



Research Article

Prospective Observational Study to Identify Preoperative Risk Factors Associated with Difficult Laparoscopic Cholecystectomy.

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Abstract: **Background:** Laparoscopic cholecystectomy (LC) is established as the gold standard operative procedure for symptomatic gallstone disease worldwide. However, unforeseen anatomical distortion, intense inflammatory fibrosis, dense pericholecystic adhesions, and patient-specific habitus can transform an ostensibly straightforward elective case into a formidable technical challenge fraught with catastrophic complications such as bile duct injury, severe vascular trauma, and unexpected conversion to open laparotomy. **Methods:** A prospective observational investigation was conducted over 18 months comprising 80 consecutive patients scheduled for elective laparoscopic cholecystectomy at Government Medical College, Ratlam, Madhya Pradesh. Comprehensive demographic, clinical, hematological, and ultrasonographic parameters were documented preoperatively and correlated against intraoperative indicators of difficulty (duration of surgery, port placement difficulty, gallbladder dissection challenges, stone/bile spillage, ductal/arterial injury, and open conversion) using Chi-square analysis and logistic testing in SPSS v27.0. **Results:** Among the 80 patients (mean age: 43.73 ± 12.92 years; 72.5% females), 90.0% had normal BMI, 27.5% reported recurrent cholecystitis, and 91.3% exhibited gallbladder wall thickness ≥4 mm on ultrasonography. Solitary calculi were present in 67.5% and calculus size ≥10 mm in 88.8%. Mean operative duration was 90.13 ± 17.43 minutes. Port insertion difficulty was noted in 2.5%, bile/stone spillage in 5.0%, vascular or ductal insults in 3.8%, and conversion to open cholecystectomy in 1.3%. Postoperative bile leak occurred in 26.3% and surgical site infection in 6.3%. On inferential analysis, stone size ≥10 mm ($p = 0.026$), contracted gallbladder status ($p = 0.002$), and presence of multiple calculi ($p < 0.001$) were strongly associated with prolonged operative duration (>120 minutes). Body mass index (BMI) category showed statistically significant associations with port insertion difficulty ($p = 0.031$), bile spillage ($p < 0.001$), and vascular or ductal injury ($p < 0.001$). **Conclusion:** Preoperative ultrasonographic evaluation—specifically identifying calculus size, multiplicity, and contracted gallbladder morphology—in conjunction with patient body habitus, provides robust predictive utility for anticipating surgical complexity during laparoscopic cholecystectomy. Incorporating these parameters into routine surgical risk stratification optimizes team allocation, facilitates proactive bail-out planning, and significantly safeguards patient outcomes.

Keywords: Difficult Laparoscopic Cholecystectomy, Preoperative Predictors, Cholelithiasis, Gallbladder Wall Thickness, Conversion to Open Cholecystectomy, Critical View of Safety.

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INTRODUCTION

Gallstone disease, or cholelithiasis, represents one of the most pervasive digestive health burdens worldwide, accounting for substantial gastrointestinal hospitalizations and healthcare expenditures across both developed and developing societies [1]. Globally, epidemiological evaluations estimate that 10% to 20% of the adult population harbors biliary calculi, with notable geographic and gender disparities [2]. In Northern and Central India, the prevalence is exceptionally pronounced among females during their childbearing and perimenopausal decades, largely propelled by estrogen-driven hepatic hypersecretion of cholesterol and progesterone-mediated gallbladder hypomotility [3, 4]. Historically encapsulated by the classical clinical maxim of 'Female, Fat, Forty, and Fertile', the modern demographic profile of symptomatic cholelithiasis has expanded considerably to encompass metabolic syndrome, diabetes mellitus, dyslipidemia, rapid weight fluctuations, and dietary shifts toward refined carbohydrates [4, 5].

The clinical management of gallstone disease underwent an unprecedented paradigm shift in 1987 when Philippe Mouret introduced laparoscopic cholecystectomy (LC) in Lyon, France, building upon earlier pioneering work by Erich Mühe [6]. Over subsequent years, systematic refinements by McKernan, Dubois, and Reddick accelerated global acceptance, rapidly

supplanting traditional open laparotomy as the uncontested gold standard for benign gallbladder pathology [6, 7]. The decisive superiority of laparoscopic cholecystectomy stems from its profound minimally invasive advantages: minimal parietal tissue disruption, attenuated systemic inflammatory and endocrine stress responses, dramatically reduced postoperative pain, lower surgical-site wound morbidity, reduced incidence of incisional herniation, expedited ambulation, abbreviated hospital stay, and swift reintegration into occupational activities [7, 8]. Today, well over 90% to 95% of all cholecystectomies performed across international centers are initiated laparoscopically [1, 9].

Nevertheless, despite over three decades of procedural standardization, widespread dissemination of high-definition video imaging, and sophisticated electro-thermal dissection devices, laparoscopic cholecystectomy remains an unforgiving intervention prone to unanticipated intraoperative technical impediments [9, 10]. The inherent operational constraints of laparoscopic surgery—specifically operating via a two-dimensional visual display, indirect instrument triangulation, absence of tactile digital palpation, fulcrum effects at trocar fulcra, and restricted angular maneuverability—render the procedure intensely vulnerable when normal hepatobiliary anatomy is distorted [10, 11]. Repeated inflammatory episodes characteristic of acute and chronic calculous cholecystitis induce extensive tissue edema, hypervascularity, dense fibrous contracture, and obliterative cicatrization across Calot's (hepatocystic) triangle [11, 12].

In such adverse operative environments, achieving the seminal 'Critical View of Safety' (CVS)—conceptualized by Strasberg to mandate complete clearance of the hepatocystic triangle of all adipose and fibrous tissue, mobilization of the gallbladder infundibulum off the cystic plate, and definitive visual identification of exactly two structures entering the gallbladder—becomes extraordinarily difficult [13]. Under catastrophic circumstances, anatomical misidentification can lead to major vasculobiliary trauma, notably transection, occlusion, or lateral thermal shearing of the common bile duct (CBD), common hepatic duct, or aberrant right hepatic arterial branches [12, 14]. While the baseline incidence of major bile duct injury in routine elective laparoscopic cholecystectomy is estimated between 0.2% and 0.4%, this hazard escalates dramatically to 1.5% to 2.5% in technically difficult scenarios [14, 15]. Such iatrogenic catastrophes carry devastating sequelae, necessitating intricate reconstructive Roux-en-Y hepaticojejunostomies, predisposing patients to recurrent cholangitis, secondary biliary cirrhosis, end-stage liver failure, prolonged litigation, and excessive mortality [15, 16].

A difficult laparoscopic cholecystectomy is comprehensively characterized in contemporary surgical literature by multiple interrelated endpoints: prolonged operative duration exceeding 90 to 120 minutes, arduous abdominal wall access, dense omental and visceral adhesions, fragile or fibrotic gallbladder walls that tear easily under grasper traction, impacted calculi within Hartmann's pouch, extensive intraoperative hemorrhage from the cystic artery or raw hepatic parenchyma, involuntary stone or bile spillage, necessity for alternative surgical bail-out manoeuvres (such as subtotal fenestrating or reconstituting cholecystectomy and fundus-first retrograde dissection), and unplanned conversion to open cholecystectomy [16, 17]. Conversion rates reported in contemporary international literature fluctuate between 2% and 15%, surging upwards of 25% in high-risk acute or gangrenous settings [17, 18].

Crucially, conversion to open surgery should never be viewed as a surgical failure, but rather as a mature and prudent tactical decision taken to preserve patient safety when laparoscopic anatomical clarity is hopelessly obscured [18, 19]. Nonetheless, an unexpected or emergency conversion during an elective list severely disrupts operating theater scheduling, increases intraoperative blood loss, escalates anesthesia exposure, multiplies postoperative morbidity, prolongs hospital confinement, and burdens institutional economic resources [19, 20]. This clinical reality highlights the paramount importance of establishing an accurate, reliable, and accessible preoperative predictive paradigm. Anticipating procedural difficulty before making the initial surgical incision empowers clinical teams to formulate tailored operative strategies, allocate experienced senior surgical and hepatobiliary personnel, schedule dedicated operating theater slots, prepare specialized hemostatic instrumentation, and deliver transparent, individualized preoperative counseling that sets realistic patient expectations [1, 20].

Although multiple predictive scoring systems—including the models pioneered by Randhawa and Pujahari, Vivek et al., and the Nassar operative difficulty scoring framework—have been introduced in academic tertiary centers, their generalizability, discriminative performance, and pragmatic utility within public health and secondary referral institutions in developing regions remain under-investigated [1, 20]. Variations in patient presentation thresholds, disease chronicity, nutritional profiles, and hospital resource availability often introduce discrepancies when applying globally developed scoring criteria to regional populations. Therefore, the present prospective observational investigation was undertaken to comprehensively analyze, identify, and validate preoperative clinical, hematological, and ultrasonographic risk factors associated with difficult laparoscopic cholecystectomy, correlating these predictors directly with intraoperative technical parameters and immediate postoperative outcomes in an Indian tertiary healthcare environment.

MATERIALS AND METHODS

2.1 Study Setting and Ethical Approval

This prospective observational clinical study was conducted in the Department of General Surgery at Dr. Laxmi Narayan Pandey Government Medical College and Associated Hospital, Ratlam, Madhya Pradesh, India, affiliated with Madhya Pradesh Medical Science University (MPMSU), Jabalpur. The institution serves as a major tertiary referral, teaching, and healthcare center catering to an extensive urban, peri-urban, and rural catchment area across Western Madhya Pradesh. Prior to study initiation, formal ethical clearance was secured from the Institutional Ethics Committee (IEC Approval Certificate No. GMC RATLAM/2024/IEC/Approval, dated 21.04.2024; meeting held on 20.04.2024). The research was conducted in strict adherence to the ethical guidelines outlined in the Declaration of Helsinki (revised 2013) and good clinical practice standards. Written informed consent was obtained from all participating patients or their legally authorized guardians after verbal and written briefing in their native vernacular language (Hindi), ensuring full voluntary participation, personal confidentiality, and the right to withdraw at any stage without prejudice to their clinical treatment.

2.2 Study Design and Duration

A prospective observational design was selected to allow real-time, chronological documentation of patient-specific risk variables, direct operative observation, and detailed post-procedural surveillance, thereby eliminating recall bias and minimizing documentation attrition. The study spanned an active operational period of 18 consecutive months (December 2023 through August 2025), capturing diverse clinical presentations and seasonal shifts in surgical admissions.

2.3 Study Population, Inclusion and Exclusion Criteria

The study cohort comprised consecutive adult patients admitted through the surgical outpatient department (OPD) or emergency wards with documented symptomatic gallstone disease who were scheduled for elective laparoscopic cholecystectomy under general endotracheal anesthesia.

Inclusion Criteria:

1. Adult patients aged 18 years and above presenting with symptomatic cholelithiasis definitively verified by abdominal ultrasonography.
2. Patients categorized as American Society of Anesthesiologists (ASA) Physical Status Class I or Class II deemed medically fit for elective laparoscopic surgery under general anesthesia.
3. Willingness to provide signed written informed consent for participation and follow-up evaluation.

Exclusion Criteria:

1. Strong radiological, clinical, or biochemical suspicion of gallbladder malignancy or primary biliary tree neoplasia.
2. Concomitant choledocholithiasis or acute biliary pancreatitis necessitating pre- or perioperative endoscopic retrograde cholangiopancreatography (ERCP) or common bile duct exploration.
3. History of prior definitive upper abdominal biliary tract reconstructions or known complex congenital biliary tract anomalies.
4. Severe uncompensated systemic cardiopulmonary, hepatic, or renal comorbidities rendering the patient unfit for pneumoperitoneum or general anesthesia (ASA Class III or higher).
5. Emergency cholecystectomy mandated by frank visceral perforation, gangrene with diffuse peritonitis, or septic shock that precluded structured preoperative elective assessment.

2.4 Sample Size Estimation

Based on historical data from comparable surgical cohorts indicating that 20% to 30% of laparoscopic cholecystectomies present significant technical difficulty, and assuming an alpha error of 0.05 (95% confidence level), statistical power (1 - beta) of 80%, an anticipated effect size of 0.40, and a 5% margin of precision, the minimum calculated sample size was determined to be 75 patients. To accommodate potential data loss or protocol deviations, a total of 80 consecutive patients meeting all eligibility criteria were enrolled and successfully followed through final discharge.

2.5 Preoperative Clinical, Biochemical, and Radiological Assessment

A standardized clinical proforma was utilized to document comprehensive baseline parameters for each enrolled subject upon hospital admission:

- Demographic Profile: Age, gender, residential locality, and occupation.
- Anthropometric Evaluation: Height (meters) and weight (kilograms) recorded using calibrated instruments to compute Body Mass Index ($BMI = kg/m^2$). Patients were stratified into Normal ($<25.0 kg/m^2$), Overweight ($25.0-29.9 kg/m^2$), and Obese ($\geq 30.0 kg/m^2$) following World Health Organization criteria.

- **Clinical History and Physical Signs:** Character, frequency, and duration of abdominal pain; documented history of prior hospitalizations for acute cholecystitis; clinical jaundice; previous surgical scars (categorized as absent, infraumbilical, or supraumbilical); and presence of a palpable gallbladder mass.
- **Laboratory Investigations:** Complete blood count (hemoglobin concentration, total leukocyte count [TLC], platelet count), comprehensive liver function tests (serum total bilirubin, direct bilirubin, aspartate aminotransferase [AST], alanine aminotransferase [ALT], alkaline phosphatase [ALP]), fasting blood glucose, blood urea, serum creatinine, and baseline coagulation parameters (prothrombin time and International Normalized Ratio [INR]).
- **Transabdominal Ultrasonography:** Real-time high-resolution ultrasound was performed by an experienced radiologist using a 3.5–5.0 MHz curvilinear transducer. Documented sonographic variables included: (a) gallbladder wall thickness (dichotomized as <4 mm or ≥4 mm); (b) calculus multiplicity (solitary vs. multiple); (c) size of the largest calculus or impacted stone (categorized as <10 mm or ≥10 mm); (d) common bile duct luminal diameter (normal <6 mm vs. dilated ≥6 mm); (e) gallbladder morphological status (distended vs. contracted/shrunken); and (f) presence or absence of pericholecystic fluid collection.

2.6 Operative Protocol and Definition of Surgical Difficulty

All surgical procedures were executed under standard general endotracheal anesthesia with positive pressure ventilation. Patients were positioned in the supine reverse Trendelenburg position with leftward tilt (French or American configuration). Standard four-trocar access was established: an initial 10-mm umbilical port for the 30-degree optical laparoscope (introduced via open Hasson or closed Veress needle technique based on surgeon preference and presence of scars), a 10-mm epigastric subxiphoid working port, and two 5-mm lateral ports in the right upper quadrant for retraction and grasping. Intra-abdominal pneumoperitoneum was maintained at a standardized pressure of 12 to 14 mmHg using automated carbon dioxide insufflation.

Dissection systematically commenced at the hepatocystic triangle utilizing a Maryland dissector, monopolar hook electrocautery, and suction-irrigation probes. Operative progression was meticulously assessed across predefined intraoperative domains:

1. Ease of primary and secondary port insertion (effortless vs. difficult).
2. Gallbladder morphology encountered upon laparoscopy (normal/distended vs. contracted/intrahepatic).
3. Extent and density of adhesions involving omentum, stomach, or duodenum (mild/filmy vs. dense/fibrotic).
4. Presence of gallbladder empyema or mucocoele necessitating preliminary percutaneous/laparoscopic aspiration.
5. Intraoperative assessment of gallbladder wall thickness (thin pliable vs. thick fibrotic/edematous).
6. Duration and complexity of Calot's triangle clearance to achieve Strasberg's Critical View of Safety.
7. Total operative duration, precisely measured from initial skin incision to completion of final skin suture (stratified into <60 minutes, 60–120 minutes, and >120 minutes).
8. Adverse intraoperative events: significant vascular trauma (cystic artery hemorrhage requiring energetic measures or clip ligation), involuntary bile or gallstone spillage resulting from wall perforation, and iatrogenic biliary duct injury.
9. Requirement for conversion to open laparotomy, documented with specific anatomical or technical justifications.

2.7 Postoperative Monitoring

Patients were evaluated daily during postoperative recovery until discharge. Parameters monitored included duration of hospital confinement, visual analog scale (VAS) pain scores, drain output volume and character (checking specifically for serobillous or bilious discharge indicating bile leakage), signs of superficial or deep surgical site infection (SSI), secondary hemorrhage, and clinical or biochemical jaundice.

2.8 Statistical Analysis

All collected clinical, radiological, operative, and postoperative data were systematically curated in Microsoft Excel and imported into IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY). Continuous demographic and operative variables were evaluated for distributional normality and summarized as mean ± standard deviation (SD), median, range, and interquartile boundaries. Categorical parameters were expressed as absolute frequencies (n) and relative percentages (%). Bivariate associations between categorical preoperative risk factors and intraoperative difficulty markers (prolonged operative time, port insertion difficulty, bile spillage, vascular/duct injury, and open conversion) were analyzed using Pearson's Chi-square test (χ^2) or Fisher's exact test when expected cell frequencies were fewer than five. All statistical tests were two-tailed, and a probability value of $p < 0.05$ was considered statistically significant.

RESULTS

3.1 Baseline Demographic and Anthropometric Profile

A total of 80 patients who underwent elective laparoscopic cholecystectomy met all protocol criteria and formed the primary analytical cohort. The overall patient age ranged from 20 to 75 years, with a mean age of 43.73 ± 12.92 years and a median

of 43.50 years. When classified into distinct age categories, the fourth and fifth decades predominated: 42 patients (52.5%) were aged 41 to 60 years, 31 patients (38.8%) were aged 21 to 40 years, 5 patients (6.3%) were aged 61 years or older, and 2 patients (2.5%) were 20 years or younger.

Regarding sex distribution, a pronounced female predominance was observed: 58 patients (72.5%) were female and 22 patients (27.5%) were male, establishing a female-to-male ratio of approximately 2.6:1. The mean Body Mass Index (BMI) of the cohort was 23.09 ± 2.12 kg/m² (range: 18.80 to 34.60 kg/m²; median: 23.20 kg/m²). Categorization according to standard criteria demonstrated that 72 patients (90.0%) possessed a normal BMI (<25.0 kg/m²), 7 patients (8.8%) were classified as overweight (25.0–29.9 kg/m²), and 1 patient (1.3%) was severely obese (≥ 30.0 kg/m²).

Table 1: Baseline Demographic and Clinical Characteristics of the Study Cohort (N = 80)

Clinical / Demographic Parameter	Category / Unit	Frequency (n)	Percentage (%)
Age Group	≤20 years	2	2.5%
	21–40 years	31	38.8%
	41–60 years	42	52.5%
	≥61 years	5	6.3%
Gender	Female	58	72.5%
	Male	22	27.5%
Body Mass Index (BMI)	Normal (<25.0 kg/m ²)	72	90.0%
	Overweight (25.0–29.9 kg/m ²)	7	8.8%
	Obese (≥ 30.0 kg/m ²)	1	1.3%
Presenting Symptom	Abdominal Pain	80	100.0%
Clinical History	Recurrent Cholecystitis	22	27.5%
	Prior Clinical Jaundice	11	13.8%
	Prior Abdominal Scar	2	2.5%
	History of Gallstone Pancreatitis	0	0.0%

3.2 Preoperative Clinical and Laboratory Profile

All 80 patients (100.0%) presented with episodic right upper quadrant or epigastric abdominal pain characteristic of biliary colic. A definitive history of repeated acute attacks of cholecystitis managed conservatively with antibiotics and analgesics was verified in 22 patients (27.5%). Eleven patients (13.8%) recounted a documented episode of jaundice that had resolved prior to elective admission. Only 2 patients (2.5%) presented with healed abdominal scars from prior surgeries (one lower midline appendectomy/cesarean scar and one supraumbilical scar). Importantly, no patient exhibited active systemic leukocytosis or profound hemoglobinopathy at the time of elective intervention; total leukocyte counts and hemoglobin values were within institutional normal limits across all subjects (Table 1), reflecting the elective ambulatory nature of the surgical schedule.

3.3 Preoperative Ultrasonographic Parameters

Detailed transabdominal sonographic evaluations demonstrated diverse pathological features. Calculus multiplicity analysis revealed that 54 patients (67.5%) harbored a solitary calculus, while 26 patients (32.5%) exhibited multiple intraluminal calculi. The measured size of the primary calculus ranged from 4.0 mm to 30.0 mm, yielding a mean diameter of 15.72 ± 5.10 mm (median: 16.40 mm). When dichotomized at the 10-mm threshold, 71 patients (88.8%) harbored calculi measuring ≥ 10 mm, whereas 9 patients (11.3%) presented with calculi <10 mm. Gallbladder wall thickness measured ≥ 4 mm in 73 patients (91.3%), whereas 7 patients (8.8%) presented with thin walls (<4 mm). Common bile duct luminal caliber was within normal limits (<6 mm) in 57 patients (71.3%) and borderline enlarged (≥ 6 mm) in 23 patients (28.7%). Gallbladder morphology was categorized as distended in 69 patients (86.3%) and contracted/shrunken in 11 patients (13.8%). Pericholecystic fluid collection was documented in 5 patients (6.3%).

Table 2: Preoperative Ultrasonographic Findings (N = 80)

Ultrasonographic Variable	Sub-Category	Frequency (n)	Percentage (%)
Number of Gallbladder Stones	Single Calculus	54	67.5%
	Multiple Calculi	26	32.5%
Calculus Size Category	<10 mm (<1 cm)	9	11.3%
	≥ 10 mm (≥ 1 cm)	71	88.8%
Gallbladder Wall Thickness	<4 mm (Normal)	7	8.8%
	≥ 4 mm (Thickened)	73	91.3%
Common Bile Duct (CBD) Diameter	<6 mm (Normal)	57	71.3%

	≥6 mm (Dilated)	23	28.7%
Gallbladder Status	Distended Lumen	69	86.3%
	Contracted / Shrunken	11	13.8%
Pericholecystic Collection	Absent	75	93.8%
	Present	5	6.3%

3.4 Intraoperative Observations and Procedural Metrics

The total duration of surgery ranged between 60 and 120 minutes, with an overall mean duration of 90.13 ± 17.43 minutes (median: 90.0 minutes). When stratified into operative duration brackets, 24 patients (30.0%) required <60 minutes, 37 patients (46.3%) required 60 to 120 minutes, and 19 patients (23.8%) experienced prolonged operative times exceeding 120 minutes. Difficulty during primary or secondary port insertion was documented in 2 patients (2.5%), directly related to parietal adiposity and scarring. Intraoperatively, an intrahepatic or severely contracted gallbladder was confirmed in 31 patients (38.8%), dense adhesions encompassing the omentum, duodenum, or hepatic flexure were encountered in 10 patients (12.5%), and an empyema of the gallbladder requiring preliminary decompressive needle aspiration was present in 9 patients (11.3%). The gallbladder wall was confirmed to be visibly thick and indurated in 67 patients (83.8%).

Regarding intraoperative adverse technical events, involuntary bile or gallstone spillage resulting from iatrogenic perforation during fundal grasping or dissection off the liver bed occurred in 4 patients (5.0%). Injury to the cystic artery or aberrant biliary branches occurred in 3 patients (3.8%), all of which were successfully managed laparoscopically using titanium hemoclips, electrocautery, and topical hemostatic agents without requiring emergency laparotomy. Conversion to open cholecystectomy was necessitated in exactly 1 patient (1.3%) due to an intensely scarred, contracted gallbladder featuring frozen Calot's triangle anatomy where safe identification of the cystic duct-common hepatic duct junction could not be reliably achieved.

Table 3: Intraoperative Metrics, Complications, and Postoperative Outcomes (N = 80)

Intraoperative & Postoperative Parameter	Outcome / Finding	Frequency (n)	Percentage (%)
Duration of Surgery	<60 minutes	24	30.0%
	60–120 minutes	37	46.3%
	>120 minutes	19	23.8%
Difficulty in Port Insertion	Present	2	2.5%
Contracted / Intrahepatic Gallbladder	Present	31	38.8%
Dense Pericholecystic Adhesions	Present	10	12.5%
Gallbladder Empyema	Present	9	11.3%
Intraoperative Gallbladder Wall	Thick / Indurated	67	83.8%
Bile or Stone Spillage	Present	4	5.0%
Injury to Duct or Cystic Artery	Present	3	3.8%
Conversion to Open Surgery	Yes (Converted)	1	1.3%
Postoperative Bile Leak	Present (Minor/Serobilious)	21	26.3%
Surgical Site Infection (SSI)	Present (Superficial)	5	6.3%
Postoperative Hemorrhage	Present	3	3.8%
Postoperative Jaundice	Present (Transient)	2	2.5%

3.5 Postoperative Complications

Systematic surveillance during the post-procedural period revealed that 21 patients (26.3%) exhibited transient bile leakage, manifested as low-volume serobilious drainage from the subhepatic Jackson-Pratt/corrugated drain. All such leaks resolved spontaneously under conservative management within 48 to 72 hours without requiring secondary intervention, re-laparoscopy, or endoscopic stenting, signifying superficial liver bed oozing rather than major ductal disruption. Superficial surgical site infection occurred in 5 patients (6.3%), primarily at the umbilical extraction site, and responded promptly to local wound dressing and oral antibiotic adjustment. Postoperative hemorrhage was noted in 3 patients (3.8%), manifested as blood-stained drainage that ceased spontaneously without transfusion requirements. Transient clinical jaundice was noted in 2 patients (2.5%) and resolved uneventfully within one week.

3.6 Inferential Analysis: Predictors of Operative Difficulty

To determine which preoperative variables significantly predict operative complexity, bivariate cross-tabulations and Chi-square analyses were executed against operative duration brackets and technical complications.

As detailed in Table 4, three specific parameters demonstrated statistically significant associations with operative duration (>120 minutes):

1. Number of Gallbladder Stones: Patients harboring multiple calculi experienced prolonged operative times significantly

more often than those with solitary calculi (53.8% vs. 9.3% requiring >120 min; $\chi^2 = 20.194$, $p < 0.001$).

2. Gallbladder Status (Distended vs. Contracted): A contracted or shrunken gallbladder was strongly correlated with extended operative duration compared to a distended organ ($\chi^2 = 12.052$, $p = 0.002$).

3. Calculus Size Category: Calculi measuring ≥ 10 mm (≥ 1 cm) were significantly associated with operative duration exceeding 60 and 120 minutes compared to small stones ($\chi^2 = 7.262$, $p = 0.026$).

Conversely, history of repeated attacks ($p = 0.252$), ultrasonographic wall thickness ≥ 4 mm ($p = 0.952$), pericholecystic collection ($p = 0.197$), and intraoperative wall thickness ($p = 0.475$) did not achieve statistically significant associations with operative duration categories in this cohort, largely due to high baseline frequencies.

Table 4: Bivariate Association of Preoperative Factors with Operative Duration Categories (N = 80)

Preoperative Parameter	Category	<60 min (n=24)	60–120 min (n=37)	>120 min (n=19)	Total (n=80)	Chi-Square (χ^2)	p-Value
History of Repeated Attacks	No	19	28	11	58	2.755	0.252
	Yes	5	9	8	22		
Stone Size Category	<10 mm (<1 cm)	6	1	2	9	7.262	0.026*
	≥ 10 mm (≥ 1 cm)	18	36	17	71		
USG GB Wall Thickness	<4 mm	2	3	2	7	0.099	0.952
	≥ 4 mm	22	34	17	73		
Pericholecystic Collection	No	24	37	18	79	3.251	0.197
	Yes	0	0	1	1		
GB Wall Thickness (Intraop)	Thin	3	8	2	13	1.490	0.475
	Thick	21	29	17	67		
GB Status (Ultrasound)	Distended	21	16	12	49	12.052	0.002*
	Contracted	3	21	7	31		
Number of Gallbladder Stones	Single	21	28	5	54	20.194	<0.001*
	Multiple	3	9	14	26		
BMI Category	Normal	20	34	18	72	3.181	0.528
	Overweight	3	3	1	7		
	Obese	1	0	0	1		

3.7 Association of Body Mass Index and Demographics with Technical Complications

Further inferential cross-tabulations evaluated the influence of patient habitus and demographics on discrete intraoperative adverse events. Body Mass Index (BMI) emerged as a profound determinant of surgical trauma:

- Difficulty in Port Insertion: Observed in 14.3% (1/7) of overweight and 1.4% (1/72) of normal BMI patients ($\chi^2 = 10.65$, $p = 0.031$).
- Involuntary Bile Spillage: Spillage occurred in 100.0% (1/1) of obese patients, 4.2% (3/72) of normal BMI patients, and 0% of overweight patients ($\chi^2 = 19.47$, $p < 0.001$).
- Ductal or Arterial Insult: Significant vascular or biliary injury occurred in 100.0% (1/1) of obese patients, 14.3% (1/7) of overweight patients, and 1.4% (1/72) of normal BMI patients ($\chi^2 = 28.93$, $p < 0.001$).

In contrast, demographic variables demonstrated no statistically significant correlation with technical complications. Age group was not significantly associated with bile spillage ($\chi^2 = 0.51$, $p = 0.916$) or ductal/arterial injury ($\chi^2 = 1.12$, $p = 0.773$). Similarly, gender showed no statistically significant relationship with bile spillage ($\chi^2 = 0.01$, $p = 0.909$) or ductal/arterial injury ($\chi^2 = 1.18$, $p = 0.277$), confirming that technical mishaps in this series were predominantly driven by mechanical and anatomical factors rather than age or sex alone.

DISCUSSION

Laparoscopic cholecystectomy has firmly established its position as the international standard of care for symptomatic gallstone disease [1, 2]. However, the realization that up to one-third of elective procedures encounter substantial technical difficulty—accompanied by heightened risks of vasculobiliary injury, visceral trauma, and emergency conversion—has spurred intense surgical interest in preoperative risk stratification [2, 3]. The present prospective observational study of 80 consecutive patients managed in an Indian government tertiary medical college provides critical insights into the real-world predictive efficacy of accessible clinical, anthropometric, and ultrasonographic determinants.

4.1 Demographic Factors: Age and Gender

In our cohort, the mean age was 43.73 ± 12.92 years, with over half the patients (52.5%) situated between 41 and 60 years. Although advanced age (>60 years) is widely cited across Western meta-analyses as a strong predictor of operative difficulty

and conversion—with Magnano San Lio et al. (2023) reporting an odds ratio of 4.324 and Chin et al. (2023) observing significant pooled associations in over 108,000 cases—age did not demonstrate independent statistical significance in our study [44, 45]. This apparent divergence is readily explicable by our demographic composition: only 6.3% of our patients were aged ≥ 61 years. In resource-constrained public hospitals across India, patients with symptomatic gallstones frequently seek definitive surgical intervention during active middle adulthood, resulting in an elective cohort that is younger than typical European or North American study populations [46, 47].

Similarly, while female patients dominated our series (72.5%), consistent with estrogenic gallstone epidemiology, gender was not statistically predictive of bile spillage ($p = 0.909$) or ductal/vascular injury ($p = 0.277$). Multiple international studies by Sutcliffe et al. (2016), Licciardello et al. (2014), and Lee et al. (2012) have identified male sex as an independent risk factor for operative difficulty and conversion, attributing this to higher pain tolerance, delayed medical presentation, and severe recurrent subclinical fibrosing cholecystitis [41, 43, 55]. In our series, however, male patients presented at comparable symptomatic timelines as females, mitigating the severe fibrotic end-stage presentations traditionally seen in delayed male cohorts.

4.2 Body Mass Index: Access and Dissection Vulnerabilities

Body Mass Index (BMI) emerged as one of the most critical predictors of intraoperative difficulty and technical complications in our study. Elevated BMI was significantly correlated with difficult trocar port insertion ($p = 0.031$), involuntary bile spillage ($p < 0.001$), and vascular or ductal insults ($p < 0.001$). These findings corroborate the observations of Hassan (2021) in Egypt and Thyagarajan et al. (2017) in India, who demonstrated that excessive parietal and visceral adiposity directly compromises laparoscopic access, trocar trajectory, and optical visualization [46, 52]. Thick abdominal subcutaneous and preperitoneal fat layers reduce cannula mobility, leading to excessive torque on instruments and loss of tactile feedback. Furthermore, extensive visceral adipose deposition within Calot's triangle and the gastrohepatic omentum obscures the junction between the gallbladder infundibulum and cystic duct, rendering dissection hazardous and predisposing to inadvertent arterial avulsion or ductal clipping.

4.3 Ultrasonographic Determinants: Stone Multiplicity, Calculus Size, and Contracted Gallbladder

Preoperative ultrasonography demonstrated exceptional discriminative value in predicting prolonged and complex operative procedures. Specifically, stone multiplicity exhibited a highly significant association with operative duration ($p < 0.001$), with over 53% of patients harboring multiple calculi requiring more than two hours of operative dissection. Multiple calculi are frequently associated with recurrent episodes of cystic duct obstruction and micro-cholecystitis, resulting in cumulative pericholecystic scarring, chronic wall induration, and dense omental adhesions that impede infundibular retraction [57, 59].

Similarly, a contracted or shrunken gallbladder on preoperative ultrasound was strongly associated with extended operative duration ($p = 0.002$). A contracted gallbladder represents the end-stage morphological manifestation of chronic recurrent inflammation, characterized by transmural fibrosis, architectural collapse of the lumen, and obliteration of the subserosal plane between the gallbladder and hepatic bed [58, 61]. Laparoscopically, a scarred, thick-walled, contracted gallbladder is exceptionally difficult to grasp with atraumatic forceps, slipping repeatedly and resisting cephalad retraction over the liver dome. This lack of adequate exposure severely distorts Calot's triangle, transforming standard dissection into a precarious maneuver [59, 61].

Calculus size ≥ 10 mm also demonstrated a statistically significant correlation with prolonged operative duration ($p = 0.026$). Large calculi, particularly those impacted within Hartmann's pouch, prevent inward compression of the infundibulum, create mechanical obstruction against grasper application, and persistently tent the cystic duct parallel to the common bile duct, directly predisposing to misidentification injuries [47, 48, 54]. These findings align with reports by Garg et al. (2025) and Shanker et al. (2025), who identified impacted calculi ≥ 1 cm as the single most critical anatomical factor impeding the Critical View of Safety [47, 54].

Gallbladder wall thickness ≥ 4 mm was present in 91.3% of our patient cohort. Although wall thickening is universally recognized in literature—including prospective series by Di Buono et al. (2021), Onoe et al. (2017), and Sutcliffe et al. (2016)—as a paramount hallmark of difficulty, its ubiquitous presence in our elective patient population blunted its independent statistical discriminative capacity for operative duration brackets ($p = 0.952$) [41, 42, 53]. In Central Indian populations presenting to public hospitals, prolonged histories of episodic biliary colic prior to surgical referral culminate in chronic transmural mural thickening across almost all elective candidates.

4.4 Operative Outcomes, Conversion, and Bile Duct Safety

Our observed conversion rate to open laparotomy was 1.3% (1 out of 80 cases), situated favorably at the lower boundary of the 2% to 15% range reported in international literature [41, 44, 45]. This favorable conversion threshold reflects adherence to meticulous dissection protocols, liberal use of subhepatic suction-irrigation for clearance, and strict insistence on

establishing Strasberg's Critical View of Safety prior to ductal division. In the single converted case, dense fibrotic obliteration of Calot's triangle prevented definitive discrimination of the common hepatic duct from the gallbladder neck; conversion to an open subcostal laparotomy enabled safe fundus-first subtotal cholecystectomy, averting an impending major bile duct transection.

The observed incidence of postoperative bile leakage (26.3%) was predominantly composed of minor, low-volume, transient serobiliary drainage from the raw liver bed that spontaneously ceased within 48 to 72 hours. None of these cases represented true major bile duct disruptions or required endoscopic stenting, confirming that rigorous subhepatic drainage in anticipated difficult gallbladders allows safe outpatient convalescence without catastrophic re-admissions.

4.5 Comparative Evaluation with Established Scoring Models

Established predictive scoring systems, notably the Randhawa and Pujahari model (assigning weighted points to age, male sex, prior hospitalizations, BMI, abdominal scars, palpable gallbladder, wall thickness >4 mm, impacted stone, and pericholecystic collection), have proven highly effective in predicting surgical difficulty [57]. Our findings robustly validate key components of this scoring methodology—specifically elevated BMI, calculus size, contracted gallbladder, and multiple stones—as reliable determinants of surgical complexity. However, our data demonstrate that in regional settings where wall thickening is almost universally present, physical habitus (BMI) and detailed calculus morphology (size and number) should receive greater predictive weighting to optimize risk stratification.

4.6 Clinical Implications and Tactical Recommendations

The translation of these predictive determinants into routine surgical workflow has substantial clinical value. Patients identified with multiple calculi, calculus size ≥ 10 mm, contracted gallbladder morphology, or high BMI should not be scheduled for junior resident training cases without direct consultant scrub-in. In these high-risk scenarios, operating rooms should be equipped with specialized instrumentation, including 30-degree high-definition optics, harmonic/ultrasonic scalpels, laparoscopic needle aspirators for decompressive decompression, and vascular clip applicators. Furthermore, when intense inflammation obscures the hepatocystic triangle and CVS cannot be achieved, surgeons must proactively embrace bail-out options—such as laparoscopic reconstituting or fenestrating subtotal cholecystectomy, fundus-first dissection, or timely open conversion—thereby upholding the cardinal rule of modern biliary surgery: patient safety supersedes laparoscopic pride [1, 13, 20].

4.7 Study Strengths and Limitations

The prospective observational methodology represents the primary strength of this study, ensuring standardized, real-time documentation of clinical, sonographic, and intraoperative variables without retrospective data loss. However, several limitations warrant acknowledgment. First, this was a single-center investigation conducted on a modest cohort of 80 patients, which, while statistically powered for primary endpoints, provided limited numbers in extreme BMI and age brackets. Second, advanced inflammatory biomarkers such as C-reactive protein (CRP), procalcitonin, and neutrophil-to-lymphocyte ratio (NLR) were not routinely assayed due to resource constraints in a public hospital setting. Future prospective multicenter studies with larger cohorts and integration of novel serum biomarkers are warranted to formulate and validate an Indian-specific composite scoring nomogram.

CONCLUSION

Difficult laparoscopic cholecystectomy remains a challenging and multifactorial surgical scenario encountered regularly in clinical practice. Our prospective investigation demonstrates that routine, non-invasive preoperative transabdominal ultrasonography—specifically identifying calculus size ≥ 10 mm, calculus multiplicity, and contracted gallbladder morphology—serves as an extraordinarily reliable predictor of prolonged operative time and technical complexity. Concurrently, elevated patient Body Mass Index (BMI) represents a major mechanical and anatomical risk factor directly predisposing to difficult port insertion, involuntary bile spillage, and vascular or ductal injuries.

Incorporating these accessible clinical, anthropometric, and radiological markers into routine preoperative evaluation enables effective risk stratification, realistic patient counseling, prudent allocation of experienced surgical personnel, and proactive selection of surgical bail-out strategies. Systematic adoption of this predictive paradigm will significantly enhance patient safety, decrease perioperative morbidity, and optimize resource utilization during laparoscopic cholecystectomy.

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