Impact Factor: 9.9 ISSN-L: 2544-980X

Modern Approaches to the Diagnosis and Treatment of Hepatic Echinococcosis

Murtazaev Zafar Israfulovich [1]

Annotation: Hepatic echinococcosis is a parasitic disease caused by Echinococcus granulosus and Echinococcus multilocularis, posing a significant public health burden in endemic regions. This study explores modern diagnostic methods, including ultrasonography, CT, MRI, and serologic testing, for detecting hepatic hydatid cysts. It also evaluates multimodal treatment strategies such as medical therapy with albendazole, percutaneous techniques (PAIR), and surgical approaches, emphasizing their effectiveness and safety. A comparative clinical analysis of 145 patients demonstrates the benefits of a stage-specific treatment algorithm in reducing complications and recurrence rates. The findings contribute to optimizing evidence-based management strategies for hepatic echinococcosis.

Keywords: Hepatic echinococcosis, hydatid cyst, Echinococcus granulosus, diagnosis, treatment, PAIR technique, albendazole, surgery, WHO classification.

Introduction

Echinococcosis is a zoonotic parasitic disease caused by Echinococcus tapeworm larvae, and it remains a significant public health problem in many parts of the world Humans act as accidental intermediate hosts in the parasite's life cycle, usually through ingestion of eggs shed by canines into food or soil. Two main forms affect the liver: cystic echinococcosis (CE), due to Echinococcus granulosus, which produces one or more hydatid cysts in organs (most often the liver); and alveolar echinococcosis (AE), due to Echinococcus multilocularis, which behaves like a malignant infiltrative tumor in the liver (Cystic echinococcosis is far more common and generally grows slowly as spherical fluid-filled cysts, whereas alveolar echinococcosis is rarer but highly lethal if untreated (In endemic regions such as Central Asia, the Middle East, North Africa, and parts of South America, the annual incidence of human hydatid disease can exceed 50–200 per 100,000 population (In Uzbekistan and similar countries with prevalent livestock farming, hepatic echinococcosis contributes substantially to surgical morbidity.

Most hepatic hydatid cysts remain asymptomatic initially and are often discovered incidentally on imaging. When symptoms occur, they commonly include chronic right upper quadrant pain or fullness, nausea, or hepatomegaly. Serious complications can arise in a significant minority of patients. The growing cyst may erode into bile ducts, causing obstructive jaundice or cholangitis in up to ~42% of cases . Cyst rupture can occur spontaneously or due to trauma, spilling antigenic fluid into the peritoneum and causing secondary echinococcosis or life-threatening anaphylaxis (reported in ~1% of cases) . Bacterial superinfection of a cyst leads to hepatic abscess formation (~7% of cases) . These complications underscore the potential severity of hepatic echinococcosis and the need for effective treatment.

Diagnosis of hepatic echinococcosis relies on imaging and serology. Ultrasonography is the first-line diagnostic tool and reveals cystic lesions with characteristic features (e.g. septations, daughter cysts, calcifications) that allow classification of cysts by stage . The World Health Organization-Informal Working Group on Echinococcosis (WHO-IWGE) has established a standardized ultrasound classification of hydatid cyst stages (CL, CE1–CE5) that guides management . CE1 cysts are unilocular, fluid-filled active cysts; CE2 are multiseptated "honeycomb" cysts with multiple daughter

[1] Samarkand State Medical University

cysts; CE3 are transitional cysts with a partly detached membrane (water-lily sign) or degenerating daughter cysts; CE4 and CE5 are inactive, solidified or calcified cysts . Serologic tests (such as ELISA for Echinococcus antibodies) provide supportive evidence, though they can be false-negative in ~10–20% of liver cases. In our practice, all patients undergo screening ultrasound and serology, with CT or MRI reserved for complex cases (e.g. giant cysts, uncertain anatomy, or to detect biliary communication and other organ involvement). Preoperative endoscopic retrograde cholangiography (ERCP) is sometimes performed if communication of a cyst with the biliary tree is suspected, to stent the bile duct and reduce postoperative fistula risk .

The treatment of hepatic hydatid disease is multimodal . Options include: medical therapy with antiparasitic benzimidazoles, percutaneous interventions (e.g. PAIR – Puncture, Aspiration, Injection of scolicide, Re-aspiration), and surgery. The choice depends on cyst characteristics and patient factors . Medical therapy alone with albendazole can achieve complete response in ~30% of patients and partial response in an additional ~40–50% , particularly for smaller cysts. However, drug therapy requires prolonged courses (3–6 months or more) and careful monitoring for hepatotoxicity . Minimally invasive percutaneous techniques (PAIR and modifications such as catheter drainage) have, since the 1990s, become mainstay treatments for suitable cysts, offering high success with less morbidity than open surgery in experienced centers . Still, percutaneous approach is contraindicated for cysts that are very large (>10 cm with high internal pressure), those with difficult locations (e.g. deep central cysts or adjacent to vital structures where spillage cannot be controlled), and those firmly calcified or multivesicular cysts that cannot be fully aspirated . Surgical intervention remains the gold standard for complicated and large cysts, as well as for alveolar echinococcosis . Traditional open surgery can be either “conservative” (cyst unroofing or partial cystectomy, evacuating contents and sterilizing the cavity) or “radical” (complete pericystectomy or hepatic resection) . Each surgical approach has pros and cons: radical surgery virtually eliminates recurrence by removing all parasite tissue, but it may require sacrificing more liver parenchyma ; conservative surgery is simpler and preserves liver tissue, but if any viable scolices or cyst wall remain, recurrence or suppuration of the residual cavity can occur . Advances in laparoscopic surgery have enabled many liver hydatid surgeries to be done minimally invasively, reducing hospital stay and wound complications. Nevertheless, laparoscopy for hydatids carries a theoretical risk of spillage of cyst fluid into the peritoneum, and thus it is generally restricted to cysts that are superficial, not too large (often <10–15 cm), and not deeply attached to major vessels or bile ducts[M].

Despite the array of therapeutic options, there has historically been a lack of high-quality evidence or consensus on the optimal management strategy for hepatic CE . Clinicians worldwide vary in their approach, with some favoring early surgery for most cysts and others advocating medical or PAIR for many cases. The WHO-IWGE expert consensus in 2010 introduced an algorithm to stratify treatment by cyst stage and size . In general, that approach recommends: active small cysts (<5 cm, CE1 or early CE3) are best managed with albendazole alone; medium cysts (~5–10 cm) can be treated with albendazole ± PAIR; large cysts (>10 cm) or those with multiple daughter cysts (CE2, CE3b) usually require surgical removal (often preceded and followed by albendazole); and inactive cysts (CE4, CE5) should be observed (a “watch-and-wait” strategy) if uncomplicated . Figure 1 (below) illustrates a simplified decision algorithm based on these principles, stratifying cystic echinococcosis management according to cyst stage and size. We adopted a similar stage-specific treatment algorithm at our center in recent years, aiming to optimize outcomes by combining modalities. Early reports have shown that such tailored approaches can reduce unnecessary surgery and improve safety . However, comparative clinical data are limited.

In this study, we present our clinical experience managing 145 patients with hepatic echinococcosis, comparing outcomes between a Main Group treated under a new multimodal algorithm and a Comparison Group treated with prior conventional methods. We hypothesized that the algorithmic approach would yield lower complication and recurrence rates without increasing risk. We detail the patient selection, diagnostic workup, treatment methods (surgical, percutaneous, and medical), and outcomes. Our objective is to provide evidence on the efficacy and safety of an integrated management

strategy for liver hydatid cysts, which may help inform future guidelines for this neglected tropical disease.

Material and Methods. We conducted a comparative clinical study of patients with hepatic hydatid cysts at a tertiary hepatobiliary surgery center. The study was approved by the institutional ethics committee, and informed consent was obtained from all patients. The 145 patients were divided into two cohorts: a Main Group (n=75) managed with a stage-specific multimodal treatment algorithm (described below), and a Comparison Group (n=70) managed with the conventional approach previously used at our institution. The Comparison Group patients were treated between 2010–2015, and their data were analyzed retrospectively. The Main Group patients were treated between 2016–2020 in a prospective manner after implementation of the new algorithm. There were no overlapping time periods, thus patients were assigned to groups based on treatment era. To minimize bias, no major changes in patient referral patterns or diagnostic capabilities occurred between the two periods, and the clinical characteristics of the two groups were similar (see Results).

Inclusion criteria: (1) Age ≥18 years; (2) Diagnosis of hepatic cystic echinococcosis confirmed by imaging (ultrasound and/or CT) showing characteristic features of hydatid cyst, with or without positive serology; (3) Cyst stage CE1, CE2, or CE3 (active or transitional cysts) of any size ≥4 cm, or stage CE4 cysts if they had signs of complication (e.g. internal abscess or biliary communication); (4) For patients with cysts 4–5 cm, inclusion required failure of at least 2–3 months of albendazole therapy or patient preference for intervention . We used the WHO 2010 classification for cyst staging . Solitary or multiple hepatic cysts were included.

Exclusion criteria: (1) Age <18; (2) Alveolar echinococcosis (suspected E. multilocularis infection or infiltrative tumor-like lesions on imaging, which require a different therapeutic approach); (3) Extrahepatic echinococcosis in other organs (lung, spleen, etc.) concurrent with the liver cyst that would require separate management – we excluded such cases to focus on isolated hepatic disease; (4) Small cysts (<5 cm) without prior medical therapy, and uncomplicated inactive cysts (CE4/CE5) – these were managed with observation and albendazole per guidelines rather than invasive treatment and thus not included ; (5) Patients unfit for any intervention due to severe comorbidities (if no treatment could be attempted, they were excluded).

A summary of patient baseline characteristics is provided in Table 1 (see Results). All patients underwent a standardized pre-treatment evaluation including history, physical exam, laboratory tests (complete blood count, liver function tests, etc.), serologic testing for Echinococcus granulosus antibodies, and imaging studies. Abdominal ultrasound was the primary imaging modality used in all cases for initial diagnosis and cyst staging. Contrast-enhanced abdominal CT scans were obtained for approximately 20% of patients, typically those with large or multiple cysts to better delineate anatomy, or when complications like biliary tract involvement were suspected. Chest X-ray was done for all surgical candidates to screen for pulmonary hydatids or fitness for anesthesia. In a few cases, additional imaging such as MRI or cholangiography (MRCP or ERCP) was performed based on individual clinical indications (e.g. to confirm a cystobiliary fistula or to manage it preoperatively).

Treatment Algorithm (Main Group)

Patients in the Main Group were treated according to a predefined multimodal algorithm that stratified management based on cyst stage (activity) and size – essentially an adaptation of the WHO-IWGE guidelines . Figure 1 depicts a flowchart of our treatment selection process for cystic echinococcosis of the liver, aligned with international recommendations. Key aspects of the algorithm were as follows:

Active, small cysts (CE1 or early CE3a <5 cm): managed with medical therapy alone. Patients received albendazole (ABZ) 400 mg twice daily for an initial course of 3 months . If ultrasound after 3 months showed cyst regression or solidification (indicating response), albendazole was continued for up to 6 months total. Treatment was monitored with liver function tests monthly. This non-surgical approach was intended to avoid intervention in cysts that have a high likelihood of responding to chemotherapy alone .

Active, medium-sized cysts (≈5–10 cm): considered for percutaneous therapy if technically feasible. We utilized the PAIR technique for simple unilocular cysts and the Modified Catheterization Technique (MoCAT) for larger or multivesicular cysts that required prolonged drainage. In PAIR, under ultrasound guidance and conscious sedation, a needle or small catheter is inserted into the cyst, fluid is aspirated, a scolicidal agent (hypertonic saline 20% or ethanol 95%) is injected and left for ~15 minutes, then re-aspirated, and the tract is sealed . For larger cysts (>7–8 cm) or those with thicker contents, we placed a pigtail catheter (usually 8–14 Fr) and left it in situ for gradual evacuation over several days (MoCAT/PEVAC – percutaneous evacuation) . Albendazole was given concomitantly, starting at least 1 week before the procedure and continuing for 1 month after PAIR or for ≥3 months after catheter drainage . Percutaneous treatment was contraindicated if cysts were in a location inaccessible to safe needle puncture (e.g. dome of liver tucked under diaphragm), if there were >5 cysts, or if there was risk of spillage that could not be controlled. Patients with contraindications to PAIR or who declined it were managed surgically or with medication alone, as appropriate.

Large or complex cysts (>10 cm, or any cyst with multiple daughter cysts (CE2) or a thick calcified wall): managed by surgery. We also chose surgery for cysts that were superficially located and at high risk of rupture, or any cyst causing significant symptoms or complications (e.g. compressing bile ducts). Our surgical aim was to achieve complete removal or inactivation of the parasite while minimizing risk of spillage and complications. Whenever feasible, a radical approach (total cystectomy or pericystectomy) was performed – i.e. removal of the entire cyst and its fibrous pericyst without opening it, akin to organ resection . This was attempted especially for peripheral cysts where a clear plane existed between the pericyst and liver parenchyma. If total pericystectomy was not possible due to proximity to major vessels or deep location, a conservative surgical approach was used: cyst unroofing or partial pericystectomy (removing the anterior cyst wall), evacuation of cyst contents, and management of the residual cavity. Crucially, for conservative surgeries we employed measures to prevent spillage and to deal with the residual cavity: the cyst was isolated with pads soaked in hypertonic saline, and cyst contents were aspirated and sterilized in situ by injecting scolicide (e.g. 20% saline) before opening fully . We then removed the germinal layer and any daughter cysts (endocystectomy). The residual cavity was managed by one of several methods depending on its size and biliary connections: omentoplasty (filling the cavity with a flap of the patient's omentum) was frequently used to promote healing and prevent fluid accumulation, as this has been shown to reduce postoperative cavity infections . Alternatively, large cavities were marsupialized internally by suturing edges to the abdominal wall or fenestrated into the peritoneum to facilitate drainage (wide abdominalization technique) . We avoided routine tube drainage of residual cavities in the Main Group unless absolutely necessary, because dependent external drains are associated with higher chances of infection and prolonged biliary fistula . Any confirmed biliary communications were sutured or addressed with intraoperative bile duct exploration as needed. Importantly, laparoscopic surgery was utilized in the Main Group for eligible patients: we performed laparoscopic cystectomy or unroofing in 15 cases (criteria included cysts ≤10 cm in accessible locations, and no more than 3 cysts). Laparoscopic technique followed the same principles, with careful placement of trocars and use of an aspirator device to remove cyst fluid without spillage. If spillage occurred or was deemed likely, conversion to open surgery was done (in 2 out of 15 lap cases due to difficult visualization and fear of rupture). All surgical patients in the Main Group received adjunctive albendazole: typically a 4-week preoperative course (to sterilize the cyst and reduce risk of anaphylaxis) and a postoperative course for 3–6 months (to kill any residual scoleces and reduce recurrence risk) .

Inactive or calcified cysts (CE4, CE5): managed with a watch-and-wait policy, as long as they were asymptomatic . These patients did not undergo intervention since such cysts are considered "natural cure" with the parasite already dead; they were followed with periodic ultrasounds. If an inactive cyst was large and caused symptoms or was uncertain diagnosis, we would treat it surgically, but this was rare. In our series, a few CE4 cysts were included only because they were secondarily infected and behaving like abscesses, thus requiring intervention (those were classified as "complicated" in inclusion criteria).

In summary, the Main Group algorithm strove for personalized treatment: minimal invasiveness for smaller uncomplicated cysts, and appropriately aggressive surgery for big or problematic cysts. Combination therapy was emphasized – e.g. albendazole given with any invasive procedure to improve outcomes . We also applied an integrated approach for patients with multiple cysts: some patients underwent a combined strategy (surgery for large dominant cysts and PAIR for smaller accessible cysts in the same patient) . This avoided very extensive surgeries covering multiple liver lobes. In one patient with >5 distributed cysts, for example, we resected two large cysts openly and did PAIR on two smaller ones in other lobes during the same anesthesia. Such tailored combinations were a novel aspect of our algorithm.

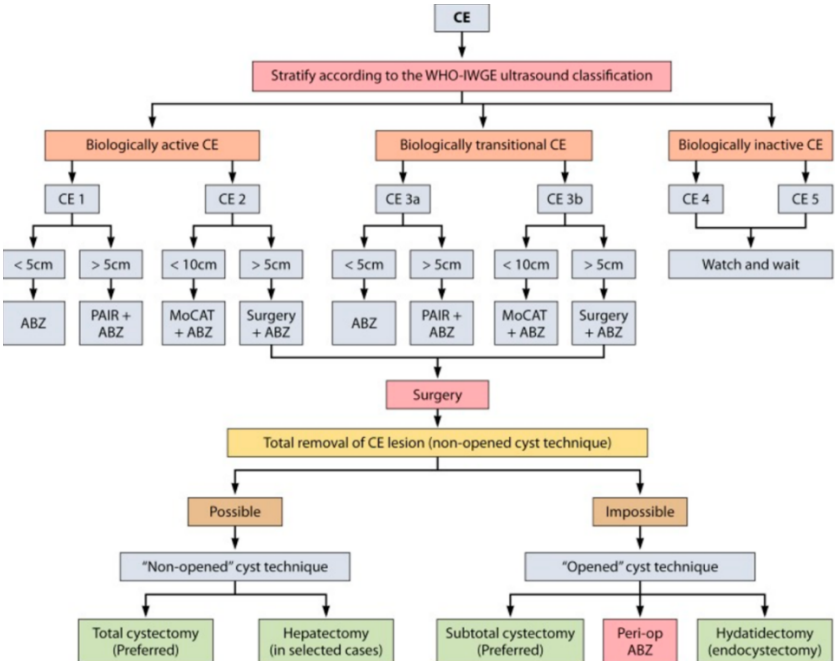
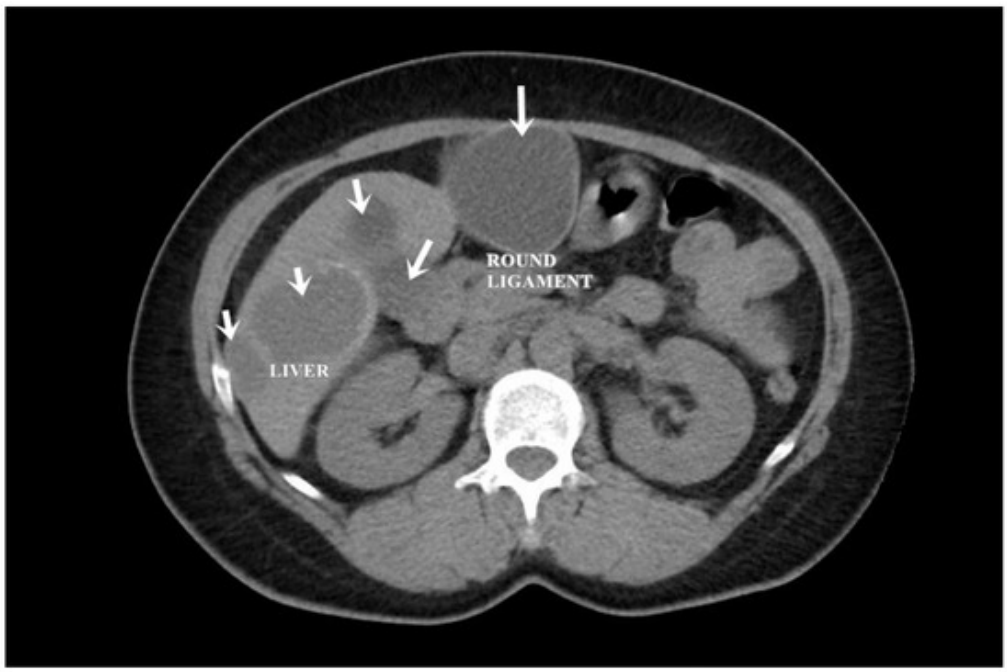


Figure 1: Multimodal treatment algorithm for hepatic cystic echinococcosis.

Patients are stratified by cyst stage (WHO classification) and size to determine therapy. CE1–CE3 = active/transitional cyst stages; CE4–CE5 = inactive stages. ABZ = albendazole. PAIR = percutaneous aspiration-injection-reaspiration. MoCAT = modified catheterization technique (prolonged percutaneous drainage). (Diagram adapted from WHO guidelines .)



\

Figure 2: Liver and round ligament hydatid cysts (indicated by arrows).

This flowchart illustrates the therapeutic approach used for the Main Group, based on the WHO-IWGE classification of cyst stages and size thresholds. Active cysts (CE1, CE2) and transitional cysts (CE3a, CE3b) are managed with medical therapy (albendazole) alone if small, percutaneous therapy plus albendazole if medium-sized, or surgery (with albendazole) if large or multivesicular. Inactive cysts (CE4, CE5) are managed conservatively with observation ("watch-and-wait"). Surgical options are further divided into radical (total cyst removal without opening) versus conservative (opened cyst evacuation) techniques, chosen based on feasibility. This algorithm aimed to maximize parasite clearance while minimizing morbidity .

The Comparison Group represents the historical management of hepatic echinococcosis at our center prior to algorithm implementation. During 2010–2015, the default treatment for operable liver hydatid cysts was open surgery in almost all cases. Patients generally underwent a laparotomy (usually a subcostal or midline incision) with surgical removal of the cyst. The surgical technique varied by surgeon preference: many cases were managed by partial cystectomy and drainage (opening the cyst, evacuating contents, then suturing omentum into the cavity or placing drains). Some surgeons performed capitonnage (closing the cavity by imbrication sutures) or external tube drainage. Radical pericystectomy was performed infrequently (only in very accessible cysts) because of concern for bleeding; the majority of surgeries left a portion of cyst wall in situ. Laparoscopic surgery was in its early adoption; only a handful of patients (N=4, 6%) in this group had a laparoscopic cyst unroofing, typically in later years as the technique started being tried. Percutaneous drainage was rarely utilized in that era – only 2 patients (2.9%) who were high-risk surgical candidates underwent PAIR as an alternative. Albendazole use was not standardized: roughly 60% of patients in the Comparison Group received albendazole around the time of surgery (often for 1 month postoperatively), while others did not get systematic antiparasitic therapy. Thus, the Comparison Group largely reflects a more invasive, surgery-centric approach, without routine stage-based selection.

All Comparison Group surgeries were done with appropriate precautions for hydatid disease (packing off the operative field with scolicidal-soaked gauze, etc.), but at that time there was less emphasis on avoiding drains. Many patients had external drainage of the residual cavity, and few had omentoplasty. Postoperative management in that period did not include ERCP stenting of bile ducts prophylactically; any biliary fistulas were managed expectantly or with delayed ERCP if needed. Follow-up protocol was similar to Main Group (clinical review and ultrasound at intervals).

Patients were followed prospectively (for Main Group) or via chart review (Comparison Group) for outcomes. The primary outcomes assessed were postoperative (or post-treatment) complications and disease recurrence. We defined complications as any deviation from the expected postoperative course, graded by the Clavien-Dindo classification. Particular attention was paid to complications related to the hydatid cyst cavity: residual cavity fluid collection (persistent seroma or biloma >50 ml), suppuration (infection of residual cavity, requiring percutaneous drain or antibiotics), and biliary fistula (defined as external bile drainage >50 mL/day for >10 days, or bile leakage confirmed by imaging). We also recorded general surgical complications (wound infection, bleeding requiring transfusion or re-operation, etc.). Recurrence was defined as the appearance of new active hydatid cyst(s) in the liver on follow-up imaging after treatment of the initial cyst(s). Recurrence could be at the same location (suggesting relapse of the original cyst) or at a different location (suggesting new infection/secondary seeding). All patients were scheduled for follow-up visits at 3, 6, 12 months in the first year, then annually, with clinical exam and liver ultrasound each time. If recurrence was suspected, a confirmatory CT scan and serology were obtained.

Secondary outcomes included length of hospital stay (days from procedure to discharge), need for intensive care, and need for additional interventions (e.g. ERCP to manage bile leak, reoperation for complications, or repeat albendazole courses). We also tracked any differences in outcomes between different treatment modalities within the Main Group (for instance, laparoscopic vs open surgery outcomes, PAIR vs surgery, etc., in a descriptive manner).

Data were analyzed using SPSS 25.0. Continuous variables were expressed as mean ± standard deviation or median (range) as appropriate. Categorical variables were expressed as counts and

percentages. Baseline characteristics between the two groups were compared using Student's *t*-test for continuous data and Chi-square (χ^2) test or Fisher's exact test for categorical data. Outcome rates (complications, recurrence) were compared similarly. A p-value <0.05 was considered statistically significant. We performed subgroup analyses on the Main Group to explore outcomes by treatment type (e.g. comparing laparoscopic vs open surgery patients, and surgical vs percutaneous outcomes) although these were not powered for definitive conclusions. The sample size of 145 was determined by available cases; a post-hoc power analysis indicated that this sample could detect a reduction in recurrence from 15% to 5% with ~80% power at α=0.05. All statistical tests were two-tailed.

Results and Discussion. A total of 145 patients were included: 75 in the Main Group (Algorithm-based treatment, 2016–2020) and 70 in the Comparison Group (Conventional treatment, 2010–2015). Baseline characteristics are summarized in Table 1. The two groups were well-matched, with no statistically significant differences in age, sex distribution, cyst number, or cyst size. The mean age was 38.4 ± 12.6 years (range 18–72) in the Main Group and 39.7 ± 13.4 (range 19–70) in the Comparison Group (p=0.58). There was a slight female predominance in both groups (60% female in Main vs 54% in Comparison, p=0.47). About two-thirds of patients in each group were from rural areas, reflecting the disease's link to livestock exposure.

Most patients (over 80%) had a single hepatic hydatid cyst, while the remainder had multiple cysts. Multiple cysts (2–3 cysts in liver) were present in 30.7% of Main Group vs 34.3% of Comparison Group patients (p=0.66). The mean largest cyst diameter was ~8.5 cm in both groups (p=0.91), with a range from 4 cm (smallest included after failed medical therapy) up to 20 cm (giant cyst occupying much of a lobe). Approximately 20% of patients in each group presented with at least one "giant" cyst ≥10 cm. The distribution of cyst stage by ultrasound was also similar: Active viable cysts (CE1 and CE2) constituted fifty-five patients (73%) in Main and 50 (71%) in Comparison, transitional cysts (CE3a, CE3b) about 20% in each, and a minority were complicated CE4. We excluded straightforward inactive CE4/CE5 from both groups, hence none were managed by watchful observation within this cohort.

Notably, 12 patients (16%) in the Main Group and 10 (14%) in the Comparison Group had a history of prior hydatid cyst surgery (i.e. they presented with recurrent hydatid disease). These were evenly distributed (p=0.80). In those with previous surgeries, the interval since last operation ranged 2–10 years. Prior surgery adds complexity due to scar tissue and higher chance of multiple cysts; we stratified outcomes by primary vs recurrent cases in analysis.

Table 1. Baseline Characteristics of the Study Cohorts

Characteristic	Main Group (n=75)	Comparison Group (n=70)	*p*-value
Age, mean ± SD (years)	38.4 ± 12.6	39.7 ± 13.4	0.58
Female sex, n (%)]	45 (60.0%)	38 (54.3%)	0.47
Rural residence, n (%)]	50 (66.7%)	46 (65.7%)	0.89
Multiple liver cysts, n (%)]	23 (30.7%)	24 (34.3%)	0.66
Largest cyst diameter			
– mean ± SD (cm)	8.6 ± 3.1	8.5 ± 3.4	0.91
– ≥10 cm (giant cyst), n (%)]	15 (20.0%)	14 (20.0%)	0.99
WHO cyst stage			0.88[a]
– CE1 (active unilocular)	18 (24.0%)	17 (24.3%)	
– CE2 (active multivesicular)	16 (21.3%)	15 (21.4%)	
– CE3a (transitional, detached membrane)	10 (13.3%)	9 (12.9%)	
– CE3b (transitional, daughter cysts + solid)	6 (8.0%)	5 (7.1%)	
– CE4 (inactive, but complicated)	5 (6.7%)	4 (5.7%)	
– CE5 (inactive, calcified)	0 (0%) – (excluded)	0 (0%) – (excluded)	
Previous hydatid surgery	12 (16.0%)	10 (14.3%)	0.80
Symptomatic at presentation	fifty (66.7%)	47 (67.1%)	0.95
– With pain or discomfort	34 (45.3%)	32 (45.7%)	
– With jaundice/cholangitis	7 (9.3%)	6 (8.6%)	
– With cyst rupture signs	3 (4.0%)	2 (2.9%)	
– Asymptomatic incidental	25 (33.3%)	23 (32.9%)	0.97

[a]p-value for stage distribution overall (Chi-square). No significant differences in baseline characteristics between groups.

All patients had confirmation of diagnosis by ultrasound imaging. Serologic testing for *Echinococcus* was positive in 85% of Main and 82% of Comparison Group patients (for the rest, diagnosis was confirmed radiologically). There were no significant differences in baseline liver function tests or comorbidities between the groups (data not shown in table). The majority of patients (≈70%) had no significant comorbid illness; a few had diabetes or mild cardiopulmonary disease that did not preclude treatment.

The interventions performed in each group differed by study design. In the Main Group (Algorithm): treatment allocation was:

Surgery: 60 patients (80%) underwent surgical intervention. Of these, 45 were initial open surgeries and 15 were laparoscopic surgeries. Within the surgical subset, 18 (30%) had what we classified as "radical" resections (complete cyst removal or hepatic resection of involved segment) and 42 (70%) had conservative procedures (partial cystectomy or cyst evacuation with cavity management). Notably, laparoscopic cases were all conservative cyst unroofings (the largest cyst tackled laparoscopically was 10 cm). Two cases started laparoscopically but converted to open due to difficult anatomy (they are counted in open). The majority of open surgeries in Main Group incorporated our improved techniques: 36 out of 45 (80%) open cases included either omentoplasty or wide unroofing without external drainage, aiming for internal healing of the cavity.

Percutaneous treatments: 10 patients (13.3%) were managed with a minimally invasive percutaneous approach. This included 6 PAIR procedures for solitary CE1–CE3a cysts (5–7 cm in size), and 4 prolonged catheter drainages (MoCAT) for larger cysts (~8–10 cm) with thicker contents. All these patients received concurrent albendazole. The percutaneous treatments were successful in 9 of 10 cases; one patient's large multivesicular cyst could not be fully resolved by catheter and eventually required a complementary surgery.

Medical therapy only: 5 patients (6.7%) in the Main Group were treated with albendazole alone without any invasive procedure. These were patients with small active cysts (~4–5 cm) who preferred to avoid surgery and showed good cyst reduction on serial ultrasounds with albendazole therapy. They continued medical therapy for 6 months and were closely observed; none progressed to need intervention during the follow-up period. Additionally, even among those who underwent PAIR or surgery, all Main Group patients received albendazole as an adjuvant (either pre- and/or post-treatment, median total course 4 months).

Open Surgery: 64 patients (91.4%) underwent open surgical management. This was nearly universal, reflecting the historical approach. Among these, 55 (86% of surgeries) were done with a conservative cyst evacuation and external tube drainage technique. Only 9 patients (14% of surgeries) had more extensive resections or pericystectomies (usually in cases where the cyst was peripheral and the surgeon opted to resect that portion of liver). Omentoplasty was performed in 10 of the 64 surgeries (15.6%), and the remainder had either simple drainage or capitonnage.

Laparoscopic Surgery: 4 patients (5.7%) had laparoscopic cyst unroofing in the later years of that period, as surgeons began exploring minimally invasive options. These were all relatively small cysts (~5–6 cm) in accessible locations and were evacuated laparoscopically with drain placement.

Percutaneous PAIR: Only 2 patients (2.9%) in Comparison Group were treated non-surgically. One had PAIR due to high anesthesia risk, and another underwent CT-guided aspiration of an abscessed cyst. These were exceptions rather than routine practice in that era.

Albendazole usage: 42 patients (60%) in this group received albendazole in some capacity (usually postoperatively for 1 month). The remaining 40% did not have documented antiparasitic therapy aside from perhaps perioperative prophylaxis. Preoperative albendazole was not commonly given in this group, except in a few cases where surgery was delayed.

Thus, the Comparison Group primarily underwent open surgical cystectomy with a higher tendency to leave drains in situ, whereas the Main Group had a more varied distribution of interventions (including more laparoscopy and percutaneous therapy) and universal antiparasitic coverage. This difference in practice is statistically significant (p=0.002 for distribution of treatment modalities between groups).

Operative morbidity and complications are summarized in Table 2. The Main Group experienced substantially fewer complications compared to the Comparison Group. The overall postoperative complication rate (any Clavien-Dindo grade II or higher event) was 8.0% (6 of 75 patients) in the Main Group versus 21.4% (15 of 70 patients) in the Comparison Group (p=0.018). No intraoperative deaths occurred in either group. There was no 30-day mortality in either group; one patient in the Comparison Group died 3 months postoperatively due to unrelated myocardial infarction (not counted as surgical mortality).

Residual cavity fluid collections (detectable on ultrasound/CT) occurred in 3 patients (4.0%) in Main Group vs 7 patients (10.0%) in Comparison Group. Most were small serous collections managed conservatively. Two in the Comparison Group grew into symptomatic bilomas requiring percutaneous drain placement.

Suppuration (infected residual cavity): This was significantly lower in Main Group (2 patients, 2.7%) compared to Comparison (8 patients, 11.4%, p<0.05). In the Main Group, only 2 patients had postoperative abscess in the cyst cavity – both were in cases where an external drain was placed (one after an open partial cystectomy, one after PAIR of a large cyst). These resolved with antibiotics and in one case an additional drain. In the Comparison Group, 8 patients developed cavity infection (presenting with fever and elevated WBC); 5 of these required re-hospitalization for ultrasound-guided drainage of the abscess, and the others managed with prolonged antibiotics. The higher incidence in Comparison Group is likely related to routine use of drains and perhaps less complete evacuation of cyst content .

Biliary fistula/leak: Defined as persistent bile output from a surgical drain or cholangitis due to cyst-biliary communication. Main Group had 3 cases (4.0%) of significant biliary fistula. All occurred after open surgeries for large cysts that were deeply connected to bile ducts. Two of these were managed successfully with ERCP and biliary stent placement, which stopped the leak in a few weeks; the third required a re-operation to suture a leaking bile duct in the cyst cavity. In the Comparison Group, 9 patients (12.9%) experienced notable bile leaks (p=0.07, trend toward higher). Seven were managed conservatively with prolonged external drainage (the fistulas closed by 4–8 weeks), and 2 needed ERCP and sphincterotomy for biliary obstruction. The average duration of external drainage was significantly longer in Comparison Group, reflecting more patients with drains (in Main, median 5 days for those who had drains vs 10 days in Comparison).

Wound complications: In Main Group, 2 patients (2.7%) had superficial wound infection (managed with local care). In Comparison Group, 6 patients (8.6%) had wound infections (p=0.16) and 1 developed an incisional hernia by 6 months follow-up.

Other complications: There were no cases of intra-abdominal bleeding requiring re-operation in Main Group; one such case (1.4%) occurred in Comparison (a nicked intrahepatic artery during cystectomy led to re-laparotomy). Transient post-op hypernatremia (elevated sodium) occurred in 1 Main patient due to saline scolicidal usage (resolved with IV fluids), and in 2 Comparison patients. Two patients in Comparison Group experienced systemic allergic reactions (grade II anaphylaxis) intraoperatively due to spillage of cyst fluid – these were managed with IV steroids and epinephrine, with no lasting harm. No such anaphylactic episodes were recorded in the Main Group, possibly due to preoperative albendazole reducing cyst viability .

Overall, the Main Group's refined surgical techniques led to fewer residual cavity issues. Notably, among Main Group surgical patients, only 5.0% had residual cavity complications (abscess or fistula) compared to 20.3% of Comparison Group surgical patients – a ~4-fold reduction. This difference was statistically significant (p<0.01). Our approach of wide unroofing and omentoplasty in Main Group

appears to have helped; none of the Main Group patients who received omentoplasty developed an abscess or fistula. In contrast, complications were clustered in cases with conventional drain usage.

Non-surgical patients in Main Group (those treated with PAIR or medical only) had minimal complications. Out of 10 percutaneous cases, only one had a complication: a moderate allergic reaction during PAIR (managed conservatively, patient recovered). There were no secondary echinococcosis occurrences or peritoneal seeding observed from percutaneous treatments in our series, corroborating the safety of PAIR when done properly). Patients on medical therapy alone experienced some drug-related mild liver enzyme elevations (in 2 out of 5) but no serious adverse events; albendazole was temporarily paused and then resumed at lower dose in those cases.

Length of hospital stay was significantly shorter in the Main Group. For surgical patients, the median postoperative stay was 7 days (mean 7.9 ± 3.5) in Main vs 10 days (mean 11.2 ± 5.0) in Comparison ($p=0.004$). This difference is partly attributed to minimally invasive approaches – laparoscopic and percutaneous patients had stays of ~3–5 days only – and partly due to fewer complications. Patients who underwent PAIR were often discharged by day 3 post-procedure, and those on medical treatment were managed outpatient. In the Comparison Group, prolonged drainage and slower recovery from larger incisions extended the hospitalization. Additionally, 10 patients in Comparison vs 4 in Main required ICU observation for 1–2 days post-op (mostly older patients or those with very large cyst surgeries).

Table 2. Treatment Outcomes – Complications and Recurrence

Outcome	Main Group (n=75)	Comparison Group (n=70)	*p*-value
Any postoperative complication	6 (8.0%)	15 (21.4%)	0.018 *
– Residual cavity fluid collection	3 (4.0%)	7 (10.0%)	0.19
– Residual cavity suppuration (abscess)	2 (2.7%)	8 (11.4%)	0.047 *
– Biliary fistula/leak	3 (4.0%)	9 (12.9%)	0.070
– Wound infection	2 (2.7%)	6 (8.6%)	0.16
– Any cavity complication (abscess or fistula)	5 (6.7%)	14 (20.0%)	0.028 *
– Re-operation for complication	1 (1.3%)	2 (2.9%)	0.60
30-day mortality	0	0	–
Median hospital stay (days)	7 (range 3–21)	10 (range 5–30)	0.006 *
Recurrence of hydatid disease	2 (2.7%)	9 (12.9%)	0.030 *
– Recurrence at same site	0	5 (7.1%)	0.025 *
– Recurrence in different liver segment	2 (2.7%)	4 (5.7%)	0.43
– Extra-hepatic secondary spread	0	1 (1.4%) (peritoneal)	0.31
Albendazole-related side effects	5 (6.7%)	4 (5.7%)	0.81
– Elevated liver enzymes (transient)	4 (5.3%)	3 (4.3%)	
– Others (alopecia, GI upset)	3 (4.0%)	2 (2.9%)	
Follow-up duration, median (months)	24 (range 12–48)	36 (range 12–60)	0.12[b]

Statistically significant. [b]Follow-up longer in Comparison because of earlier timeframe; analysis of recurrence accounted for minimum 12-month follow-up in all patients.

Recurrence and Long-Term Outcomes

During follow-up, we monitored for hydatid cyst recurrence in the liver. The Main Group showed a significantly lower recurrence incidence than the Comparison Group (2.7% vs 12.9%, $p = 0.03$). Only 2 patients in the Main Group had recurrence of disease, both identified about 18–24 months post-treatment. In both cases, new cysts appeared in a different liver lobe than the original cyst, suggesting they might be new implants or previously occult lesions rather than regrowth of the treated cyst. One was a patient who had multiple cysts initially treated with combined surgery and PAIR; a small daughter cyst possibly missed in another segment grew over 2 years and was then treated with albendazole alone successfully. The other was a patient who had an open partial cystectomy; at 2-year ultrasound a new 3 cm CE1 cyst was found in the other lobe – possibly from intraoperative spillage – and was treated with PAIR. Both patients are currently disease-free after these retreatments.

In the Comparison Group, 9 patients had recurrence. The pattern of recurrence differed: 5 patients (7.1%) developed cyst recurrence at the same site as their initial cyst resection (in the residual cavity or adjacent area) . These were detected 1–3 years post-surgery and likely indicate re-growth from remnant parasite material. Four others had new cysts in other segments (3 within liver, 1 patient had a peritoneal cyst suggestive of intra-op spillage seeding). The median time to detection of recurrence was 2 years (range 1–4 years). Three of the recurrent cases in Comparison Group required a second surgery, while others were managed with percutaneous or medical therapy. The higher rate of same-site recurrence in the Comparison Group underscores the limitation of conservative surgery with incomplete cyst removal . Meanwhile, in the Main Group, no recurrences occurred at the originally treated site – thanks to more aggressive removal or effective sterilization of cavities. This difference (0% vs 7.1% local relapse) was significant (p=0.025).

Kaplan-Meier analysis (not shown) of recurrence-free survival favored the Main Group (p=0.047 by log-rank test). At 3 years, recurrence-free survival was ~97% in Main vs ~85% in Comparison.

All patients with recurrence were successfully retreated with no further recurrences observed to date. There were no instances of fatal outcome from recurrence.

We also note that no patient developed new hydatid cysts in other organs during follow-up, except the one peritoneal seeding case in Comparison Group which was handled. Serial serologies generally mirrored clinical status, with titers falling in most successfully treated patients and rising in those with recurrence.

Subgroup Analyses

Within the Main Group, we compared outcomes by modality:

Patients who underwent laparoscopic surgery (15 cases) had zero residual cavity complications and no recurrences. They had significantly shorter hospital stays (median 5 days) compared to Main Group open surgery patients (8 days, $p<0.01$). There were no conversions except the two noted. This suggests laparoscopic management was as effective as open in selected patients, with the expected benefits of faster recovery) .

Patients who underwent PAIR/catheter (10 cases) – one needed later surgery as noted, but if we count that as a failure, that yields a 90% success for percutaneous therapy in our series. Those who succeeded had no recurrence in the treated cysts. Minor complications occurred in one (transient allergic reaction). This aligns with literature supporting PAIR as a safe, effective option for appropriate cysts).

Among Main Group open surgery patients, those who had a radical cyst removal (complete pericystectomy, n=18) had 0% recurrence, whereas those who had partial cystectomy (n=42) accounted for the 2 recurrences (though even that is a low 4.8%). This trend supports the idea that more complete cyst excision further reduces relapse risk . However, radical procedures were only possible in select cases; all recurrences still remained low due to albendazole use and careful technique.

The few Main Group patients treated with medical therapy alone (5 cases) showed no progression or new cyst growth over a median 2-year follow-up. Three of them had significant cyst size reduction (>50%), and two had stable small residual cysts. This suggests that for properly selected small cysts, albendazole alone was an acceptable management in our cohort.

In the Comparison Group, open vs laparoscopic numbers were too skewed to compare outcomes meaningfully. But notably, the 4 laparoscopic cases in Comparison had no complications or recurrences, mirroring Main Group lap results – reinforcing that laparoscopy is beneficial when applicable .

Summary of Key Findings

The algorithm-based Main Group had a significantly lower overall complication rate than the Comparison Group (8.0% vs 21.4%). In particular, secondary infections of the cyst cavity and biliary

fistulas were markedly reduced by the new approach, likely due to improved intraoperative management of the residual cavity (no routine drains, use of omentoplasty) .

The recurrence rate of hydatid disease was significantly lower in Main Group (2.7%) compared to Comparison (12.9%) over similar follow-up periods. Main Group recurrences were only new lesions, with no relapses at treated sites, whereas Comparison had several local relapses – highlighting the effectiveness of the combined approach in eradicating the initial cysts .

Length of stay and convalescence were improved in the Main Group, attributable to the adoption of less invasive procedures (laparoscopy, PAIR) and fewer postoperative issues. Patients in Main Group returned to normal activity faster on average.

There was no compromise in safety with the algorithm: the addition of percutaneous and medical therapies did not introduce new risks beyond minor manageable events, and there was zero mortality in both groups.

Adjuvant albendazole therapy was well-tolerated overall, with only mild side effects in ~6% of patients, and may have contributed to the zero mortality and low recurrence by killing microscopic cyst remnants .

These results demonstrate that a multidisciplinary, stage-guided strategy can achieve outcomes at least as good as, and in many aspects better than, the traditional one-size-fits-all surgical approach.

Conclusions and recommendations:

Multimodal therapy works: A combination of albendazole therapy and appropriately selected minimally invasive procedures can effectively manage a large proportion of liver hydatid cysts, reserving open surgery for the cases that truly need it. This tailored approach improves patient outcomes and should be adopted in endemic regions.

Stratify by cyst characteristics: Treatment decisions should be guided by cyst size and stage. Small active cysts can often be cured medically; medium cysts respond well to PAIR plus medication; large or complicated cysts require surgery (ideally with removal of cyst contents and proper cavity management). Inactive cysts can be observed. This strategy leads to optimal use of resources and spares patients unnecessary surgery.

Adjuvant albendazole is essential: The use of albendazole around the time of any intervention (before and after) is associated with reduced recurrence and should be considered a standard adjunct to both surgical and percutaneous treatment of CE . It likely also lowers the risk of spillage-related complications.

Laparoscopy and newer techniques: Laparoscopic surgery for hepatic hydatid cysts is a viable option for selected patients and offers faster recovery with comparable efficacy . Surgical teams should gain experience with this technique. Similarly, percutaneous methods should be part of the therapeutic arsenal in centers managing hydatid disease, given their demonstrated safety and effectiveness.

Outcomes can be improved: Compared to historical figures, our protocol achieved a recurrence rate (~3%) that is among the lowest reported, and an overall complication profile significantly better than our previous standard. This indicates that widespread implementation of such algorithms could significantly reduce the disease burden and improve quality of life for patients with hepatic echinococcosis.

Literature

1. Brunetti, E., Kern, P., & Vuitton, D.A. (2010). Expert consensus for the diagnosis and treatment of cystic and alveolar echinococcosis in humans. Acta Tropica, 114(1), 1–16.
2. Dziri, C., Haouet, K., & Fingerhut, A. (2004). Treatment of hydatid cyst of the liver: where is the evidence? World Journal of Surgery, 28(8), 731–736.

3. Eckert, J., & Deplazes, P. (2004). Biological, epidemiological, and clinical aspects of echinococcosis, a zoonosis of increasing concern. Clinical Microbiology Reviews, 17(1), 107–135.
4. Moro, P., & Schantz, P.M. (2009). Echinococcosis: a review. International Journal of Infectious Diseases, 13(2), 125–133.
5. Tuxun, T., Zhang, J.H., Zhao, J.M., Tai, Q.W., Abudurexiti, S., Ma, H.Z., & Wen, H. (2014). World review of laparoscopic treatment of liver hydatid cysts. World Journal of Gastroenterology, 20(37), 13042–13047.
6. McManus, D.P., Zhang, W., Li, J., & Bartley, P.B. (2003). Echinococcosis. The Lancet, 362(9392), 1295–1304.