram (CT) scans were conducted within 1 days prior to the operation. CT images were independently interpreted by two experienced abdominal radiologists who were blinded to the patients' outcomes. Distended gallbladder is defined as longitudinal diameter of gallbladder >8 cm or transverse diameter >4 cm, thick gallbladder wall is defined as the thickness of gallbladder >4 mm. Conflicts between the two observers were resolved by consensus [16,17].

2.3. Indications of PTGBD

According to Tokyo Guidelines 2018 (TG18) [18], patients with acute cholecystitis are classified into Grade I/II/III levels. For Grade I patients, PTGBD is not recommended. For Grade II patients with either a CCI score$\geq$6 or an ASA score$\geq$3, and Grade III patients with either a CCI score of $\geq$4 or an ASA score of $\geq$3, PTGBD is considered if medical therapy fails.

2.4. Definition of difficult surgery

Although there is no universally accepted definition of a difficult operation, the TG18 recognizes various factors influencing LC difficulty, including conversion rate, operative time, and complication rate [18]. TG18 also recommends "bail-out procedures" (BOP), such as open conversion, subtotal cholecystectomy, and fundus-first technique, for difficult surgeries to minimize bile duct injury risk. Furthermore, significant blood loss during surgery can escalate complexity and risks due to hemodynamic instability and compromised surgical field visibility. An international expert consensus survey has identified intraoperative bleeding as a key factor in difficult surgeries, and a growing body of research supports blood loss as a marker of surgical difficulty in LC procedures [19–22]. Based on these considerations, and given that our study did not encounter intraoperative complications, patients who meet any of the following criteria were categorized as the "difficult operation group" in our study: (1) duration of operation $>$90min, (2) blood loss $>$100 mL, (3) surgical conversion (open conversion, subtotal cholecystectomy, and fundus-first technique).

2.5. Treatment strategy for AC

The management of AC is tailored to the patient's severity and overall clinical condition according to the TG18 guideline.

For patients with Grade I AC, defined by a CCI score of 5 or less and/or an ASA class of II or less, early LC is considered the first-line treatment modality. However, in patients with a CCI score of 6 or greater and/or an ASA class of III or greater, initial management with antibiotics and supportive care is recommended. Once the patient's condition stabilizes with conservative therapy, LC can be considered.

For patients with Grade II AC, characterized by a more pronounced inflammatory response, require immediate initiation of antibiotic therapy and supportive care. If the inflammation cannot be adequately controlled with medical management, early or urgent PTGBD should be performed, followed by delayed LC. Conversely, if the inflammatory process is successfully controlled, patients should be reassessed using the CCI and ASA scores. For those with a CCI of 5 or less and/or an ASA class of II or less, early LC is recommended. For those with a CCI of 6 or greater and/or an ASA class of III or greater, delayed LC is recommended after their overall condition has improved.

For patients with Grade III AC, representing the most severe form of AC, necessitate immediate administration of antibiotics and comprehensive organ support therapy. Simultaneously, an assessment for negative predictors, including jaundice, neurological dysfunction, and respiratory failure, should be conducted. If any of these negative predictors are present, urgent PTGBD is recommended. Subsequently, patients should be reevaluated using the CCI and ASA scores. For those with a CCI of 4 or greater and an ASA class of 3 or greater, observation is recommended without surgical intervention. For those with a CCI of 3 or less and/or an ASA class of 2 or less, delayed LC is recommended.

2.6. Statistical analysis

Categorical variables were compared by using chi-square χ^2 tests. Continuous data with normal distribution were presented as means (±SD) and compared using the Student's *t*-test. Continuous data with abnormal distribution were presented as medians (interquartile ranges, IQR) and compared using Mann–Whitney *U* test. The univariate logistic analysis was performed to identify risk factors of difficult operation. The factors with $P < 0.1$ in the univariate analysis were incorporated into the multivariate logistic analysis with backward stepwise method, to determine independent risk factors of difficult operation in patients with LC after PTGBD.

In addition, R software and related packages were used to generate figures. A novel predictive nomogram was established based on the independent risk factors. The receiver operating characteristic curve (ROC) of the nomogram and all independent variables were built, and the area under the curve (AUC) was calculated to assess the discrimination. Furthermore, the calibration curves and decision curve analysis (DCA) were used to evaluate the performance of the nomogram. Statistical significance was defined as a P value < 0.05. All analysis was conducted using SPSS 24.0 and R software (version 4.2.2).

3. Results

3.1. Patients' characteristics

In a total of 161 patients, 22 patients who underwent additional operations and 12 patients with unavailable laboratory or radiographic data were excluded from the analysis. In the remaining patients, 127 patients underwent LC after PTGBD, including 91 with non-difficult operation and 36 with difficult operation. The Flow chart of patient selection is shown in Fig. 1. As shown in Table 1, baseline characteristics were listed and compared between two groups. There were no statistically significant differences in most basic data, but the CCI in difficult operation group was higher than that in non-difficult group (non-difficult group *vs.* difficult group, 2 *vs.* 3,

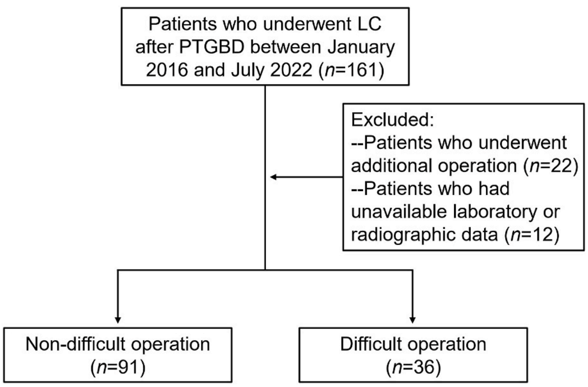

Fig. 1. The flowchart for patient selection.

Table 1
Comparisons of baseline characteristics between non-difficult and difficult operation groups.

Factors	Non-difficult operation $n = 91$	Difficult operation $n = 36$	P value
Demographic characteristics			
Age, year	65 (18)	66 (10.75)	0.303
Sex			0.472
Female	41 (45.1 %)	13 (36.1 %)	
Male	50 (54.9 %)	23 (63.9 %)	
BMI, kg/m^2	24.17 (3.99)	25.02 (5.49)	0.217
Previous abdominal surgery	18 (19.8 %)	9 (25.0 %)	0.684
ASA≥3	19 (20.9 %)	11 (30.6 %)	0.355
CCI, score	2 (3)	3 (3)	0.018[a]
Severity of cholecystitis			0.934
II	83 (91.2)	33 (91.7)	
III	8 (8.8)	3 (8.3)	
Laboratory data			
Elevated CRP	20 (22.0 %)	16 (44.4 %)	0.021[a]
Elevated WBC	4 (4.4 %)	6 (16.7 %)	0.051
Anemia	6 (6.6 %)	2 (5.6 %)	1.000
hypoalbuminemia	4 (4.4 %)	6 (16.7 %)	0.051
Jaundice	7 (7.7 %)	4 (11.1 %)	0.789
Elevated ALT	14 (15.4 %)	7 (19.4 %)	0.772
Radiographic data			
Maximum diameter of stone, cm	0.4 (1.6)	0.50 (1.48)	0.991
Multiple gallstone	25 (27.5 %)	13 (36.1 %)	0.457
Gallstone in infundibulum	14 (15.4 %)	9 (25.0 %)	0.311
Coarse gallbladder wall	75 (82.4 %)	28 (87.5 %)	0.695
Pericholecystic effusion	2 (2.2 %)	18 (50.0 %)	<0.001[a]
Distended gallbladder	9 (9.9 %)	3 (8.3 %)	1.000
Contact with colon	58 (63.7 %)	21 (58.3 %)	0.717
Contact with gastric or duodenum	42 (46.2 %)	27 (75.0 %)	0.006[a]
Thick gallbladder wall	16 (17.6 %)	13 (36.1 %)	0.045[a]
PTGBD-related data			
Interval from PTGBD to LC, day	57 (49)	48.5 (53.5)	0.744
PTGBD tube removal	26 (28.6 %)	9 (25.0 %)	0.853

Data is represented as median (interquartile range) or number (%), unless otherwise stated.
[a] Statistically significant ($P < 0.05$).

$P = 0.018$). There is a significantly higher incidence of elevated CRP in the difficult operation group (22 % *vs.* 44.4 %, $P = 0.021$), with no significant difference in other laboratory data. Besides, no statistically significant differences were observed in the blood test data obtained before PTGBD between the non-difficult and difficult operation groups (Supplementary Table 1). When comparing radiographic data, more patients in the difficult group have pericholecystic effusion (2.2 % *vs.* 50 %, $P < 0.001$), contact between gallbladder and stomach or duodenum (46.2 % *vs.* 75 %, $P = 0.006$), and thick gallbladder wall (17.6 % *vs.* 36.1 %, $P = 0.045$). No gangrenous cholecystitis, pericholecystic abscess, hepatic abscess, biliary peritonitis, and emphysematous cholecystitis were observed. In terms of outcome data (Table 2), patients in the difficult group experienced significantly poorer outcomes, including longer postoperative hospitalization days (4 *vs.* 5 days, $P < 0.001$), higher hospitalization costs (24546 *vs.* 28062 RMB, $P < 0.001$), and a higher incidence of postoperative complication classified as Clavien-Dindo grade II and above (2.2 % *vs.* 13.9 %, $P = 0.030$).

3.2. Risk factors of difficult operation

In the univariate logistic analysis, analysis showed that CCI ($P = 0.019$), elevated CRP ($P = 0.013$), elevated WBC ($P = 0.030$), pericholecystic effusion ($P < 0.001$), contact between gallbladder and stomach or duodenum ($P = 0.004$), and thick gallbladder wall ($P = 0.028$) was potential risk factors for difficult operation. In the multivariate logistic regression analysis, results showed that

Table 2
Surgery-related and short-term outcomes between non-difficult and difficult operation groups.

Factors	Non-difficult operation $n = 91$	Difficult operation $n = 36$	P value
Duration of operation, min	60 (26)	102 (22)	<0.001[a]
Conversion to open surgery	0 (0 %)	4 (11.1 %)	0.006[a]
Blood loss, ml	20 (10)	20 (40)	0.002[a]
Postoperative hospitalization days	4 (2)	5 (3)	<0.001[a]
Hospitalization costs, RMB	24546 (6143)	28062 (7412)	<0.001[a]
Clavien-Dindo grade II or higher	2 (2.2 %)	5 (13.9 %)	0.030[a]

Data is represented as median (interquartile range) or number (%), unless otherwise stated.
[a] Statistically significant ($P < 0.05$).

elevated CRP ($P = 0.011$), pericholecystic effusion ($P < 0.001$), and contact between gallbladder and stomach or duodenum ($P = 0.015$) were independent risk factors for difficult LC after PTGBD (Table 3).

3.3. Predictive model development and validation

Based on the 3 independent risk factors above, we established a novel nomogram for predicting risk of difficult operation in patients with LC after PTGBD (Fig. 2). The ROC curves of the nomogram and the three independent risk factors were shown in Fig. 3. The nomogram demonstrated a superior discriminative ability with an AUC of 0.860, compared to the individual predictors (elevated CRP, pericholecystic effusion, and contact between gallbladder and stomach or duodenum), which had AUCs of 0.612, 0.739, and 0.644, respectively. The calibration curves of the nomogram were also generated (Fig. 4A), showing good consistency between the observed and predicted outcomes. In addition, the decision curve indicated that the use of a combined model for the prediction of difficult operation added more net benefit than the use of single risk factors (Fig. 4B).

4. Discussion

AC is a prevalent condition, with the LC as the gold standard treatment. However, in high-risk AC patients, PTGBD provides an alternative option for patients temporarily intolerant to surgery, which allows their condition to stabilize before proceeding with LC. In the present study, we investigated the risk factors for difficult operation among patients who underwent PTGBD. We demonstrated that elevated CRP, pericholecystic effusion, and contact between gallbladder and stomach or duodenum were independent risk factors for difficult LC after PTGBD. A new nomogram was established based on these risk factors, which showed good performance in predicting difficult LC after PTGBD.

Although the severity of cholecystitis is significantly associated with clinical outcomes such as the incidence of postoperative complications, length of hospital stays, and medical costs for patients with acute cholecystitis (AC), patients undergoing elective cholecystectomy after percutaneous transhepatic gallbladder drainage (PTGBD) differ from those undergoing emergency cholecystectomy for AC. Their symptoms of acute cholecystitis have alleviated, and their vital signs are stable. Therefore, these individuals do not strictly meet the diagnosis criteria for acute cholecystitis. As a result, this study does not show the association between severity grading and surgical difficulty in patients with PTGBD.

The optimal timing to operate LC after PTGBD is a hot topic. Several observational studies have reported the optimal timing of LC after PTGBD or the onset of AC [8,23–25]. However, the difficulty of LC were affected by multiple factors including patient general status and intraoperative findings [26]. Probably, the optimal timing of subsequent LC changes as risk factor changes. The preoperative assessment of surgical difficulty and exploration of risk factors may be a more direct way to reflect the timing of surgery. The

Table 3
Univariate and multivariate logistic regression analysis of factors associated with difficult operation.

	Univariate analysis		Multivariate analysis	
	Odds ratio (95%CI)	*P* value	Odds ratio (95%CI)	*P* value
Demographic characteristics				
Age	1.016 (0.986–1.047)	0.293		
Male	1.451 (0.655–3.215)	0.359		
BMI	1.086 (0.963–1.226)	0.178		
Severity of cholecystitis ≥ III	0.943 (0.236–3.775)	0.934		
Previous abdominal surgery	1.352 (0.542–3.371)	0.518		
ASA≥3	1.667 (0.698–3.983)	0.250		
Interval from PTGBD to LC	1.001 (0.994–1.008)	0.780		
CCI	1.267 (1.029–1.558)	0.019[a]		
PTGBD tube removal	0.833 (0.345–2.011)	0.685		
Laboratory data				
Elevated CRP	2.840 (1.246–6.472)	0.013[a]	3.958 (1.362–11.562)	0.011[a]
Elevated WBC	4.350 (1.149–16.472)	0.030[a]		
Anemia	0.833 (0.160–4.335)	0.828		
Hypoalbuminemia	4.350 (1.149–16.472)	0.030[a]		
Jaundice	1.500 (0.411–5.472)	0.539		
Elevated ALT	1.328 (0.487–3.619)	0.580		
Radiographic data				
Maximum diameter of stone	0.876 (0.596–1.288)	0.501		
Multiple gallstone	1.492 (0.656–3.392)	0.339		
Gallstone in infundibulum	1.833 (0.712–4.718)	0.209		
Coarse gallbladder wall	1.493 (0.460–4.853)	0.505		
Pericholecystic effusion	44.505 (9.481–208.864)	<0.001[a]	59.768 (10.962–325.319)	<0.001[a]
Distended gallbladder	0.828 (0.211–3.252)	0.787		
Contact with colon	0.797 (0.362–1.752)	0.572		
Contact with gastric or duodenum	3.500 (1.482–8.268)	0.004[a]	4.001 (1.307–12.247)	0.015[a]
Thick gallbladder wall	2.649 (1.112–6.313)	0.028[a]		

[a] , $P < 0.05$; CI, confident interval.

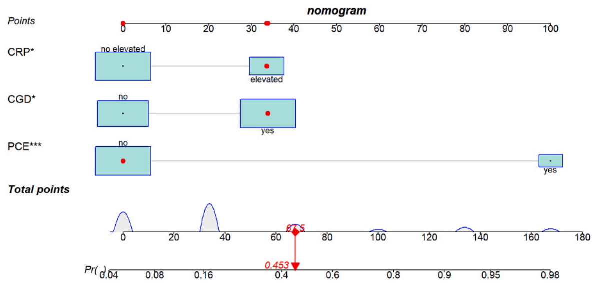

Fig. 2. Development of the nomogram for predicting the risk of difficult operation in patients who underwent LC after PTGBD.

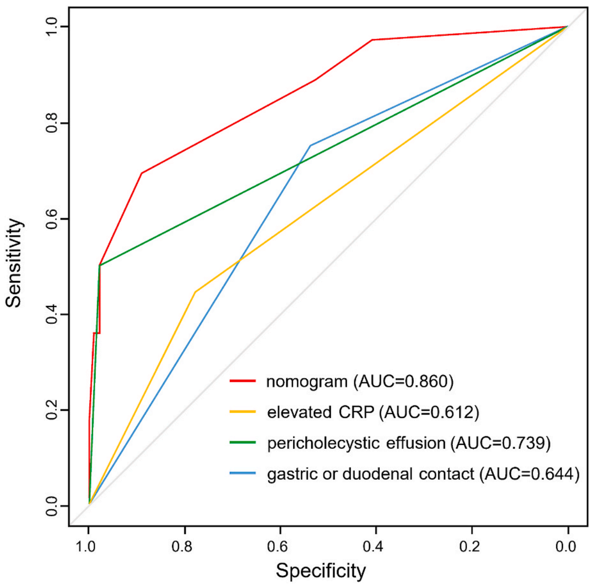

Fig. 3. The receiver operating characteristic curve (ROC) of the nomogram and independent risk factors for predicting the risk of difficult operation in patients who underwent LC after PTGBD.

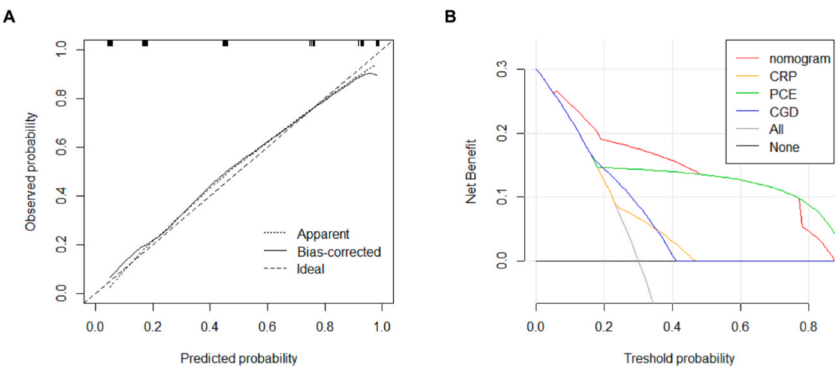

Fig. 4. The calibration curve and decision curve analysis of the nomogram and independent risk factors. (A) Calibration curve; (A) Decision curve. CRP, C-reactive protein; PCE, pericholecystic effusion; CGD, contact with gastric or duodenum.

preoperative prediction of difficult LC plays a crucial role in identifying high-risk surgeries, optimizing surgical planning and efficiency, and potentially altering surgical approaches as needed. Our study demonstrates that patients in the difficult group experience significantly worse postoperative outcomes, including prolonged hospitalization, higher hospitalization costs, and more complications.

Previous studies have mainly focused on assessing the difficulty of LC in patients without PTGBD. Several studies have reported male gender as an independent risk factor for difficult operation in patients with AC because male patients tended to pay less attention to their health [27,28]. In other previous studies about AC, there were statistically significant association among age, BMI, ASA, CCI and previous history of abdominal surgery with prolong operative time [29,30] or surgical conversion [11,12]. Elderly patients or patients with high ASA score often have worse conditions which lead to poor outcomes. Additionally, obese patients often encounter specific technical difficulties during surgery, including the placement of trocars, liver retraction, and exposure of Calot's triangle [16]. Moreover patients with a history of abdominal surgery may experience increased adhesion formation [31]. However, in our study, these factors are not related to a difficult operation. This could be attributed to advancements in surgical technology and enhanced physician expertise. These factors may elevate the complexity of the surgery to some extent but does not necessarily result in a difficult operation. Additionally, it is plausible that the safety and reliability of late LC may be superior to early in patients with AC who require PTGBD.

Radiographic data is crucial for preoperative evaluation, with CT images offering a more accurate depiction of the relationship between the gallbladder and surrounding tissues. Previous research has identified significant differences between the difficult LC group and the non-difficult group in terms of irregular or absent gallbladder wall, pericholecystic effusion, thick gallbladder wall, and gallstones within the gallbladder [32,33]. Irregular or absent wall is a common presentation of gangrenous cholecystitis. Thus, we have not considered this feature as a potential factor for assessing difficult surgeries. In our study, both gallstone in infundibulum and thick gallbladder wall is not independent risk factor for difficult operation.

Our study revealed that elevated CRP, pericholecystic effusion and contact with gastric or duodenum in CT scan were independent risk factors for difficult operation in subsequent LC after PTGBD. This suggests that systemic inflammation as well as inflammation and fibrosis surrounding the gallbladder, particularly in the region near Calot's triangle, are crucial. The surgical procedure in LC consists of two phases: the dissection of Calot's triangle involving the identification of the cystic duct and cystic artery, and the detachment of the gallbladder from the liver. The former is more critical, as it is in this phase that technical difficulties often arise. Local inflammation serves as a contributing factor to difficult LC. Inflammation can impede the accurate identification of Calot's triangle anatomy [34]. Pericholecystic effusion, also known as pericholecystic hyper CT attenuation, occurs when inflammation from cholecystitis extends beyond the gallbladder wall into the surrounding fat tissue. This leads to the accumulation of a substantial exudate, inducing edema in the adipose tissue. Under normal conditions, adipose tissue exhibits a CT attenuation value below 0 HU. However, exudate, enriched with proteins surpassing the water concentration, elevates the attenuation value beyond 0 HU. Consequently, as inflammation becomes more severe, increased exudate permeates the adipose tissue, resulting in a higher CT attenuation value. Based on our study, laboratory tests such as CRP, in conjunction with CT scans, enable us to obtain precise information about systemic and local inflammatory conditions.

The strength of our study is its pioneering exploration of the risk factors contributing to difficult operation in subsequent LC after PTGBD. We formulated a novel predictive model incorporating independent risk factors for difficult operation and created a visually represented nomogram. The model surpasses the efficacy of individual independent risk factors, and demonstrates good discernment and accuracy. Our study facilitates risk stratification for patients undergoing LC after PTGBD, enabling improved outcomes through timely intervention and strategic approaches.

The present study has some potential limitations. First, the nature of observational design does not allow us to draw firm conclusions on the causal relationship between the risk factors and difficult operation. Second, there are no globally recognized standards for assessing the difficulty level of laparoscopic cholecystectomy. In our study, we combined previous studies to identify the three most important criteria for difficult surgery. Third, retrospective designs may introduce unforeseen biases, emphasizing the need for rigorous study designs in future. Fourth, surgeon factors are not included under the consideration of the subjective nature of surgeon-related factors and the lack of comparability between different hospitals and regions. However, all the surgeons involved in this study are all experienced in hepatobiliary pancreatic surgery, with over 10 years of clinical experience and extensive expertise in laparoscopic cholecystectomy procedures. Fifth, due to the variation in specific strategies used among patients, we did not collect detailed compliance rates. However, patients in this study generally demonstrated good compliance. After receiving PTGBD treatment, all patients showed significant alleviation of cholecystitis symptoms and met the indication for undergoing LC surgery.

5. Conclusion

Our study determined that elevated CRP, pericholecystic effusion and contact between gallbladder and stomach or duodenum were independent risk factors of difficult LC after PTGBD. This predictive model effectively identifies high-risk AC patients who may encounter difficult operation during LC after PTGBD, thereby guiding clinical decision-making.

Data availability statement

Data will be made available on request.

Ethics approval

This study was approved by the Ethics Committee of Shanghai Tenth People's Hospital, and informed consent was waived due to the retrospective nature of the study (No. 24KN74).

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CRediT authorship contribution statement

Hai-Hong Wei: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Yu-Xiang Wang:** Visualization, Software, Methodology, Investigation, Formal analysis, Data curation. **Bin Xu:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Yong-Gui Zhang:** Writing – review & editing, Supervision, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e36081.

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