

Personalised Minimally Invasive Approach to Surgical Correction of Acute Cholangitis

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Abstract Background: Acute cholangitis remains a life-threatening condition with mortality rates up to 30% in severe forms. Current guidelines (TG18) define timing of decompression but do not prescribe the specific method, leaving a critical gap in personalised treatment algorithms for regional centres with high comorbidity burden. Objectives: To evaluate the clinical efficacy of a personalised minimally invasive (MI) algorithm based on TG18/CCI/ASA stratification, including the Rendez-vous technique and an innovative endosurgical cutting instrument (ESCI, Patent UZ FAP 01283), compared with conventional open surgery. Methods: Comparative cohort study; 184 consecutive patients with acute cholangitis (2019–2025). Comparison group (CG, n=87): predominantly open surgery; Main group (MG, n=97): personalised MI algorithm. Primary endpoints: 30-day complications and mortality; secondary: PHES rate, late complications by aetiology, and SF-36 quality of life at 12 months. Results: MI procedures constituted 90.7% of MG vs 3.4% in CG (p<0.001). Operative time decreased by 34.5% (p<0.001), blood loss by 56.9% (p<0.001). Non-fatal complications fell from 16.1% to 2.1% (OR=0.11; p<0.001); 30-day mortality from 6.9% to 1.0% (p<0.05). PHES rate for choledocholithiasis: 18.3% vs 5.5% (OR=0.26; p<0.05); 0% after Rendez-vous. SF-36 PCS improved by 16.8 points regardless of aetiology (p<0.001). Conclusions: The TG18–CCI–ASA algorithm with Rendez-vous technique and ESCI significantly outperforms open surgery across all measured outcomes, including long-term quality of life.

Keywords Acute cholangitis, Minimally invasive surgery, Rendez-vous technique, Endosurgical instrument, PHES, Quality of life, SF-36, TG18

1. Introduction

Acute cholangitis an infectious-inflammatory condition of the biliary tract resulting from the combination of biliary obstruction and bacterial contamination represents one of the most challenging emergencies in abdominal surgery, with global incidence continuing to rise in parallel with the prevalence of cholelithiasis [1,2]. The Tokyo Guidelines (TG18) provide internationally accepted diagnostic criteria and a severity classification comprising three grades: Grade I (mild), Grade II (moderate), and Grade III (severe with organ dysfunction), with corresponding recommendations for the timing of decompression [3]. While TG18 define when to decompress, they do not prescribe how leaving the choice between endoscopic, percutaneous, and open approaches to the individual centre's resources and the surgeon's discretion [4].

In Uzbekistan, the epidemiological landscape is further complicated by endemic hepatic echinococcosis in several

regions, notably Navoi Province, where rupture of an echinococcal cyst into the biliary ducts accounts for 8–15% of cholangitis cases a proportion substantially exceeding that reported in Western series [5,6]. This specific aetiological variant demands a tailored surgical strategy that extends beyond standard choledocholithiasis protocols.

Minimally invasive technologies endoscopic sphincterotomy (EST), laparoscopic cholecystectomy (LC), percutaneous transhepatic cholangiostomy (PTCS), and their combinations — have fundamentally transformed biliary surgery over the past three decades [7,8]. The Rendez-vous technique, combining synchronous antegrade wire guidance by a laparoscopic team with retrograde EST by an endoscopic team, provides a compelling solution when standard ERCP fails due to anatomical obstacles [9]. Despite promising results in small series, its systematic application and outcomes in regional centres of Central Asia remain unreported in the literature.

A further unresolved technical challenge concerns destructive phlegmonous cholecystitis with transmural wall thickening (≥ 5 mm), which renders the gallbladder ungrasped by standard laparoscopic instruments the so-called 'non-grasping gallbladder' phenomenon and Veress needle puncture

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unfeasible due to fibrous wall induration [10]. The authors developed and patented an original endosurgical cutting instrument (ESCI, Patent UZ FAP 01283) specifically designed to address this challenge through a controlled fundus incision with a disposable, permanently sharp blade.

The present study aimed to evaluate the clinical efficacy of a personalised TG18–CCI–ASA-based minimally invasive algorithm, encompassing hybrid procedures, two-stage tactics, the Rendez-vous technique, and the ESCI, compared with conventional open surgery, across intraoperative, early postoperative, and long-term outcomes including health-related quality of life in three aetiological subgroups.

2. Materials and Methods

This was a single-centre comparative cohort study conducted at the Department of Surgery, Navoi Branch of the Republican Scientific Centre of Emergency Medicine (Navoi, Uzbekistan), from January 2019 to December 2025. Consecutive adult patients with a verified diagnosis of acute cholangitis according to TG18 criteria (definite cholangitis: criteria from groups A + B + C) were enrolled. The study was approved by the Institutional Ethics Committee of Samarkand State Medical University (protocol No. 8/2019). Written informed consent was obtained from all participants.

Patients were assigned to two groups by chronological principle: Comparison Group (CG, n=87; 2019–2021) treated with conventional open surgery; and Main Group (MG, n=97; 2022–2025) treated according to the personalised MI algorithm. Exclusion criteria: malignant biliary obstruction, age <18 years, refusal of surgical treatment, and loss to follow-up before 30-day assessment.

The personalised algorithm was based on a decision matrix integrating TG18 severity grade, Charlson Comorbidity Index (CCI), and ASA physical status class. For Grade I with CCI \leq 3 and ASA I–III: simultaneous EST + LC (hybrid, single anaesthesia). When standard ERCP failed (periampullary diverticulum, stone >15 mm, previous Billroth-II gastrectomy): Rendez-vous technique (synchronous two-team: laparoscopic antegrade 0.035-inch guidewire introduction via cystic duct + retrograde EST over guidewire). For Grade II–III with organ dysfunction: two-stage approach (EST/PTCS as first stage followed by LC/OC after stabilisation at 48–72 hours). For biliary strictures: staged biliodigestive anastomosis (PTCS \rightarrow hepaticojejunostomy after cholangitis resolution, 5–10 days). For hepatic echinococcosis: EST followed by laparoscopic echinococectomy utilising ESCI for pericyst incision.

The Endosurgical Cutting Instrument (ESCI) (Patent UZ FAP 01283, IPC A61B 17/32, registered 21.02.2018; inventors: Mamatov K.S., Malikov Yu.R., Davronov A.U.) comprises a round-cross-section handle (diameter $K_1=5$ mm, total length $K=400$ mm) connected to a rectangular parallelepiped working part (length $K_2=25$ mm) with two longitudinal grooves on opposite faces and a rectangular recess for a disposable sterile surgical blade (No. 11/13/15,

width ≤ 6 mm) secured by a bevel without additional fixation elements. The instrument is fully compatible with standard 5-mm trocars. The disposable blade provides 100% cutting sharpness at each operation, eliminating the 'crushing cut' phenomenon of blunted reusable scissors and enabling precise incision through fibrous-inflammatory tissue resistant to standard instruments (fig. 1).



Figure 1. The Endosurgical Cutting Instrument

In destructive phlegmonous cholecystitis (wall thickness ≥ 5 mm), ESCI was used to perform a controlled 8–12 mm incision through the gallbladder fundus, enabling aspiration of infected bile/pus, decompression, and subsequent retrograde (fundus-first) laparoscopic cholecystectomy according to Strasberg's difficult cholecystectomy principles [10].

Primary outcomes: 30-day non-fatal complication rate (Clavien–Dindo classification) and 30-day mortality. Secondary outcomes: intraoperative parameters (duration, blood loss, transfusion, complications); hospital and ICU stay; rate of post-cholecystectomy syndrome (PHES, Rome IV 2016 criteria) in the choledocholithiasis subgroup; late complications in stricture and echinococcosis subgroups; and health-related quality of life (SF-36 questionnaire at 6 and 12 months). Survivors available for follow-up: CG n=74/81 (91.4%), MG n=90/96 (93.8%).

Data were analysed using SPSS v.26.0. Continuous variables are presented as mean \pm SD; categorical variables as n (%). Between-group comparisons: Mann–Whitney U test (continuous), chi-square or Fisher's exact test (categorical). Odds ratio (OR) with 95% confidence interval (CI) was

calculated for binary outcomes. Spearman's rank correlation (ρ) was used for association analysis. Statistical significance was set at $p < 0.05$.

3. Results

Both groups were comparable at baseline across all demographic, severity, and biochemical parameters (Table 1). The overall cohort was characterised by advanced age (mean 67.1 ± 5.4 years), significant comorbidity (CCI median 3.0, 45.0% with ≥ 2 comorbidities), and predominantly moderate-to-severe cholangitis (TG18 Grade II: 48.4%; Grade III: 29.3%). The unique aetiological structure included choledocholithiasis (79.9%), biliary strictures (9.2%), and hepatic echinococcosis (10.9%).

The MI algorithm achieved 90.7% minimally invasive procedures in the MG vs 3.4% in the CG ($p < 0.001$). Intraoperative results are detailed in Table 2. Operative duration decreased by 34.5% ($p < 0.001$) and blood loss by 56.9% ($p < 0.001$). No patient in the MG required intraoperative transfusion (0% vs 12.6%; $p < 0.001$). The Rendez-vous technique ($n=12$) achieved 100% stone clearance with zero conversion. ESCI was applied in 76.3% of MG operations across five clinical scenarios: phlegmonous cholecystitis fundus incision (18.9%), scarred Calot's triangle dissection

(58.1%), biliary stricture resection for anastomosis (8.1%), echinococcal pericyst incision (12.2%), and adhesiolysis (2.7%). No technical failures, blade disengagement, or ESCI-related complications were recorded.

Early results are presented in Table 3. Non-fatal complications fell from 16.1% to 2.1% (OR=0.11; 95% CI: 0.02–0.50; $p < 0.001$); 30-day mortality from 6.9% to 1.0% (OR=0.14; $p < 0.05$). Wound complications (5.7% vs 0%), cardiovascular events (2.3% vs 0%), and post-hepaticojejunostomy anastomotic failures (10.0% vs 0% in the single-stage anastomosis subgroup) were exclusively found in the CG. The sole MG death occurred in an 84-year-old patient (SOFA=8, CCI=7) with Grade III cholangitis and decompensated diabetes, despite timely PTCS attributable to pre-existing critical multiorgan dysfunction rather than the surgical approach. Hospital stay decreased by 50% and ICU stay by 75% (both $p < 0.001$).

In the choledocholithiasis subgroup, PHES occurred in 18.3% (CG) vs 5.5% (MG; OR=0.26; $p < 0.05$). The highest PHES rate in the CG was after open cholecystectomy with T-tube drainage (29.2%), driven by sphincter of Oddi dysfunction following choledochotomy closure. The Rendez-vous technique achieved zero PHES at 30 months follow-up attributed to 100% stone clearance and minimal sphincter trauma with targeted incision over a guidewire.

Table 1. Baseline Patient Characteristics

Characteristic	CG (n=87)	MG (n=97)	p
Age, years (M \pm SD)	65.8 \pm 8.4	68.2 \pm 7.9	>0.05
Female sex, n (%)	54 (62.1%)	59 (60.8%)	>0.05
CCI score (median)	3.0	3.0	>0.05
ASA class III–IV, n (%)	38 (43.7%)	42 (43.3%)	>0.05
TG18 Grade I, n (%)	19 (21.8%)	22 (22.7%)	>0.05
TG18 Grade II, n (%)	43 (49.4%)	46 (47.4%)	>0.05
TG18 Grade III, n (%)	25 (28.7%)	29 (29.9%)	>0.05
Choledocholithiasis, n (%)	69 (79.3%)	78 (80.4%)	>0.05
Biliary strictures, n (%)	10 (11.5%)	7 (7.2%)	>0.05
Hepatic echinococcosis, n (%)	8 (9.2%)	12 (12.4%)	>0.05
Bilirubin μ mol/L (M \pm SD)	124.3 \pm 38.2	118.6 \pm 35.4	>0.05
Procalcitonin ng/mL (M \pm SD)	3.12 \pm 1.45	3.08 \pm 1.38	>0.05
INR (M \pm SD)	1.42 \pm 0.26	1.39 \pm 0.24	>0.05

CG: Comparison Group; MG: Main Group; CCI: Charlson Comorbidity Index; TG18: Tokyo Guidelines 2018; INR: International Normalised Ratio. All $p > 0.05$.

Table 2. Intraoperative Outcomes: Main Group vs. Comparison Group

Parameter	CG (n=87)	MG (n=97)	p	Effect (95% CI)
Operative duration, min (M \pm SD)	148.4 \pm 32.1	97.2 \pm 24.6	<0.001	↓34.5% (–51.2 min)
Blood loss, mL (M \pm SD)	287.3 \pm 84.2	123.8 \pm 51.7	<0.001	↓56.9% (–163.5 mL)
Intraop. transfusion, n (%)	11 (12.6%)	0 (0%)	<0.001	OR=0; ↓100%
Intraop. complications, n (%)	16 (18.4%)	7 (7.2%)	<0.01	OR=0.35 (0.13–0.91)
Intraop. mortality, n (%)	2 (2.3%)	0 (0%)	<0.05	—
Complete biliary clearance, n (%)	71 (81.6%)	89 (91.8%)	<0.05	OR=2.57 (1.06–6.22)

M \pm SD: mean \pm standard deviation; OR: odds ratio; 95% CI: confidence interval; ↓/↑: direction of change in MG vs CG.

Table 3. Early Postoperative Outcomes and Recovery Parameters

Parameter	CG (n=81*)	MG (n=96*)	p	Reduction
Non-fatal complications, n (%)	14 (16.1%)	2 (2.1%)	<0.001	OR=0.11; ↓87%
30-day mortality, n (%)	6 (6.9%)	1 (1.0%)	<0.05	OR=0.14; ↓85%
Hospital stay, days (M±SD)	14.8±4.2	7.4±2.6	<0.001	↓50.0%
ICU stay, days (M±SD)	3.2±1.8	0.8±0.6	<0.001	↓75.0%
Bilirubin normalisation, days	8.6±3.1	5.2±2.1	<0.001	↓39.5%
Resume enteral feeding, days	3.8±1.4	1.2±0.6	<0.001	↓68.4%
Return to activity, weeks	5.6±1.8	2.4±0.9	<0.001	↓57.1%

* Survivors only. All differences significant at $p<0.001$ (Mann–Whitney *U* test) unless stated otherwise.

Table 4. SF-36 Health-Related Quality of Life at 6 and 12 Months

SF-36 Domain	CG 6m	CG 12m	MG 12m	Difference (12m)
Physical Functioning (PF)	52.3±12.4	58.4±11.8	74.3±9.8	+15.9
Role Physical (RP)	43.2±15.6	51.3±14.2	70.8±11.3	+19.5
Bodily Pain (BP)	55.4±14.3	62.1±13.8	76.4±10.4	+14.3
General Health (GH)	48.6±13.2	54.2±12.4	70.1±10.6	+15.9
Vitality (VT)	50.2±12.8	55.6±12.1	72.4±9.6	+16.8
Social Functioning (SF)	58.4±13.6	64.2±12.8	78.3±9.4	+14.1
Role Emotional (RE)	46.8±14.2	53.4±13.6	70.6±10.2	+17.2
Mental Health (MH)	54.6±13.4	60.3±12.6	74.2±9.8	+13.9
Physical Component (PCS)	48.4±12.8	54.8±11.6	71.6±9.2	+16.8*
Mental Component (MCS)	50.8±13.2	56.4±12.4	72.4±9.6	+16.0*

CG: comparison group; MG: main group; PCS: Physical Component Summary; MCS: Mental Component Summary. Population norm for Uzbekistan: PCS=78.4±8.2, MCS=75.6±7.8. * $p<0.001$ vs CG at 12 months (Mann–Whitney *U* test).

In the biliary stricture subgroup, late complications (anastomotic stricture, cholangitis recurrence) fell from 50.0% to 14.3% ($p<0.05$) through staged reconstruction after infection control. In the echinococcosis subgroup, residual cavity formation and biliary fistula were entirely eliminated in the MG (0% vs 28.6%; $p<0.05$) through ESCI-assisted precise pericyst incision and laparoscopic approach; overall late complication rate dropped from 42.9% to 9.1% ($p<0.05$).

SF-36 scores at 12 months are detailed in Table 4. The Physical Component Summary (PCS) exceeded CG values by 16.8 points (71.6±9.2 vs 54.8±11.6; $p<0.001$), and Mental Component Summary (MCS) by 16.0 points (72.4±9.6 vs 56.4±12.4; $p<0.001$) regardless of aetiology. Patients with PHES scored 18.4 PCS points lower than those without ($\rho=-0.68$; $p<0.001$). Subgroup analysis showed the greatest PCS improvement in the echinococcosis subgroup (+17.8 points) and biliary strictures (+17.2 points), reflecting the particularly high surgical trauma of open approaches in these conditions. Correlation analysis confirmed that long-term quality of life is determined predominantly by the type of surgical procedure rather than by initial disease severity.

4. Discussion

The present study demonstrates that a personalised, TG18–CCI–ASA-driven minimally invasive algorithm achieves clinically and statistically significant improvements

across all measured endpoints from intraoperative parameters through 30-day outcomes to 12-month quality of life compared with predominantly open surgical management of acute cholangitis in a regional centre with a high-risk patient population.

The pathophysiological rationale for prioritising endoscopic decompression as the primary intervention is well-established: EST directly eliminates biliary hypertension, interrupting the cholangiovenous reflux–endotoxaemia cascade within 2–6 hours, an effect unachievable by open surgery that introduces additional immunological 'second hit' [11]. Our results confirm this mechanism: the two-stage approach (EST/PTCS → deferred surgery) reduced 30-day mortality 6.9-fold among Grade II–III patients by avoiding full surgical trauma during active sepsis.

The Rendez-vous technique, achieving 100% stone clearance and zero PHES in all 12 patients in this series, merits wider adoption at centres managing anatomically complex cholangitis. The technique's superiority over standard ERCP in selected cases is consistent with the meta-analysis by Kedia *et al.* [9], which reported 90–100% technical success. Our novel finding zero PHES after Rendez-vous at 30 months can be attributed to the precise, guidewire-controlled sphincterotomy minimising collateral sphincter damage, which represents an important contribution to the existing literature.

The ESCI (Patent UZ FAP 01283) addresses a specific

and hitherto unsolved technical challenge: laparoscopic cholecystectomy in phlegmonous cholecystitis with wall thickness ≥ 5 mm. The 'non-grasping gallbladder' phenomenon, described by Strasberg (2010) as a recognised factor of difficult cholecystectomy, has no standardised instrumental solution in published literature [10]. Our application of a disposable ultra-sharp blade mounted on the ESCI reduced conversion rate from 96.6% (predominantly open in CG) to 7.1% among phlegmonous cholecystitis cases a result consistent with the 5–8% conversion benchmark for complex cholecystitis at high-volume centres [12]. The instrument's additional applications (Calot's triangle dissection, anastomotic preparation, pericyst incision) underscore a unifying pathomorphological criterion: utility whenever standard scissors fail to achieve a precise cut through fibrotic or parasitically altered tissue.

The finding that SF-36 quality of life at 12 months correlates with the type of surgery ($\rho=+0.52$ for laparoscopic approach vs PCS; $p<0.001$) rather than initial disease severity represents a novel contribution to the understanding of long-term outcomes following acute cholangitis. Existing literature predominantly reports quality-of-life data after uncomplicated cholecystectomy for cholelithiasis; aetiological -subgroup-specific SF-36 analysis in cholangitis patients has not previously been published [13].

Several limitations deserve acknowledgment. First, the non-randomised design, while mitigated by the comparable baseline characteristics and chronological cohort structure, cannot fully exclude selection bias. Second, the shorter follow-up period in the MG (median 18.2 months vs 28.4 months in CG) is an inherent constraint of the prospective component; extended surveillance is ongoing. Third, the absence of preoperative SF-36 values precludes within-patient longitudinal analysis. Fourth, the results derive from a single regional centre in Central Asia with a specific aetiological profile including endemic echinococcosis, which may limit generalisability to centres with different case mixes.

5. Conclusions

A personalised minimally invasive algorithm based on TG18–CCI–ASA stratification, incorporating hybrid EST+LC, the Rendez-vous technique, staged biliary reconstruction, and the novel ESCI (Patent UZ FAP 01283), significantly outperforms conventional open surgery for acute cholangitis across all key outcomes: intraoperative blood loss ($\downarrow 56.9\%$), 30-day mortality ($\downarrow 6.9$ -fold), PHES rate in choledocholithiasis ($\downarrow 70\%$), late complications in strictures ($\downarrow 71.4\%$) and echinococcosis ($\downarrow 78.8\%$), and 12-month SF-36 PCS ($+16.8$

points). The evidence presented establishes that long-term quality of life after acute cholangitis is determined primarily by the nature of the surgical procedure rather than by the severity of the initial condition a clinically actionable insight for surgical planning and post-discharge surveillance. The algorithm is implementable in regional-level surgical departments without specialised infrastructure.

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