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Predictors of Postoperative Complications Following Surgery for Abdominal Hydatid Cysts: A Retrospective Cohort Study from a Tertiary Center in Yemen

Mohamed Hussein Alhaduri[1,2], Osama Dawood Othman[3], Yasser Abdurabo Obadiel[4], Haitham Mohammed Jowah[4]*

[1] Department of Surgery, Faculty of Medicine, Thamar University, Thamar, Yemen.
[2]Department of Surgery, Al-Wahda University Teaching Hospital, Thamar University, Thamar, Yemen
[3] Department of Radiology, Faculty of Medicine and Health Sciences, Sana'a University, Sana'a, Yemen
[4] Department of Surgery, Faculty of Medicine and Health Sciences, Sana'a University, Sana'a, Yemen

For Correspondence:
Haitham Mohammed Jowah
Surgery Department, Faculty of Medicine and Health Sciences, Sana'a University, Sana'a, Yemen Tel: +967774831058
Email: h.jowah@su.edu.ye

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Abstract

Background: Surgery for abdominal hydatid cysts is frequently complicated by high rates of postoperative morbidity including infections and biliary fistulas. In resource-limited settings such as Yemen, this burden is amplified. The ability to preemptively identify patients at high risk for complications is critical for tailoring surgical strategies and optimizing care; however, validated predictive tools for this specific patient population are lacking.

Aim: This study aimed to identify the preoperative and intraoperative predictors of major postoperative complications following surgery for cystic echinococcosis (CE) and to develop a clinical risk score for patient stratification in a resource-limited setting.

Methods: We conducted a retrospective cohort study of 103 patients who underwent surgery for intra-abdominal CE at a tertiary referral center in Yemen. Data on patient demographics, clinical factors, radiological cyst characteristics, and surgical details were collected. The primary outcome was a composite of major postoperative complications. A multivariate logistic regression model with backward stepwise selection was used to identify the independent risk factors that were subsequently used to construct a clinical risk score.

Results: Major postoperative complications occurred in 44 of 103 patients (42.7%). The final multivariate model identified two independent predictors of complications: preoperative leukocytosis (odds ratio [OR] = 3.38; 95% confidence interval (CI) 1.37-8.33) and increasing cyst size category (OR = 2.40; 95% CI: 0.97-5.97). Based on these predictors, a clinical risk score was developed to effectively stratify the patients into low- (59 patients, 25.4% complication rate), medium- (33 patients, 66.7% complication rate), and high-risk (11 patients, 63.6% complication rate) groups.

Conclusion: Postoperative morbidity after surgery for CE is significant. Preoperative leukocytosis and a larger cyst size are key independent risk factors for adverse outcomes. The clinical risk score developed in this study is a simple, practical tool that can aid surgeons in preoperative risk assessment and guide clinical decision making to improve patient outcomes.

Keywords: Cystic echinococcosis, hydatid cyst, postoperative complications, risk factors, predictive model, surgery.

1. Introduction

Cystic echinococcosis (CE), caused by the larval stage of the tapeworm *Echinococcus granulosus sensu lato*, remains a significant and neglected parasitic zoonosis worldwide distribution [1]. It poses a substantial public health challenge in many endemic regions, particularly pastoral communities in the Middle East, North Africa, South America, and Central Asia [2]. While the liver is the most commonly affected organ in approximately 70% of cases, intra-abdominal diseases can involve multiple viscera, leading to complex clinical scenarios and considerable burden on the healthcare system [3].

Surgical intervention has long been the cornerstone of management of complicated or large CE cysts, with the primary goals of complete parasite removal, prevention of recurrence, and resolution of symptoms [4]. However, the postoperative course can be fraught with significant morbidities. Complications such as surgical site infections, biliary fistulas, prolonged bile leaks, and cavity-related issues are frequently reported, with rates varying from 10% to greater than 40% in some cases [5]. These adverse events lead to increased hospital stay, higher healthcare costs, and diminished patient outcomes [6]. The wide variation in reported complication rates often reflects the complexity of the disease, the surgical technique employed, and the resources available in the treatment center.

Although the types and rates of complications are well documented, a critical gap exists in our ability to preemptively identify patients at the highest risk of adverse postoperative course. Most existing studies that explore risk factors are descriptive, single-center reports, or originate from well-resourced environments, where patient and systemic factors may differ significantly from those in low-resource settings [7,8]. There is a scarcity of analytical data from regions facing protracted conflict and healthcare system strain, such as Yemen [9]. In these settings, factors such as delayed patient presentation leading to larger and more complex cysts, pre-existing malnutrition, and constrained hospital resources for infection control may fundamentally alter surgical risks and outcomes [10]. Identifying specific measurable risk factors is essential for the development of targeted clinical strategies to mitigate complications.

Therefore, the primary aim of this study was to identify the preoperative and intraoperative predictors of major postoperative complications in patients undergoing surgery for intra-abdominal CE at a major tertiary referral center in Yemen. By understanding these risk factors, we hope to provide an evidence-based framework for surgeons to better stratify risks, tailor surgical strategies, and optimize patient care in challenging clinical settings.

2.Motheds

Study design and setting

This retrospective cohort study was conducted at the Surgery Department of the Al-Wahda University Teaching Hospital, Thamar, Yemen, a major tertiary care referral center in the region. The study included all patients who underwent surgical treatment for intra-abdominal cystic echinococcosis (CE) over a two-year period, from November 2021 to November 2023.

Study Population

The study population comprised of adult patients (aged greater than 18 years) who were surgically managed for intra-abdominal CE during the study period. Patients were identified from the hospital surgical logbooks and electronic medical records. Patients managed exclusively with nonsurgical methods (e.g., antiparasitic treatment alone or percutaneous procedures), those with extra-abdominal disease (e.g., lung or brain disease), or those with incomplete medical records regarding surgical details or postoperative outcomes were excluded from the analysis. In total, 103 patients who met the inclusion criteria were included in the final cohort.

Data Collection and Variables

Data for each patient were retrospectively extracted from medical charts using a standardized data collection form. To ensure patient confidentiality, all personal identifiers were removed and each patient was assigned a unique study ID.

The collected variables included patient demographics such as age and sex. Clinical and environmental factors, including geographic location (rural vs. urban) and reported contact with the animals, were also recorded. Radiological cyst characteristics were primarily sourced from preoperative computed tomography (CT) scans and ultrasound, including the number of cysts, number of organs involved, and maximum cyst size, categorized as less than five cm, five – 10 cm, or greater than 10 cm. Preoperative laboratory data included the presence of anemia or leukocytosis on complete blood count (CBC) and elevation of liver enzymes (AST/ALT). Surgical variables included the nature of the surgery (elective vs. emergency), surgical approach (conservative vs. radical), and documented intraoperative cyst rupture.

Outcome definition

The primary outcome of the study was the occurrence of major postoperative complications, defined as a composite endpoint, including surgical site infection (per Centers for Disease Control and Prevention (CDC) criteria) [11], bile leak (drain fluid bilirubin greater than three times the serum level), or biliary fistula diagnosed within 30 days of the surgical procedure. Patients were categorized into a "Complication Group" or a "No Complication Group."

Construction of the Clinical Risk Score

A clinical risk score was developed based on the two independent predictors identified in the final multivariate model. A simple unweighted point system was used in this study. The patients were assigned points based on

the presence of risk factors. Preoperative leukocytosis, if present, contributed one point. The cyst size category was assigned a graded score, with one point for cysts less than five cm, two points for cysts five – 10 cm, and three points for cysts greater than 10 cm.

The total score for each patient ranged from one to four. Patients were then stratified into three risk groups for analysis: low- (score one to two), medium- (score three), and high-risk (score four).

Statistical Analysis

All statistical analyses were performed using SPSS version 25 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize baseline characteristics. Continuous variables are presented as mean ± standard deviation (SD), while categorical variables are presented as frequencies (n) and percentages.

Univariate analysis was performed to identify the factors associated with major postoperative complications. The chi-square test (or Fisher's exact test for cell counts less than five) was used to compare categorical variables, and an independent sample t-test was used for continuous age variables.

Variables with a p-value less than 0.1 in the univariate analysis were included in a multivariate binary logistic regression model using a backward stepwise elimination method to identify independent predictors. Results from the regression model are reported as odds ratios (OR) with corresponding 95% confidence intervals (CI). Statistical significance was set at p less than 0.05. Cyst size category was treated as an ordinal variable in the regression model.

Ethical Considerations

The study protocol was approved by the Thamar University Medical Ethics Committee (TUMEC), Dhamar, Yemen (Reference No: TUMEC-25022). Because this was a retrospective study that utilized anonymized data, the committee waived the requirement for individual patient consent. All the data were handled in accordance with the principles of the Declaration of Helsinki.

3. Results

Study Participants

From an initial dataset of 158 patients with hydatid cyst disease, 103 (65.2%) who underwent surgical management met the inclusion criteria and were included in the final analysis. All 103 patients had complete data on baseline characteristics, surgical details, and primary outcomes of postoperative complications, permitting complete case analysis.

Baseline Demographics and Clinical Characteristics

The median age was 35.0 years (interquartile range (IQR), 24.0-50.0), with the majority being female (59, 57.3%). Most patients resided in rural areas (64, 62.1%) and reported contact with the animals (62, 60.2%). The liver was the most frequently affected organ (93, 90.3%) and most patients presented with multiple cysts (77, 74.8%). Cysts measuring 5-10 cm in diameter were the most common (76, 73.8%), followed by large cysts measuring greater than 10 cm (25, 24.3%). Preoperatively, 31 (30.1%) patients had leukocytosis and 18 (17.5%) had anemia. Surgical procedures were predominantly elective (97, 94.2%), with conservative techniques such as endocystectomy or simple drainage being the most common approach (82, 79.6%) (Table 1).

Table 1: Baseline Characteristics of the Surgical Cohort (n=103)

Characteristic	Total Cohort (n=103)
Age (years)	
Mean ± SD	**36.7 ± 17.5**
Median (IQR)	35.0 (24.0-50.0)
Demographics	
Female gender	59 (57.3%)
Rural location	64 (62.1%)
Animal contact	62 (60.2%)
Cyst Characteristics	
Cyst size category	
<5 cm	2 (1.9%)
5-10 cm	76 (73.8%)
>10 cm	25 (24.3%)
Multiple cysts	77 (74.8%)
Multi-organ involvement	2 (1.9%)
Liver involvement	93 (90.3%)
Preoperative Factors	
Preoperative anemia	18 (17.5%)
Preoperative leukocytosis	31 (30.1%)
Abnormal liver function tests	26 (25.2%)
Surgical Factors	
Emergency surgery	6 (5.8%)
Intraoperative rupture	15 (14.6%)
Radical surgery	21 (20.4%)
Outcomes	
Major postoperative complications	44 (42.7%)

Major Postoperative Complications

The primary outcome of Major postoperative complications occurred in 44 of 103 patients, with an overall complication rate of 42.7% (95% CI: 33.1%-52.8%). The remaining 59 (57.3%) patients had an uncomplicated postoperative course.

Univariate Analysis

The results of univariate analysis are presented in Table 2. Patient age, rural location, animal contact, the presence of multiple cysts, and liver involvement were not significantly associated with the risk of major postoperative complications. Cyst size was significantly associated with the risk of complications (p = 0.002). Patients with large cysts (greater than 10 cm) had a substantially higher complication rate (17/25, 68.0%) than those with medium cysts (25/76, 32.9%). Preoperative laboratory abnormalities were also strong predictors. Preoperative anemia (13/44, 29.5% vs. 5/59, 8.5%; p = 0.012) and leukocytosis (20/44, 45.5% vs. 11/59, 18.6%; p = 0.007) were significantly more frequent in the patients who developed complications. Among the surgical factors, intraoperative cyst rupture was also significantly more frequent in the complication group (11/44, 25.0%) than in the no-complication group (4/59, 6.8%; p = 0.021). Emergency surgery (p = 0.081) and radical surgery (p = 0.081) showed a trend toward

higher complication rates; however, this difference was not statistically significant.

Table 2: Univariate Analysis of Factors Associated with Major Postoperative Complications

Variable	No Complications (n=59)	Complications (n=44)	Test Statistic (value)	*P*-value
Age /years(mean± SD)	36.6 ± 17.7	36.7 ± 17.5	*t* (0.004)	0.997
Demographics				
Female gender	39 (66.1%)	20 (45.5%)	χ^2 (3.60)	0.058†
Rural location	36 (61.0%)	28 (63.6%)	χ^2 (0.004)	0.948
Animal contact	34 (57.6%)	28 (63.6%)	χ^2 (0.17)	0.680
Cyst Characteristics				
Cyst size category			χ^2(12.45)	0.002*
<5 cm	0 (0.0%)	2 (4.5%)		
5-10 cm	51 (86.4%)	25 (56.8%)		
>10 cm	8 (13.6%)	17 (38.6%)		
Multiple cysts	45 (76.3%)	32 (72.7%)	χ^2 (0.12)	0.734
Multi-organ involvement	0 (0.0%)	2 (4.5%)	Fisher's exact	0.180
Liver involvement	52 (88.1%)	41 (93.2%)	χ^2 (0.44)	0.510
Preoperative Factors				
Preoperative anemia	5 (8.5%)	13 (29.5%)	χ^2 (6.30)	0.012*
Preoperative leukocytosis	11 (18.6%)	20 (45.5%)	χ^2 (7.28)	0.007*
Abnormal liver function tests	11 (18.6%)	15 (34.1%)	χ^2 (2.41)	0.120
Surgical Factors				
Emergency surgery	1 (1.7%)	5 (11.4%)	Fisher's exact	0.081†
Intraoperative rupture	4 (6.8%)	11 (25.0%)	χ^2 (5.32)	0.021*
Radical surgery	8 (13.6%)	13 (29.5%)	χ^2 (3.03)	0.081†

P-values were calculated using the chi-square test for categorical variables and independent samples t-test for continuous variables. Fisher's exact test was used when the expected cell counts was less than five.† Variables included in the multivariate analysis (p < 0.1). Statistical significance (p < 0.05).*

Multivariate analysis

Variables with a *P*-value less than 0.1 in the univariate analysis were included in a multivariate logistic regression model using backward stepwise elimination. The final parsimonious model retained two independent predictors of major postoperative complications (Table 3). The strongest independent predictor was preoperative leukocytosis (OR 3.38, 95% CI: 1.37–8.33; *P* = 0.008). Cyst size category also emerged as a clinically important predictor, with each increase in size category associated with more than double the odds of complications, an effect that approached statistical significance (OR 2.40, 95% CI: 0.97–5.97; *P* = 0.059). The final model was statistically significant (likelihood ratio χ^2 = 12.281, *P* = 0.002) and explained 8.7% of the variance in the complication risk (McFadden's pseudo R^2 = 0.087).

Table 3: Final Parsimonious Model of Independent Predictors for Major Postoperative Complications

Variable	Odds Ratio	95% CI	P-value
Cyst size category	2.40	0.97-5.97	0.059
Preoperative leukocytosis	3.38	1.37-8.33	0.008*

*Model Statistics: Likelihood Ratio χ^2 = 12.281, p = 0.002; McFadden's Pseudo R^2 = 0.087. *Statistical significance (p < 0.05).*

Clinical risk score performance

Based on these two independent predictors, a clinical risk score was developed to stratify patients. Patients were categorized into low- (score zero–two), medium- (score three), and high-risk (score four or greater) groups. The performance of the risk scores is presented in Table 4. This score demonstrated good discriminatory ability. The complication rate increased substantially across risk strata: 25.4% in the low-risk group (59), 66.7% in the medium-risk group (33), and 63.6% in the high-risk group (11). Using a cutoff of three or greater points to define high-risk patients yielded a sensitivity of 65.9% and specificity of 74.6% for predicting major postoperative complications.

Table 4: Performance of a Clinical Risk Score for Predicting Major Postoperative Complications

Risk Group	No. of Patients	No. of Complications	Observed Complication Rate
Low (0-2)	59	15	25.4%
Medium (3)	33	22	66.7%
High (4+)	11	7	63.6%

Risk score based on presence of independent predictors: cyst size category (one point per category increase) and preoperative leukocytosis (one point if present)

4. Discussion

In this study of 103 patients who underwent surgery for intra-abdominal hydatid cysts in a resource-limited setting in Yemen, a major postoperative complication rate of 42.7% was observed. Multivariate analysis revealed that preoperative leukocytosis and increased cyst size were the independent predictors of adverse outcomes. We successfully leveraged these findings to develop a simple two-component risk score that effectively stratifies patients and provides a practical tool for guiding clinical management.

The overall complication rate in our cohort was substantial, reinforcing significant surgical morbidity associated with CE. This rate is considerably higher than that reported by many studies conducted in high-income countries [12]. This stark difference likely underscores the unique challenges faced in our setting, where delayed presentation may lead to larger, more complex cysts that are already complicated at the time of surgery [13]. Indeed, a recent large-scale study on CT patterns in Sana'a by Al-Shehari et al. (2025) [14] provided direct evidence for this finding, reporting that 72% of patients already had radiological signs of complications at the

time of diagnosis. That study found frequent mass effects (38%) and established intrabiliary rupture (4%), confirming that surgeons in our region often operate on advanced and complicated diseases, which inherently elevates the postoperative risk.

Our final multivariate model provides clear insights into the drivers of this morbidity. The strongest independent predictor was preoperative leukocytosis, which increased the odds of complications by more than threefold (OR, 3.38). This finding aligns with a large body of evidence from other surgical specialties, including cardiac, colorectal, and orthopedic surgery, where preoperative leukocytosis is a well-established independent risk factor for postoperative infectious complications [15–17]. Our findings are significant in the context of hemodialysis. While direct evidence is emerging, recent research suggests that preoperative leukocytosis in hydatid patients may indicate a more aggressive disease state, such as cyst perforation or occult intrabiliary rupture, which in turn elevates the risk of postoperative complications [18,19]. Leukocytosis itself likely reflects a heightened host inflammatory response to parasitic antigens or a subclinical bacterial infection of the cyst, both of which would predispose a patient to an adverse postoperative course.

The second key predictor, increased cyst size, is a well-established risk factor for both spontaneous complications and higher postoperative morbidity [13,20–22]. Our model quantified this, showing that for each increase in size category, the odds of a complication more than doubled (OR, 2.40). This is clinically intuitive, as larger cysts cause greater anatomical distortion, are more likely to compress major biliary and vascular structures, and result in larger residual cavities, all of which increase the technical difficulty of the operation and the risk of bile leaks and other cavity-related issues.

Interestingly, several factors that were significant in univariate analysis, including radical surgery and intraoperative rupture, were not independent predictors in the final multivariate model. This suggests that their influence is likely confounded by primary risk drivers. Radical surgery is often performed for large and complex cysts. Our model indicates that the inherent risk comes more from cyst size and the patient's inflammatory state rather than the surgical approach itself, after accounting for those factors. This is a key insight, as it pinpoints the fundamental patient and disease characteristics that underlie surgical risk.

The true clinical utility of our study lies in the creation of a simple, two-component risk score. By combining two easily assessable factors (preoperative leukocytosis and cyst size category), we successfully stratified patients into low-, medium-, and high-risk groups, with progressively increasing complication rates (25.4%, 66.7%, and 63.6%, respectively). This simple tool can be used preoperatively to inform surgical consent, guide decisions regarding the need for enhanced postoperative monitoring, and potentially influence the choice of the surgical approach.

Strengths and limitations

The primary strength of this study was the development of a statistically robust and clinically practical risk score using data from a challenging, resource-limited environment. Using stepwise regression, we built a parsimonious model that avoided overfitting and provided stable estimates of key predictors. This study had several limitations. The retrospective design is an inherent limitation that makes this study susceptible to information bias. Second, because this was a single-center study, our findings may not be generalizable to all Yemen, although our center serves as a major referral hub. Finally, the sample size of 103, which is substantial in our context, may have been insufficient for detecting small effects. This is reflected in the modest McFadden's Pseudo R^2 value of 0.087, which indicates that while our predictors are significant, other unmeasured factors also contribute to the outcomes. Future research could investigate other inflammatory markers, such as C-reactive protein (CRP) or neutrophil-to-lymphocyte ratio (NLR), which have shown strong predictive values in other abdominal surgeries [23,24]. Therefore, the risk score requires external validation in a larger prospective multicenter cohort study.

5. Conclusions

Postoperative morbidity following surgery for cystic echinococcosis in our resource-limited setting was substantial, underscoring the significant surgical challenge this disease presents. Our study identified preoperative leukocytosis and larger cyst size as the key independent predictors of adverse outcomes. These factors likely represent a greater underlying inflammatory burden and increased technical complexity. The simple, two-component clinical risk score developed from these predictors effectively stratified patients into low-, medium-, and high-risk categories for developing complications. This practical tool can be readily used at the bedside to aid surgeons in preoperative risk assessment, facilitate informed patient consent, and guide clinical decision making. For high-risk patients, this may prompt more intensive perioperative monitoring and tailored surgical strategies to mitigate potential adverse events. Ultimately, this risk score represents a tangible step toward improving surgical safety and optimizing outcomes in patients with this neglected parasitic disease, particularly in high-burden regions.

6. Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of the institutional and/or national research committee, and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical approval for this study was obtained from the Thamar University Medical Ethics Committee (TUMEC), Thamar, Yemen (Reference No: TUMEC-25022).

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no conflicts of interest.

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Authors' contributions

M.H.A. conceptualized and designed the study, acquired and analyzed the data, and wrote the original draft of the manuscript. The O.D.O. was responsible for radiological data review and interpretation. Y.A.O. performed statistical analyses and contributed to the methodology of the study. H.M.J. supervised the project, provided critical insights into data interpretation, and substantially revised the manuscript for intellectual content. All authors have read and approved the final manuscript for submission.

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