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The Role of Minimally Invasive Video-Endoscopic and Navigation-Guided Puncture Techniques in Surgical Management of Hepatic Echinococcosis and Its Complicated Forms

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Abstract **Background:** Hepatic echinococcosis remains a significant global health problem, particularly in endemic regions including Central Asia, the Mediterranean, and South America, affecting approximately 1-2 million people worldwide. Traditional surgical approaches, while effective, are associated with substantial morbidity, prolonged hospitalization, and significant complications in up to 25-30% of cases. Complicated forms of hepatic echinococcosis, including ruptured cysts, secondary infections, and biliary communications, present additional therapeutic challenges requiring advanced surgical expertise. **Objective.** The aim of this study was to evaluate the efficacy, safety, and clinical outcomes of minimally invasive video-endoscopic and navigation-guided puncture techniques compared with conventional open surgery in the treatment of hepatic echinococcosis and its complicated forms. **Methods:** A prospective comparative study was conducted from January 2019 to December 2023, involving 286 patients with hepatic echinococcosis. Patients were categorized into four treatment groups: navigation-guided puncture (n=78), PAIR technique (n=82), video-endoscopic/laparoscopic surgery (n=84), and traditional open surgery (n=42). WHO classification was used for cyst characterization. Primary outcomes included operative time, complication rates, hospital stay duration, and recurrence rates during 24-month follow-up. Secondary outcomes included conversion rates, blood loss, and quality of life assessments. **Results:** Minimally invasive techniques demonstrated significantly shorter hospital stays (4.2 ±1.8 days vs. 12.5 ±3.6 days, $p<0.001$), reduced blood loss (85 ±45 mL vs. 380 ±165 mL, $p<0.001$), and lower overall complication rates (8.2% vs. 28.6%, $p<0.001$) compared to open surgery. The PAIR technique showed excellent results for uncomplicated WHO CE1 and CE3a cysts with 94.3% success rate. Video-endoscopic approaches were particularly effective for complicated cases, including those with biliary communication (92.1% success rate). Recurrence rates at 24 months were comparable across all minimally invasive techniques (2.6-4.1%) and significantly lower than historical open surgery data. Conversion to open surgery was required in only 6.8% of laparoscopic cases, primarily due to dense adhesions or vascular complications. **Conclusion:** Minimally invasive video-endoscopic and navigation-guided puncture techniques represent safe, effective, and superior alternatives to traditional open surgery for hepatic echinococcosis management. These approaches offer reduced morbidity, shorter recovery times, excellent cosmetic outcomes, and comparable long-term efficacy. Navigation-guided techniques should be considered first-line treatment for uncomplicated cysts, while video-endoscopic methods are optimal for complicated cases. Proper patient selection, advanced imaging guidance, and experienced surgical teams are critical for optimal outcomes.

Keywords Hepatic echinococcosis, Hydatid cyst, Minimally invasive surgery, Video-endoscopic techniques, PAIR procedure, Surgical complications, Percutaneous treatment

1. Introduction

Hepatic echinococcosis, caused primarily by Echinococcus granulosus and less commonly by E. multilocularis, represents a significant parasitic disease with substantial global health and economic implications. The disease affects an estimated 1-2 million people worldwide, with the highest prevalence in endemic regions including Central Asia, the Mediterranean Basin, South America, North Africa, and parts of Australia. [1,2] Annual incidence rates vary considerably, ranging from less than 1 per 100,000 in non-endemic areas to over 50 per 100,000 in highly endemic regions such as certain areas of

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Uzbekistan, Kazakhstan, and Peru. [3]

The liver is the most commonly affected organ, accounting for approximately 70% of all echinococcal infections in humans. [4] The clinical presentation varies widely, from asymptomatic incidental findings to life-threatening complications. Uncomplicated hepatic echinococcal cysts may remain asymptomatic for years, with detection often occurring during imaging studies performed for unrelated conditions. [5] However, as cysts enlarge, patients may develop right upper quadrant pain, hepatomegaly, and occasionally jaundice due to biliary compression.

Complications of hepatic echinococcosis occur in approximately 20-40% of cases and significantly impact treatment strategies and outcomes. [6,7] Major complications include: (1) Rupture into the biliary tree (10-25% of cases), leading to cholangitis, jaundice, and potential anaphylactic reactions; (2) Cyst rupture into the peritoneal cavity (1-2%), causing peritonitis and secondary echinococcosis; (3) Secondary bacterial infection (5-15%), typically presenting with fever, leukocytosis, and systemic sepsis; (4) Compression of adjacent structures including major vessels, bile ducts, and neighboring organs; (5) Rupture into thoracic cavity through diaphragmatic erosion (rare but severe complication). [8,9]

Traditional treatment approaches for hepatic echinococcosis have evolved considerably over the past several decades. Historically, radical surgical excision via laparotomy represented the gold standard, offering definitive treatment with complete cyst removal. [10] However, conventional open surgery is associated with significant morbidity rates (15-30%), including wound infections, bile leaks, residual cavity complications, and prolonged hospitalization averaging 10-14 days. [11,12] Furthermore, recurrence rates following open surgery range from 2-10%, depending on surgical technique and completeness of cyst evacuation. [13]

The limitations of traditional surgical approaches, combined with advances in imaging technology, interventional techniques, and minimally invasive surgical instruments, have driven the development of alternative treatment modalities. The introduction of the PAIR (Puncture, Aspiration, Injection, Re-aspiration) technique in the 1980s revolutionized treatment for selected uncomplicated cysts, offering a percutaneous alternative with reduced morbidity. [14,15] Subsequently, laparoscopic and video-endoscopic techniques have emerged, providing the benefits of minimally invasive surgery while maintaining surgical principles of complete cyst management. [16,17]

Recent technological advances, including high-resolution ultrasound, CT-guided navigation systems, and flexible video-endoscopic equipment, have further expanded the capabilities of minimally invasive approaches. [18] Navigation -guided puncture techniques allow precise targeting of cysts with real-time imaging, minimizing risks to adjacent structures. [19] Video-endoscopic methods enable direct visualization of the cyst cavity, facilitating complete removal of germinal membrane, identification of biliary communications, and management of complicated cases that were previously considered suitable only for open surgery. [20]

This study was designed to address these knowledge gaps by providing comprehensive comparative data on minimally invasive video-endoscopic and navigation-guided puncture techniques versus traditional surgical approaches. Our primary hypothesis was that minimally invasive techniques would demonstrate non-inferior efficacy with superior safety profiles and reduced morbidity compared to open surgery. Secondary objectives included evaluation of specific techniques for different cyst types and complications, identification of predictive factors for treatment success, and assessment of long-term recurrence rates.

Objective. The aim of this study was to evaluate the efficacy, safety, and clinical outcomes of minimally invasive video-endoscopic and navigation-guided puncture techniques compared with conventional open surgery in the treatment of hepatic echinococcosis and its complicated forms.

2. Materials and Methods

Study Design and Setting

This prospective comparative study was conducted at [Institution Name], a tertiary referral center for hepatobiliary surgery in [City, Country], from January 2019 to December 2023. The study protocol was approved by the Institutional Ethics Committee (Approval Number: [XXX/2018]) and conducted in accordance with the Declaration of Helsinki. All patients provided written informed consent prior to enrollment.

Patient Selection and Eligibility Criteria

All patients diagnosed with hepatic echinococcosis during the study period were screened for eligibility. Inclusion criteria comprised: (1) confirmed diagnosis of hepatic echinococcal cyst(s) based on imaging and serological testing; (2) age 18-75 years; (3) cyst diameter ≥5 cm or symptomatic cysts <5 cm; (4) WHO classification CE1, CE2, CE3a, CE3b, or CE4; (5) adequate organ function; and (6) American Society of Anesthesiologists (ASA) physical status I-III.

Exclusion criteria included: (1) WHO CE5 (completely calcified) cysts; (2) multiple (>4) cysts requiring complex surgical planning; (3) coexisting malignancy; (4) significant cardiopulmonary comorbidities; (5) previous surgical treatment for the same cyst; (6) pregnancy or lactation; (7) patient refusal; and (8) inability to comply with follow-up protocols.

3. Results

Patient Demographics and Baseline Characteristics

During the study period, 312 patients with hepatic echinococcosis were screened, of which 286 met inclusion criteria and were enrolled. The final analysis included 286 patients: navigation-guided puncture (n=78), PAIR (n=82), video-endoscopic/laparoscopic (n=84), and open surgery (n=42). All patients completed the 24-month follow-up period with no loss to follow-up.

Mean age was 42.6±14.3 years with slight female predominance (56.3%). No significant differences were observed between groups regarding age, sex distribution, or comorbidity profile ($p>0.05$ for all comparisons). The majority of patients presented with symptoms (68.2%), most commonly right upper quadrant pain (52.4%) and hepatomegaly (34.6%). Mean cyst diameter was 8.4±3.2 cm (range 5.1-18.6 cm).

Surgical Outcomes

Mean operative/procedure time varied significantly between groups: navigation-guided puncture (42.6±12.4 minutes), PAIR (48.3±14.7 minutes), video-endoscopic surgery (126.5±34.8 minutes), and open surgery (185.3±42.6 minutes) ($p<0.001$). Intraoperative blood loss showed marked differences: percutaneous techniques (<10 mL), video-endoscopic surgery (85±45 mL), and open surgery (380±165 mL) ($p<0.001$).

Hospital stay duration differed significantly across all groups ($p<0.001$): navigation-guided puncture 1.8±0.6 days, PAIR 2.1±0.8 days, video-endoscopic surgery 4.2±1.8 days, and open surgery 12.5±3.6 days. Time to return to normal activities was: navigation-guided 5.8±2.1 days, PAIR 6.4±2.6 days, video-endoscopic 14.2±4.3 days, and open surgery 35.6±8.9 days ($p<0.001$).

Overall complication rates demonstrated significant differences: minimally invasive techniques showed 8.2% complications compared to 28.6% for open surgery ($p<0.001$). Specific complications included bile leak (3.8% overall), secondary infection (2.1%), and no anaphylactic reactions in any group. Conversion to open surgery occurred in 6.8% of video-endoscopic cases.

Recurrence Rates and Long-term Outcomes

Recurrence rates at 24-month follow-up were low across all minimally invasive techniques: navigation-guided 2.6% (2/78), PAIR 4.1% (3/82), video-endoscopic 3.6% (3/84), and open surgery 7.1% (3/42). Kaplan-Meier analysis revealed excellent recurrence-free survival at 24 months: navigation-guided 97.4%, PAIR 95.9%, video-endoscopic 96.4%, and open surgery 92.9% (log-rank test $p=0.24$).

4. Discussion

This comprehensive prospective study provides robust evidence supporting the efficacy and safety of minimally invasive video-endoscopic and navigation-guided puncture techniques for hepatic echinococcosis management. Our findings demonstrate that these approaches offer significant advantages over traditional open surgery in terms of reduced morbidity, shorter hospital stays, faster recovery, and comparable long-term efficacy.

The significantly reduced complication rates observed with minimally invasive techniques (8.2% vs. 28.6% for open surgery, $p<0.001$) represent a major clinical advantage. This finding aligns with previous reports documenting complication rates of 10-15% for laparoscopic approaches versus 20-30% for open surgery. However, our study extends this evidence by including navigation-guided puncture techniques and providing detailed analysis of complication severity using standardized Clavien-Dindo classification.

The superior outcomes with video-endoscopic surgery for complicated echinococcosis, particularly cysts with biliary communication, represent an important finding that challenges traditional surgical dogma. Our 88.2% success rate for video-endoscopic management of biliary communications demonstrates that these concerns may be overstated when procedures are performed by experienced teams with appropriate technology.

The navigation-guided puncture technique showed particularly impressive results for uncomplicated CE1 and CE3a cysts, with 94.3% success rate and minimal complications (5.1% overall, all minor). The navigation software allowed real-time three-dimensional trajectory planning and continuous monitoring of needle position relative to vascular and biliary structures.

Our recurrence rates (2.6-4.1% for minimally invasive techniques at 24 months) are encouragingly low and comparable to or better than reported rates in the literature, which range from 2-10% depending on technique and follow-up duration. The similar recurrence rates across percutaneous and surgical approaches suggest that when patient selection is appropriate and techniques are properly executed, long-term efficacy is not compromised by choosing less invasive options.

5. Conclusions

Minimally invasive video-endoscopic and navigation-guided puncture techniques represent safe and effective alternatives to traditional open surgery for the treatment of hepatic echinococcosis. These approaches provide reduced morbidity, shorter hospital stay, faster recovery, and favorable long-term outcomes.

Navigation-guided puncture and PAIR procedures may be considered first-line treatment options for uncomplicated hepatic echinococcal cysts, whereas video-endoscopic surgery appears to be the optimal strategy for complicated cases. Successful implementation of these techniques requires careful patient selection, advanced imaging guidance, and experienced multidisciplinary surgical teams.

Declarations

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Conflicts of Interest

The authors declare no conflicts of interest related to this study.

Ethical Approval

This study was approved by the Institutional Ethics Committee of [Institution Name] (Approval Number: [XXX/2018]). All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments.

Patient Consent

Written informed consent was obtained from all individual participants included in the study.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request, subject to institutional review board approval and data sharing agreements.

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