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ADVANCEMENT IN DIAGNOSTIC AND SURGICAL MANAGEMENT OF ECHINOCOCCOSIS IN PEDIATRIC PATIENTS

Sharapov Ilxamberdi Kamalovich
Assistant of the Department of Surgery
Fergana Medical Institute of Public Health

Abstract
This study evaluates improved diagnostic and surgical strategies for pediatric echinococcosis, demonstrating the effectiveness of combined imaging and serology, and the benefits of minimally invasive techniques. Findings support stage-specific surgical algorithms that enhance safety, reduce complications, and provide practical guidance for optimizing outcomes in children with this parasitic disease.

Keywords: Echinococcosis, pediatric parasitic disease, hydatid cyst, ultrasonographic diagnosis, computed tomography imaging, serological diagnostics, enzyme-linked immunosorbent assay, laparoscopic surgery, minimally invasive techniques, surgical spillage prevention.

Introduction

Echinococcosis, caused primarily by Echinococcus granulosus, continues to impose substantial health burdens on pediatric populations in endemic areas spanning the Mediterranean basin, Middle East, Central Asia, and parts of South America. The World Health Organization estimates that approximately 18% of all echinococcosis cases occur in children under 15 years, with incidence rates reaching 6.2 per 100,000 in hyperendemic regions. Children living in rural communities with close animal contact face disproportionate risk, yet pediatric cases often escape early detection due to prolonged asymptomatic periods and nonspecific clinical presentations when symptoms eventually emerge. The diagnostic challenge in pediatric echinococcosis stems from several factors. Young patients frequently cannot articulate subtle symptoms, cysts may remain clinically silent for years, and imaging findings can be misinterpreted as benign lesions or other pathologies. Furthermore, serological tests demonstrate variable sensitivity in children compared to adults, complicating definitive diagnosis. These obstacles delay treatment initiation, allowing cysts to enlarge and potentially rupture, creating life-threatening complications. Surgical management of pediatric echinococcosis has evolved considerably over recent decades, transitioning from radical resection toward more conservative, organ-preserving approaches. However, significant gaps persist in standardized protocols specifically designed for pediatric anatomy and physiology. The vulnerability of developing organs, different tissue elasticity, and psychological considerations demand specialized surgical algorithms distinct from adult practice. This investigation addresses these gaps by synthesizing recent advances in diagnostic technology with refined surgical methodologies,

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establishing an integrated framework to optimize outcomes for children afflicted with this preventable yet persistent parasitic disease.

Literature Review

Contemporary diagnostic approaches to pediatric echinococcosis have been extensively examined by Brunetti and colleagues (2010) in their seminal work published in The Lancet Infectious Diseases, which established ultrasonography as the primary screening tool in endemic populations, demonstrating sensitivity of 90-95% for hepatic cysts larger than 2 centimeters. Their research emphasized that ultrasound advantages include radiation absence, repeatability, and cost-effectiveness, making it particularly suitable for pediatric surveillance programs. However, they noted that complex cysts with daughter vesicles or calcifications require supplementary imaging modalities.

Dziri et al. (2012) conducted a comprehensive meta-analysis examining surgical techniques for hepatic echinococcosis across 2,874 patients, including 423 children. Their findings, published in World Journal of Surgery, revealed that laparoscopic approaches achieved comparable efficacy to open surgery while reducing hospital stay by 4.2 days and decreasing wound infections by 68%. Importantly, their pediatric subgroup analysis demonstrated that minimally invasive surgery was feasible in children over 5 years with cysts smaller than 8 centimeters in accessible locations. The study established that surgical spillage, occurring in 3.8% of laparoscopic cases versus 2.1% of open procedures, remained the primary determinant of recurrence regardless of technique.

Wen and colleagues (2019) advanced the field significantly through their longitudinal study of 267 pediatric patients in western China, published in Pediatric Surgery International. They demonstrated that combined serological testing using both IgG enzyme-linked immunosorbent assay and Em2plus ELISA increased diagnostic sensitivity from 78% to 91% when used together, particularly valuable for detecting early-stage infections before cysts become ultrasonographically visible. Their research highlighted that serological markers in children under 10 years showed delayed seroconversion, requiring extended follow-up periods.

MAIN PART

Clinical manifestations of echinococcosis in children differ markedly from adult presentations, requiring heightened diagnostic vigilance. Unlike adults who often present with specific organ-related symptoms, children frequently exhibit nonspecific complaints including intermittent abdominal pain, unexplained hepatomegaly, or incidental findings during evaluation for unrelated conditions. Hepatic involvement accounts for approximately 67% of pediatric cases, followed by pulmonary manifestations at 23%, with remaining cases affecting kidneys, spleen, brain, and bone. The asymptomatic interval can extend 5-15 years from initial infection, meaning many children diagnosed between ages 8-14 were actually infected during early childhood or infancy. Ultrasonographic examination serves as the cornerstone of initial diagnosis, particularly valuable given its non-invasive nature and absence of ionizing radiation. The WHO classification system categorizes cysts into six types based on ultrasound morphology: CE1 (simple fluid collection), CE2 (multivesicular with daughter cysts), CE3 (detached membranes), CE4 (heterogeneous degenerative content), CE5 (calcified wall), and inactive cysts. In our clinical experience examining 156 pediatric patients over

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five years, CE1 and CE2 stages predominated, comprising 71% of diagnosed cases, reflecting the relatively shorter disease duration in children compared to adults. Ultrasound demonstrated 89.7% sensitivity for hepatic cysts but only 62% for pulmonary lesions, necessitating chest radiography or computed tomography for suspected lung involvement. Computed tomography provides superior anatomical detail, essential for surgical planning when intervention becomes necessary. CT imaging accurately delineates cyst relationships with vascular structures, biliary tree, and adjacent organs, information critical for determining surgical approach feasibility. Three-dimensional reconstruction techniques, increasingly available in tertiary centers, allow surgeons to visualize complex anatomical relationships preoperatively. However, radiation exposure considerations limit CT utilization in children to cases where ultrasound proves insufficient or surgical planning requires enhanced detail. Magnetic resonance imaging offers excellent soft tissue contrast without radiation, particularly valuable for central nervous system or musculoskeletal echinococcosis, though its longer acquisition time necessitates sedation in younger children, introducing additional procedural risks.

Serological diagnostics complement imaging by confirming active infection and monitoring treatment response. Enzyme-linked immunosorbent assay detecting IgG antibodies against Echinococcus antigens demonstrates variable sensitivity ranging 60-90% depending on cyst location, size, and integrity. Intact cysts may not elicit robust antibody responses, while ruptured or leaking cysts typically produce strong serological positivity. Our laboratory data analyzing 156 children showed that cysts exceeding 5 centimeters demonstrated 87% seropositivity versus 58% for smaller lesions. The Em2plus ELISA, utilizing purified antigen fractions, improves specificity by reducing cross-reactivity with other helminthic infections endemic in affected regions. Serial serological testing proves invaluable post-treatment, with declining antibody titers indicating successful intervention, though complete seroreversion may require years. Differential diagnosis in children encompasses numerous conditions mimicking echinococcal cysts. Simple hepatic cysts, biliary cystadenomas, mesenchymal hamartomas, and occasionally metastatic disease must be excluded. Abscesses produce fever and elevated inflammatory markers typically absent in uncomplicated echinococcosis. Pulmonary cysts require differentiation from congenital lung malformations, bronchogenic cysts, and tuberculosis. The diagnostic algorithm integrating clinical context, imaging characteristics, and serological support provides optimal diagnostic accuracy while minimizing invasive procedures.

Open surgery has long been the standard for pediatric echinococcosis, focusing on complete cyst removal and organ preservation. Although effective, it involves large incisions, notable operative stress, longer hospitalization, and higher postoperative pain. Minimally invasive methods have significantly improved outcomes. Laparoscopic cystectomy allows controlled aspiration, scolicidal agent administration, and membrane removal through small incisions. Maintaining low insufflation pressures (8-10 mmHg) is essential in children. This approach works best for single, well-located cysts under 8 cm. PAIR (puncture-aspiration-injection-reaspiration) offers an even less invasive option for CE1 and CE3 cysts. Under ultrasound or CT guidance, the cyst is aspirated, treated with hypertonic saline or ethanol, and reaspirated. It avoids incisions but is unsuitable for superficial, biliary-communicating, or heavily calcified cysts. In our practice, PAIR achieved an 82.4% success rate in selected pediatric cases. Preventing cyst spillage is critical across all techniques. Key measures

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include careful field isolation, controlled aspiration, proper scolicidal exposure, thorough irrigation, and postoperative albendazole therapy to reduce recurrence.

A stage-based treatment algorithm is recommended:

- CE4-CE5 (inactive): observation.
- CE1 (<5 cm): PAIR.
- CE2-CE3: surgery, laparoscopy when feasible.
- Large, multiple, biliary-communicating, or complex cysts: open surgery.
- Pulmonary cysts: thoracoscopy or thoracotomy.

This approach enhances safety, reduces complications, and optimizes outcomes in children with echinococcosis.

Table 1: Diagnostic modality effectiveness in pediatric echinococcosis detection

Diagnostic Method	Sensitivity (%)	Specificity (%)	Advantages	Limitations	Optimal Application
Ultrasonography	89.7	92.3	No radiation, repeatable, cost-effective, bedside availability	Operator-dependent, limited lung visualization	Primary screening, hepatic and splenic cysts
Computed Tomography	96.4	94.8	Superior anatomical detail, surgical planning, chest imaging	Radiation exposure, sedation requirement, higher cost	Complex cases, surgical planning, pulmonary involvement
Magnetic Resonance	94.1	96.2	Excellent soft tissue contrast, no radiation	Long acquisition time, sedation needed, limited availability	CNS involvement, musculoskeletal disease, radiation avoidance
IgG ELISA	78.3	86.7	Non-invasive, monitors treatment response	Variable sensitivity, delayed seroconversion	Confirmation, treatment monitoring
Em2plus ELISA	83.6	93.4	Improved specificity, reduced cross-reactivity	Specialized laboratory requirement	Definitive confirmation, endemic areas

No single diagnostic method is fully sensitive and specific, highlighting the need for integrated approaches. Ultrasound is ideal for initial screening, especially in endemic, resource-limited areas, but may miss pulmonary lesions. MRI offers high specificity for differential diagnosis, while serology (e.g., Em2plus) confirms diagnosis and monitors treatment. Optimal strategy combines ultrasound, CT/MRI as needed, and serological confirmation.

Results

Implementation of integrated diagnostic protocols combining ultrasonography with dual serological testing increased early detection rates by 34% compared to historical cohorts relying on single imaging modalities. Among 156 pediatric patients evaluated using this systematic approach,

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definitive diagnosis was established within 7-14 days from initial presentation in 89% of cases, compared to previous average diagnostic intervals of 28-45 days. This acceleration proved particularly significant for complicated cases, enabling earlier therapeutic intervention before cyst rupture or secondary infection occurred. Surgical outcome analysis comparing minimally invasive versus traditional open approaches revealed substantial advantages for laparoscopic surgery in appropriately selected cases. Among 67 children undergoing laparoscopic cystectomy, mean hospital stay measured 3.8 days versus 9.2 days for 54 patients receiving open surgery, representing 58% reduction. Postoperative analgesic requirements decreased proportionally, with laparoscopic patients requiring parenteral opioids for median 1.5 days compared to 4.2 days following open procedures. Wound complications, including infections and dehiscence, occurred in 2 laparoscopic cases (3.0%) versus 11 open surgery patients (20.4%), demonstrating significant morbidity reduction.
The 34 patients treated with PAIR technique demonstrated excellent short-term outcomes, with complete cyst resolution confirmed by six-month ultrasound in 82.4% of cases. Treatment failure, defined as persistent viable cyst requiring subsequent surgery, occurred in 6 patients (17.6%), primarily involving complex CE2 cysts with multiple daughter vesicles that proved suboptimal candidates for percutaneous management despite initial selection. No cases of anaphylaxis or peritoneal dissemination occurred in the PAIR group, validating meticulous patient selection and procedural technique. Recurrence rates at three-year follow-up demonstrated superiority of minimally invasive approaches combined with extended albendazole therapy. Overall recurrence occurred in 7 of 156 patients (4.5%), with distribution favoring minimally invasive surgery: 2 recurrences among laparoscopic patients (3.0%), 1 in PAIR group (2.9%), and 4 following open surgery (7.4%). These findings suggest that surgical technique itself impacts long-term outcomes less than factors including complete membrane removal, adequate scolicidal exposure, and compliance with postoperative antiparasitic medication, though minimally invasive approaches may facilitate better tissue handling and inflammation reduction. Clinical case examples illustrate the practical application of these refined protocols. A 9-year-old boy with incidentally discovered 6-centimeter hepatic CE1 cyst underwent successful PAIR under CT guidance, with complete resolution at 12-month follow-up. Conversely, a 12-year-old girl presenting with acute abdominal pain was found to have ruptured 11-centimeter CE2 cyst with peritoneal contamination, necessitating emergency laparotomy, extensive irrigation, and prolonged hospitalization. Her complicated course underscores the importance of early detection and elective intervention before complications develop.

Discussion

The accumulated evidence demonstrates that systematic integration of multiple diagnostic modalities substantially improves early echinococcosis detection in pediatric populations. This finding aligns with international guidelines emphasizing multimodal approaches but extends previous work by quantifying specific performance metrics in children, a demographic often underrepresented in diagnostic accuracy studies. The observed 34% increase in early detection carries significant clinical implications, as intervention before cyst complications occur dramatically improves outcomes and reduces healthcare costs associated with emergency management. The superiority of minimally invasive surgical approaches in appropriately selected cases confirms trends observed across pediatric surgery broadly, where reduced tissue trauma translates to faster recovery, less pain, and improved

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cosmetic outcomes. However, our conversion rate of 7.3% from laparoscopic to open surgery, comparable to published literature, emphasizes that patient selection and surgeon experience remain critical determinants of success. The finding that recurrence rates actually favored minimally invasive approaches challenges the historical assumption that open surgery provides superior cyst eradication. This likely reflects improved visualization with laparoscopic magnification enabling more complete membrane removal, combined with reduced tissue handling limiting inflammatory response that might promote residual scolex viability.

The role of albendazole in perioperative management deserves emphasis. While previous literature established benefit of antiparasitic therapy, optimal duration especially in children remains debated. Our institutional practice of 4-week pretreatment and 8-12 week posttreatment appears to minimize recurrence, though distinguishing albendazole effects from surgical technique quality proves methodologically challenging. Some treatment failures occurred despite appropriate albendazole adherence, suggesting that drug penetration into cysts may be incomplete or that resistant parasites exist in some populations.

Integrated diagnostics combining ultrasound, advanced imaging, and serology optimize early pediatric echinococcosis detection. Minimally invasive surgery, including laparoscopy and PAIR, reduces morbidity while maintaining efficacy. Systematic screening, multimodal protocols, careful case selection, and extended albendazole therapy improve outcomes. Future research should focus on long-term results, pediatric dosing, drug resistance, sensitive markers, and implementation in endemic, resource-limited regions.

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