

Surgical Management of Hepatic Echinococcosis and Its Complicated Forms Using Minimally Invasive Endovideosurgical and Image-Guided Percutaneous Techniques: A Comparative Cohort Study

Short title: Minimally Invasive Surgery for Hepatic Echinococcosis

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Abstract

Background: Hepatic echinococcosis remains a persistent surgical challenge in endemic regions, where complicated forms—suppuration, cystobiliary fistulation, obstructive jaundice, and intracavitary rupture—are still managed predominantly by open surgery, with reported complication rates exceeding one-fifth of operated patients. Whether a structured, criteria-based shift toward minimally invasive endovideosurgical and image-guided percutaneous techniques can durably lower this morbidity has not been settled by the existing literature, much of which addresses uncomplicated cysts only.

Objective: To evaluate whether a differentiated surgical strategy prioritising minimally invasive endovideosurgical and navigation-guided percutaneous methods improves early and long-term outcomes in patients with hepatic echinococcosis and its complicated forms, relative to conventional open surgery.

Methods: We conducted a retrospective–prospective comparative cohort study of 448 patients treated for hepatic echinococcosis and its complications at the multidisciplinary clinic of Samarkand State Medical University between 2015 and 2024. Patients were allocated by treatment era and clinical eligibility into a study group (n=236) managed with minimally invasive techniques—percutaneous transhepatic puncture-drainage, laparoscopic echinococcectomy, laparoscopic pericystectomy, mini-access (“Mini-Assistant”) echinococcectomy, and endoscopic transpapillary clearance—and a comparison group (n=212) managed by conventional open echinococcectomy. Diagnostic workup combined ultrasonography with duplex Doppler, computed tomography, magnetic resonance imaging, and endoscopic retrograde cholangiopancreatography. Hepatic perfusion, endotoxaemia markers, and bacterial translocation were assessed in a subgroup of 58 patients. Group comparisons used the χ^2 test, Fisher’s exact test, the Mann–Whitney U test, and the Kruskal–Wallis H test, with significance set at $p \leq 0.05$.

Results: Criteria built from cyst type, location, and complication status allowed a minimally invasive approach to be applied in 65.3% of the cohort. Postoperative complications fell from 24.1% (51/212) in the conventional group to 8.1% (19/236) in the minimally invasive group ($p < 0.05$), and in-hospital

mortality, recorded in one conventional-group patient (0.5%), was eliminated entirely in the study group. A staged strategy—percutaneous sanitation of the septic focus followed by delayed radical surgery once endotoxaemia had resolved—was used in 9.7% of study-group patients with suppurated or biliary-communicating cysts. Hepatic arterial and portal flow correlated with cyst diameter, with volumetric portal flow below 480 mL/min identifying patients at elevated postoperative risk. Among 387 patients followed for one to five years, recurrence was less frequent after minimally invasive treatment than after open surgery (6.7% vs 12.3%, $p < 0.01$); a hepatoprotector-supported albendazole regimen was associated with this reduction and required no treatment discontinuation for toxicity.

Conclusion: A differentiated surgical algorithm that prioritises minimally invasive endovideosurgical and percutaneous navigation-guided techniques, combined with hepatoprotector-supplemented chemotherapy, substantially reduces postoperative morbidity, eliminates short-term mortality, and lowers recurrence in hepatic echinococcosis, including its complicated forms.

Keywords: *Echinococcosis, Hepatic; Laparoscopy; Minimally Invasive Surgical Procedures; Drainage; Cholestasis, Extrahepatic; Recurrence; Postoperative Complications*

Introduction

Hepatic echinococcosis continues to impose a disproportionate burden on health systems in regions where livestock husbandry and rural living are widespread, and Central Asia remains among the areas where the disease is encountered most frequently in clinical practice. Beyond the direct cost of surgical care, the condition is associated with prolonged convalescence, recurrent hospitalisation, and a tangible loss of working capacity among patients who are often of working age at diagnosis. A substantial share of patients still present late, after the cyst has already suppurated, ruptured into the biliary tree or peritoneal cavity, or produced obstructive jaundice through biliary compression—clinical scenarios in which conventional open echinococcectomy has historically carried complication rates in the range of one-fifth to one-quarter of operated cases.

Interest in minimally invasive alternatives—percutaneous aspiration–injection–reaspiration (PAIR), laparoscopic echinococcectomy, and combined endoscopic–percutaneous strategies—has grown steadily over the past two decades, driven largely by their lower tissue trauma and shorter recovery times in uncomplicated CE1–CE3 cysts. The World Health Organization has endorsed PAIR for selected cyst types, and laparoscopic echinococcectomy is now widely regarded as a safe option for superficial, single-segment disease. What the literature has not resolved with comparable confidence is how these techniques perform once the cyst has already become complicated: suppuration, cystobiliary fistulation, and rupture introduce a risk of peritoneal or ductal contamination that has made some

surgeons reluctant to extend minimally invasive approaches beyond straightforward cases. Most published series either exclude complicated echinococcosis altogether or treat it as a secondary subgroup, leaving the comparative safety of a minimally invasive-first strategy in this setting only partially characterised.

A further gap concerns the physiological consequences of progressive parenchymal involvement. While endotoxaemia and biliary insufficiency are recognised contributors to poor outcomes in complicated echinococcosis, relatively few studies have linked quantitative haemodynamic parameters—hepatic arterial and portal venous flow on duplex Doppler—to cyst burden in a way that could inform the timing of intervention. Similarly, although albendazole is the mainstay of adjuvant chemotherapy, its hepatotoxic potential and variable tolerability are not uniformly addressed through protective co-therapy in existing surgical protocols.

This study set out to address these gaps by evaluating, in a cohort drawn from a single multidisciplinary centre over a ten-year period, whether a differentiated strategy that prioritises minimally invasive endovideosurgical and image-guided percutaneous techniques—supported by staged management of septic complications and hepatoprotector-supplemented chemotherapy—could measurably improve early and long-term surgical outcomes compared with conventional open treatment of hepatic echinococcosis and its complicated forms.

Materials and Methods

Study design and patient population

This comparative cohort study included 448 patients treated for hepatic echinococcosis and its complications in the surgical and radiology departments of the multidisciplinary clinic of Samarkand State Medical University between 2015 and 2024. Patients were assigned to a study group (n=236), treated with a minimally invasive-first strategy, and a comparison group (n=212), treated by conventional open surgery, reflecting the gradual introduction of minimally invasive technology into departmental practice over the study period combined with case-by-case eligibility. Rural residents accounted for 301 patients (67.2%) and urban residents for 147 (32.8%); women slightly outnumbered men (237 [52.9%] versus 211 [47.1%]). Most patients were between 18 and 40 years of age (280, 62.5%), with a further 141 (31.4%) aged 40–65 years and 27 (6.1%) over 65. The right hepatic lobe was involved in 334 cases (74.4%), the left lobe in 67 (14.9%), and both lobes in 47 (10.6%).

Patients were stratified by complication status: uncomplicated cysts in 135 cases (34.1%), cyst suppuration in 131 (28.5%), obstructive jaundice in 122 (22.9%)—itself subdivided into biliary rupture (97 cases) and compressive biliary obstruction without rupture (25 cases)—intraperitoneal or

intrathoracic rupture in 17 (2.1%), and recurrent echinococcosis in 43 (8.1%). The distribution of complication subtypes was broadly comparable between the two groups, allowing outcome differences to be attributed principally to the surgical strategy rather than to baseline disease severity.

Diagnostic protocol

All patients underwent abdominal ultrasonography as the first-line investigation, with cyst typing performed according to the World Health Organization classification (CL, CE1–CE5). Sonographic features used to characterise cysts included anechoic content with a well-defined wall in CL/CE1 lesions, the multivesicular “honeycomb” pattern in CE2/CE3, heterogeneous hypoechoic content suggesting degeneration in CE4, and arc-shaped calcification in CE5. Computed tomography was performed in 148 patients (33.1%) to differentiate parasitic from neoplastic or non-parasitic hepatic lesions and to guide selection of the surgical approach; it confirmed cyst-related pathology in 126 of 128 examined patients (99.1%). Magnetic resonance imaging was used as a final diagnostic step in 72 patients (21.2%), particularly to characterise biliary communication. Endoscopic retrograde cholangiopancreatography was reserved for patients with suspected cystobiliary rupture or obstructive jaundice. Hepatic and portal haemodynamics were assessed by duplex Doppler ultrasonography, with volumetric arterial flow calculated from vessel diameter, peak systolic and end-diastolic velocities, and time-averaged mean velocity; resistive and pulsatility indices were derived from the corresponding flow-velocity waveforms. Intraoperative duplex scanning was additionally performed in 35 patients to assess portal flow according to cyst size.

Histological, parasitological, and microbiological methods

Liver biopsy specimens, obtained intraoperatively or by percutaneous needle biopsy in 58 patients, were processed using a Sakura VIP-E150F tissue processor and embedded with a Sakura Tissue-Tek TEC automated system; 3-µm sections were stained on a Sakura Tissue-Tek DRS-601 autostainer and examined under an Olympus BX-50 light microscope. Cyst-fluid sediment was assessed for protoscolex viability using 0.1% eosin staining, with viable protoscoleces remaining unstained and motile after exposure to 80% glycerol, and fertility rate calculated as the proportion of protoscolex-bearing cysts among those examined. Cyst fluid, pus, and bile specimens were submitted for microbiological culture at the Department of Microbiology of Samarkand State Medical University.

Surgical and percutaneous techniques

In the comparison group, all patients underwent conventional open echinococectomy through a subcostal (56 patients, 26.4%) or midline laparotomy (156 patients, 73.6%) incision. In the study group, the choice of minimally invasive technique was guided by cyst type, segmental location, size,

and complication status. Mini-access echinococcectomy using a “Mini-Assistant” retractor set was performed in 60 patients (25.4%), exploiting an enlarged visual angle and working area to access deep or centrally located cysts without the trauma of a full laparotomy; intraoperative videoendoscopy was used in 18 of these cases to identify and coagulate cystobiliary communications. Laparoscopic echinococcectomy, performed with standard endoscopic instrumentation after creation of pneumoperitoneum and placement of one 10-mm and two 5-mm ports, was carried out in 37 patients (15.6%) and laparoscopic ideal echinococcectomy in a further 16 (6.7%); laparoscopic total or subtotal pericystectomy was performed in 40 patients (16.9%). Cyst evacuation followed scolicidal irrigation with 80% glycerol retained in the cavity for ten minutes before aspiration, with chitinous membrane retrieval via an endo-bag and residual-cavity disinfection using 96% ethanol.

Percutaneous transhepatic puncture-drainage, performed under ultrasound guidance using Chiba needles (20–22 G) or pigtail catheters, was used in 23 patients (9.7%), twelve of whom had suppurated cysts; in 12 of these 23 patients percutaneous drainage was curative, while the remaining 11 underwent delayed radical surgery once systemic toxemia had improved. A two-stage strategy—percutaneous or endoscopic decompression followed by interval laparoscopic or open echinococcectomy—was applied in 16 patients (6.8%) overall. Patients with obstructive jaundice from cystobiliary rupture underwent endoscopic retrograde cholangiopancreatography with endoscopic papillosphincterotomy and transpapillary extraction of cyst fragments, followed by biliary sanitation and nasobiliary drainage, in 17 cases; definitive echinococcectomy was performed once bilirubin and hepatic synthetic function had normalised. Videoendoscopic inspection of the residual cavity, combined with conventional open echinococcectomy, was used in 35 patients (14.8%) specifically to detect and coagulate occult cystobiliary leaks.

Antiparasitic chemotherapy

Postoperative antirecurrence therapy with albendazole followed a standard weight-adjusted regimen administered in cyclical courses. In patients judged at elevated risk of hepatotoxicity, albendazole was combined with a hepatoprotective agent for the duration of treatment; no patient in this combined regimen required drug discontinuation because of adverse effects, in contrast to a subset of patients on albendazole monotherapy in whom toxicity necessitated treatment interruption.

Statistical analysis

Continuous variables are presented as mean $\pm$ standard deviation, and categorical variables as absolute numbers and percentages. Differences between two independent groups for continuous data were assessed using the Mann–Whitney U test; comparisons across three or more independent groups used

the Kruskal–Wallis H test. Categorical variables were compared using the χ^2 test, with Fisher’s exact test applied when expected cell counts were small. Pre- and post-procedural paired comparisons used the Wilcoxon signed-rank test. A two-sided p-value ≤ 0.05 was considered statistically significant throughout.

Ethical approval

The study was approved by the Institutional Review Board of Samarkand State Medical University and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to inclusion.

Results

Distribution of complications

Of 448 patients, complication subtypes were distributed similarly between the study and comparison groups (Table 1), confirming that the two cohorts were broadly comparable in baseline disease severity despite differing in treatment era and surgical approach.

Complication	Study group (n=236) abs. (%)	Comparison group (n=212) abs. (%)	p
No complications	72 (30.4)	63 (29.7)	>0.05
Cyst suppuration	68 (28.8)	63 (29.7)	>0.05
Obstructive jaundice	65 (27.5)	57 (26.8)	>0.05
– Biliary rupture	51 (21.6)	46 (21.7)	—
– Compressive obstruction	14 (5.9)	11 (5.2)	—
Intracavitary rupture (abdominal/thoracic)	11 (4.7)	6 (2.8)	>0.05
Recurrent echinococcosis	20 (8.4)	23 (10.8)	<0.05
Total	236 (100.0)	212 (100.0)	

Table 1. Distribution of patients by complication type, study versus comparison group (n=448).

Hepatic and portal haemodynamics

Hepatic arterial volumetric flow increased progressively with cyst diameter: 248 mL/min for cysts up to 10 cm, 286 mL/min for cysts of 10–15 cm, and 410 mL/min for cysts exceeding 15 cm ($p<0.05$). Portal venous flow below 480 mL/min identified patients at high risk of postoperative hepatic dysfunction, whereas flow of 700–1120 mL/min or above was associated with a favourable prognosis. Intraoperative duplex scanning in 35 patients with large or giant cysts (Table 2) demonstrated significantly higher portal vein diameter, mean flow velocity, and volumetric flow in patients with cysts exceeding 15 cm compared with those harbouring cysts of 10–15 cm, consistent with a direct relationship between parenchymal compression and portal haemodynamic derangement.

Parameter	Cysts >15 cm (n=15)	Cysts 10–15 cm (n=20)
Portal vein diameter, mm	9.2 ± 2.8	8.4 ± 1.4
Mean velocity, cm/s	21.2 ± 1.5	20.4 ± 2.8
Volumetric flow, mL/min	1062.3 ± 82.1	1005.4 ± 76.1

Table 2. Intraoperative duplex Doppler parameters of portal haemodynamics by cyst size (Mann–Whitney U test, $p < 0.05$ for all comparisons).

Operative parameters and minimally invasive technique distribution

Among the 236 patients managed with a minimally invasive-first strategy, mini-access echinococectomy accounted for the largest single category (60 patients, 25.4%), followed by laparoscopic subtotal pericystectomy (21, 8.9%), laparoscopic total pericystectomy (19, 8.1%), and laparoscopic echinococectomy (37, 15.6%) (Table 3). Mean operative time for laparoscopic procedures was 115.2 ± 36.8 minutes, with mean blood loss of 255.8 ± 75.0 mL (range 60–370 mL). No conversions to open surgery and no intraoperative complications were recorded in the laparoscopic subgroup.

Type of minimally invasive intervention	n	%
Mini-access (“Mini-Assistant”) echinococectomy	60	25.4
Laparoscopic echinococectomy	37	15.6
Laparoscopic subtotal pericystectomy	21	8.9
Laparoscopic total pericystectomy	19	8.1
Laparoscopic “ideal” echinococectomy	16	6.7
Open echinococectomy with residual-cavity videoendoscopy	35	14.8
Endoscopic transpapillary clearance + open echinococectomy	17	7.2
Percutaneous puncture-drainage alone	12	5.1
Percutaneous puncture-drainage + open echinococectomy	9	3.8
Percutaneous puncture-drainage + laparoscopic echinococectomy	7	2.9
Videolaparoscopic choledochotomy with drainage + open echinococectomy	3	1.3
Total	236	100.0

Table 3. Distribution of minimally invasive surgical and percutaneous interventions in the study group (n=236).

Postoperative complications

Overall postoperative morbidity was significantly lower in the study group than in the comparison group: 19 patients (8.1%) versus 51 patients (24.1%) ($p < 0.05$) (Table 4). Bile leakage from the residual cavity occurred in 2.9% of study-group patients compared with 8.4% of comparison-group patients ($p < 0.05$); wound suppuration was reduced from 17.9% to 2.9% ($p < 0.001$); residual-cavity suppuration

fell from 6.6% to 1.7% ($p<0.01$); postoperative intra-abdominal haemorrhage decreased from 5.6% to 0.8% ($p<0.05$); and exudative pleurisy fell from 6.1% to 2.5% ($p<0.05$). Relaparotomy was required in 10 comparison-group patients (4.7%) but in none of the study group, and the single in-hospital death recorded in the entire cohort (0.5%) occurred in the comparison group, attributable to multiorgan failure following extensive open surgery.

Complication	Comparison group n (%)	Comparison group management	Study group n (%)	p
Bile leakage from residual cavity	18 (8.4)	Conservative – 12; relaparotomy – 6	7 (2.9)	<0.05
Wound suppuration	38 (17.9)	Local treatment – 8; redrainage – 10	7 (2.9)	<0.001
Residual cavity suppuration	14 (6.6)	Conservative – 10; redrainage – 4	4 (1.7)	<0.01
Intra-abdominal haemorrhage	12 (5.6)	Conservative – 8; relaparotomy – 4	2 (0.8)	<0.05
Exudative pleurisy	13 (6.1)	Pleural puncture – 8; conservative – 5	6 (2.5)	<0.05
Total	51 (24.1)	1 death (0.5%)	19 (8.1)	<0.05

Table 4. Postoperative complications and their management, comparison versus study group (Fisher's exact test).

Long-term outcomes and recurrence

Long-term follow-up of 1–5 years was completed in 387 patients (study group, $n=209$; comparison group, $n=178$). Overall recurrence occurred in 36 patients (9.3%): 14 (6.7%) in the study group and 22 (12.3%) in the comparison group ($p<0.01$) (Table 5). Early recurrence (within 3 years), generally of residual origin, was recorded in 3 study-group and 7 comparison-group patients, while late recurrence, more often implantation-related or metastatic, occurred in 11 and 15 patients respectively. A primary hepatic cyst location was present in 81.5% of recurrences ($p=0.01$). In 12 recurrence cases (31.5%), albendazole had been discontinued because of adverse effects—identified as the principal modifiable risk factor for recurrence in this cohort. Of 38 patients with confirmed recurrence, 23 (60.5%) required reintervention, 11 by percutaneous drainage and 12 by radical surgery; mean hospital stay for recurrent disease was 6.2 ± 3.2 days, and postoperative albendazole was tolerated without discontinuation in this subgroup.

Type of primary intervention	Recurrences, n	%
Minimally invasive interventions ($n=209$)	14	6.7
Conventional open laparotomy ($n=178$)	22	12.3
Total ($n=387$)	36	9.3

Table 5. Recurrence frequency at 1–5-year follow-up by primary intervention type (χ^2 test, $p<0.01$).

Hepatic biochemical and oxidative stress parameters

Among 58 patients who underwent liver biopsy, biochemical disturbance scaled with complication severity. Diene conjugate concentration exceeded control values by a factor of 2.9 in uncomplicated echinococcosis and was elevated by 38.2% in obstructive jaundice and 34.9% in suppurated cysts ($p < 0.001$ for both complicated subgroups). Malondialdehyde was 58.1% below control levels in uncomplicated disease but rose progressively with complication severity, reaching increases of 23.9% in obstructive jaundice and 43.4% in suppurated echinococcosis. Total bilirubin averaged 18.99 $\mu\text{mol/L}$ in uncomplicated disease, 168.05 $\mu\text{mol/L}$ in obstructive jaundice, and 23.67 $\mu\text{mol/L}$ in suppurated cysts, with procalcitonin and C-reactive protein markedly elevated in both complicated subgroups (3.5 ng/mL and 180.7 mg/L in obstructive jaundice; 5.6 ng/mL and 210.6 mg/L in suppurated disease), consistent with superimposed bacterial translocation and systemic inflammatory activation in the more severe clinical phenotypes.

Discussion

The principal finding of this study is that a criteria-based, minimally invasive-first strategy can be extended safely beyond uncomplicated hepatic echinococcosis into suppurated, biliary-communicating, and jaundice-producing disease, with a near three-fold reduction in postoperative morbidity (8.1% versus 24.1%) and elimination of short-term mortality. This finding extends rather than merely confirms the existing literature, which has generally restricted minimally invasive techniques to CE1–CE3 cysts without major complications. The staged approach used here—percutaneous or endoscopic decompression of the septic or obstructed biliary system, followed by interval radical surgery once endotoxaemia had resolved—appears to have been central to this result, allowing definitive surgery to be performed in a more favourable physiological state rather than in the context of active sepsis or cholestasis.

The haemodynamic data offer a plausible mechanistic explanation for why earlier intervention in smaller cysts may be advantageous. The progressive rise in hepatic arterial flow with cyst diameter, together with the threshold effect seen in portal venous flow below 480 mL/min, suggests that compressive vascular derangement accumulates well before a cyst reaches the size typically associated with overt complications. This is broadly consistent with reports linking parenchymal compression to perfusion abnormalities in space-occupying hepatic lesions generally, though the specific volumetric thresholds identified here have not, to our knowledge, been reported previously in echinococcosis and merit external validation.

The recurrence data merit particular comment. Although the lower recurrence rate after minimally invasive treatment (6.7% versus 12.3%) might initially appear counterintuitive—given longstanding concerns that minimally invasive cyst evacuation could increase the risk of intraperitoneal spillage and seeding—the result is consistent with strict adherence to scolical protocols (glycerol instillation, protective draping of the puncture site, and endo-bag retrieval of chitinous membranes) and, importantly, with better tolerance of adjuvant albendazole in the hepatoprotector-supported regimen. The observation that drug discontinuation for hepatotoxicity accounted for nearly a third of all recurrences reframes recurrence prevention partly as a pharmacological tolerability problem rather than a purely surgical one, a dimension that has received less attention in prior comparative series.

Several limitations should be acknowledged. The allocation of patients to study and comparison groups reflected the chronological introduction of minimally invasive technology into departmental practice rather than formal randomisation, introducing the possibility of temporal confounding from concurrent improvements in perioperative care, imaging, and anaesthesia. The single-centre design, while ensuring procedural consistency, limits generalisability to settings with different case mixes or resource availability. Long-term follow-up, although extending to five years, was not achieved in the full cohort, and recurrence ascertainment relied on clinical and imaging follow-up rather than systematic protocol-driven surveillance, which may have led to under-detection of asymptomatic late recurrences. Finally, the biochemical and histological substudy was restricted to a subset of 58 patients, limiting the precision of inferences about oxidative stress pathways in the wider cohort.

Notwithstanding these constraints, the consistency of the morbidity, mortality, and recurrence findings across multiple complication subtypes supports the broader applicability of a differentiated, minimally invasive-first algorithm in centres with comparable endoscopic and interventional radiology capability.

Conclusion

A differentiated surgical strategy that prioritises minimally invasive endovideosurgical and image-guided percutaneous techniques—supported, where indicated, by staged management of septic or biliary complications and by hepatoprotector-supplemented antiparasitic chemotherapy—substantially reduces postoperative complications, eliminates short-term mortality, and lowers recurrence in patients with hepatic echinococcosis, including its complicated forms. These findings support wider adoption of criteria-based minimally invasive selection in centres equipped for combined laparoscopic, percutaneous, and endoscopic management of this disease.

Declarations

Ethical approval: This study was approved by the Institutional Review Board of Samarkand State Medical University and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients.

Conflicts of interest: The author declares no conflicts of interest.

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Data availability: De-identified data are available from the corresponding author upon reasonable request.

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