



CONGENITAL HYDRONEPHROSIS: CLINICAL COURSE, DIAGNOSTIC APPROACHES, AND SURGICAL TREATMENT OPTIONS

Xakimjonova Gulshodaxon Eldorbek qizi
Kokand University, Andijan Branch
Student of the Pediatrics Program, Group 25-02
Akromjonova Xalimaxon O'rmonbek qizi
Lecturer at the Department of Clinical and Pathological Anatomy
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Abstract

Congenital hydronephrosis is one of the most common developmental anomalies of the urinary tract in neonates and infants, characterized by dilatation of the renal pelvis and calyces due to impaired urinary outflow. Early detection and appropriate management are essential to prevent progressive renal dysfunction and irreversible parenchymal damage. The etiology of congenital hydronephrosis is multifactorial, involving genetic predisposition, anatomical obstruction, and functional abnormalities at the ureteropelvic junction. This paper provides a comprehensive overview of the clinical progression, diagnostic strategies, and surgical treatment options for congenital hydronephrosis in pediatric patients. The study discusses the significance of prenatal ultrasonography for early identification, postnatal imaging modalities such as diuretic renography and magnetic resonance urography, and differential diagnosis with other congenital renal anomalies. Special emphasis is placed on grading systems like the Society for Fetal Urology SFU classification, which aid in determining the severity of obstruction and guiding treatment decisions. The review also evaluates current surgical approaches, including open pyeloplasty, laparoscopic pyeloplasty, and robot-assisted procedures, in terms of their indications, outcomes, and postoperative complications. Additionally, the paper highlights the role of conservative management in mild cases, monitoring protocols, and long-term renal function preservation strategies. Overall, understanding the natural history and clinical behavior of congenital hydronephrosis allows clinicians to tailor individualized treatment plans, optimize surgical timing, and minimize the risk of renal impairment in affected children.

Keywords

Congenital hydronephrosis; ureteropelvic junction obstruction; prenatal diagnosis; pediatric urology; pyeloplasty; renal function; ultrasonography; diuretic renography; minimally invasive surgery; neonatal kidney anomalies.

Introduction

Congenital hydronephrosis represents one of the most prevalent developmental anomalies of the urinary system in neonates and infants. It is characterized by dilation of the renal pelvis and calyceal system due to an obstruction in urine outflow or functional impairment of the ureteropelvic junction. The condition may vary in severity from mild and transient dilatation detected incidentally on prenatal screening to severe obstruction that can lead to progressive renal parenchymal damage and permanent loss of renal function if left untreated. Over the past few decades, significant advances in prenatal imaging, molecular genetics, and minimally invasive surgical techniques have transformed the understanding and management of this condition, making early diagnosis and individualized treatment crucial for long-term renal preservation. The incidence of congenital hydronephrosis has increased

notably with the widespread use of prenatal ultrasonography, which allows for the detection of urinary tract abnormalities during the fetal period. Studies estimate that approximately 1–5% of all pregnancies reveal some degree of hydronephrosis on antenatal screening, making it one of the most commonly diagnosed congenital anomalies. However, not all detected cases are clinically significant; many resolve spontaneously postnatally, while others may progress to obstructive uropathy requiring surgical intervention. Therefore, distinguishing between transient physiological dilatation and clinically relevant obstruction remains a key diagnostic challenge. The pathogenesis of congenital hydronephrosis is multifactorial and may involve structural, functional, and genetic components. The most frequent underlying cause is obstruction at the ureteropelvic junction, where the renal pelvis meets the ureter, leading to impaired urine drainage from the kidney. Other causes include vesicoureteral reflux, ureterovesical junction obstruction, posterior urethral valves, and, more rarely, aberrant crossing vessels compressing the ureter. Genetic and environmental factors during fetal development can also contribute to abnormal nephrogenesis and urinary tract formation, predisposing the infant to hydronephrosis. Clinically, the presentation of congenital hydronephrosis varies depending on the degree and duration of obstruction. Mild forms are often asymptomatic and detected incidentally, whereas severe cases may manifest with palpable abdominal masses, urinary tract infections, hematuria, or impaired renal function. In infants and young children, non-specific symptoms such as poor feeding, vomiting, or failure to thrive may also be present, making early detection and evaluation essential. Accurate diagnosis and assessment of hydronephrosis severity rely on a combination of imaging modalities. Prenatal ultrasonography remains the cornerstone of early detection, enabling obstetricians and pediatric nephrologists to plan appropriate postnatal follow-up. Postnatal evaluations typically involve renal ultrasonography, voiding cystourethrography, and diuretic renography using technetium-99m mercaptoacetyltriglycine to assess drainage patterns and differential renal function. Magnetic resonance urography has also emerged as a non-invasive tool that provides detailed anatomical and functional information without ionizing radiation exposure. Several grading systems, such as the Society for Fetal Urology classification and the anterior-posterior renal pelvic diameter measurement, have been developed to standardize evaluation and guide management decisions.

Management of congenital hydronephrosis depends on the underlying etiology, degree of obstruction, and renal function status. Mild cases are often managed conservatively through regular imaging and clinical monitoring, as many spontaneously resolve within the first few years of life. In contrast, moderate to severe obstruction, progressive hydronephrosis, or declining renal function necessitate surgical correction.

Pyeloplasty either open, laparoscopic, or robot-assisted remains the gold standard for treating ureteropelvic junction obstruction, offering excellent long-term outcomes in preserving renal function. Advances in minimally invasive pediatric urology have significantly reduced postoperative morbidity and hospital stay while improving cosmetic and functional results. Despite these advancements, challenges remain in defining the optimal timing for intervention and identifying which infants will benefit most from surgery. The natural history of hydronephrosis varies widely, and overtreatment can be as detrimental as delayed intervention. Therefore, multidisciplinary collaboration among pediatric urologists, nephrologists, and radiologists is essential to ensure accurate diagnosis, risk stratification, and

individualized care. Congenital hydronephrosis continues to be a major topic of interest in pediatric nephrology and urology due to its high prevalence, complex pathophysiology, and implications for lifelong renal health. Understanding its clinical course, refining diagnostic algorithms, and improving surgical outcomes remain central goals in contemporary research and clinical practice. This paper aims to explore in detail the clinical manifestations, diagnostic methodologies, and surgical treatment options for congenital hydronephrosis, emphasizing evidence-based strategies for optimal patient management and renal preservation.

Main Body

Etiology and Pathogenesis. Congenital hydronephrosis primarily results from obstruction or impaired urine flow at any level of the urinary tract, most frequently at the ureteropelvic junction. The obstruction may be caused by intrinsic or extrinsic factors. Intrinsic causes include congenital narrowing of the ureteral lumen, abnormal muscular arrangement at the UPJ, or developmental failure of the smooth muscle peristalsis necessary for urine transport. Extrinsic causes involve compression by aberrant crossing vessels, fibrous bands, or external masses that mechanically impede urine flow from the renal pelvis to the ureter. From a developmental perspective, hydronephrosis originates during nephrogenesis, the process by which the metanephric mesenchyme interacts with the ureteric bud to form the kidney and collecting system. Genetic mutations affecting signaling pathways such as GDNF/RET, PAX2, and BMP4 may disrupt ureteric branching and lead to structural malformations. Environmental factors, including maternal diabetes, oligohydramnios, or intrauterine infections, have also been implicated in abnormal renal morphogenesis. The pathophysiological consequence of obstruction is progressive dilatation of the renal pelvis and calyces, which increases intrapelvic pressure and compromises renal blood flow. Over time, this leads to tubular atrophy, interstitial fibrosis, and irreversible loss of nephrons. The severity and duration of obstruction determine whether renal function can recover after surgical correction.

Epidemiology and Risk Factors. Congenital hydronephrosis is among the most frequently diagnosed fetal abnormalities, with a prevalence ranging from 1 in 100 to 1 in 500 live births. The widespread use of prenatal ultrasonography has increased detection rates, but many of these cases represent transient or physiological dilatation rather than true obstruction. The male-to-female ratio is approximately 2:1, with the left kidney being more commonly affected. Bilateral involvement occurs in about 20–40% of cases. Several risk factors have been associated with the development of congenital hydronephrosis. These include genetic predisposition, a family history of urinary tract anomalies, consanguinity, and certain maternal conditions such as gestational diabetes or preeclampsia. Moreover, infants with other congenital malformations, including neural tube defects and cardiac anomalies, are at higher risk of concurrent renal abnormalities.

Clinical Manifestations. The clinical presentation of congenital hydronephrosis is variable and largely depends on the degree and duration of obstruction. Mild cases often remain asymptomatic and may be detected incidentally during prenatal or postnatal imaging. Moderate to severe cases can present with symptoms such as flank or abdominal pain, palpable abdominal mass, recurrent urinary tract infections, hematuria, or hypertension. In neonates and infants, non-specific symptoms such as irritability, poor feeding, vomiting, or growth retardation may also occur. In cases of bilateral obstruction or solitary kidney involvement, signs of renal insufficiency, such as elevated serum creatinine, electrolyte imbalance, or

metabolic acidosis, may develop. Recurrent urinary infections due to urinary stasis can further contribute to renal damage and scarring if not promptly addressed.

Prenatal Diagnosis. Prenatal ultrasonography plays a critical role in the early detection of congenital hydronephrosis. It can identify renal pelvic dilatation as early as the second trimester. Measurement of the anteroposterior diameter of the renal pelvis is used to assess severity. An APD greater than 4 mm before 33 weeks of gestation or greater than 7 mm after 33 weeks suggests hydronephrosis. However, mild dilatation may resolve spontaneously after birth due to maturation of the urinary tract. **Postnatal Evaluation.** After delivery, postnatal ultrasonography is performed within the first week of life to confirm the persistence and extent of hydronephrosis. Subsequent imaging modalities include. **Voiding cystourethrography:** Used to rule out vesicoureteral reflux or posterior urethral valves. **Diuretic renography:** Assesses drainage dynamics and differential renal function; a delayed excretion pattern indicates obstruction. **Magnetic resonance urography:** Provides high-resolution anatomical and functional imaging without radiation exposure. **Serum creatinine and urinalysis:** Evaluate renal function and rule out infection. The combination of these studies helps to determine whether the hydronephrosis is obstructive or non-obstructive and to guide management decisions.

Grading and Classification Systems. Several grading systems are used to standardize the description and severity of hydronephrosis. **Society for Fetal Urology Grading System:** Ranges from Grade I to Grade IV. **Anteroposterior Renal Pelvic Diameter:** Provides a quantitative measurement; >15 mm postnatally is usually considered severe. **Onen Grading System:** Considers both anatomical and functional parameters to improve accuracy of predicting surgical necessity. These classification tools are essential for monitoring disease progression, selecting patients for surgery, and predicting long-term renal outcomes.

Management and Surgical Treatment Options. The management of congenital hydronephrosis depends on the severity of obstruction, renal function, and symptoms. The approach is broadly divided into conservative and surgical management.

Conservative Management. In cases of mild hydronephrosis with preserved renal function and no clinical symptoms, conservative management is preferred. This includes regular follow-up with serial ultrasonography every 3–6 months and periodic functional assessment. Many mild cases resolve spontaneously within the first two years of life as the urinary tract matures and peristaltic function improves. Antibiotic prophylaxis may be considered in infants with high risk of urinary tract infection. **Indications for Surgical Intervention.** Surgical treatment is indicated in the following conditions. **Progressive dilatation on serial imaging.** **Differential renal function <40% on diuretic renography.** **Symptomatic obstruction pain, infection, hematuria.** **Bilateral disease with impaired renal function.** **Surgical Techniques.** **Open Pyeloplasty.** The gold standard for correcting UPJ obstruction, involving excision of the narrowed segment and re-anastomosis of the ureter to the renal pelvis. It offers success rates above 90%. **Laparoscopic Pyeloplasty:** Minimally invasive approach providing comparable success rates with shorter recovery time, less postoperative pain, and better cosmetic results. **Robot-Assisted Pyeloplasty:** Gaining popularity due to enhanced precision and visualization, especially in complex or recurrent cases. **Endopyelotomy and Balloon Dilatation:** Reserved for selected cases with minimal scarring; however, long-term success rates are lower than open or laparoscopic techniques. **Postoperative Care and Outcomes.** After surgery, patients are followed up with serial ultrasonography and renal scintigraphy to monitor



improvement in drainage and renal function. Most children show significant functional recovery, especially if surgery is performed before irreversible damage occurs. Complications such as urinary leakage, infection, or restenosis are relatively rare with modern surgical methods.

Prognosis and Long-Term Follow-Up. The prognosis of congenital hydronephrosis largely depends on the degree of obstruction and timing of intervention. Early diagnosis and appropriate surgical correction yield excellent long-term renal outcomes. However, delayed management may result in chronic kidney disease or hypertension later in life. Continuous monitoring of renal function, blood pressure, and growth parameters is essential, especially in children with bilateral disease or solitary kidneys.

Conclusion

Congenital hydronephrosis remains one of the most frequent and clinically significant urinary tract anomalies in pediatric practice. It represents a spectrum of disorders that vary in severity, etiology, and clinical outcome from transient physiological dilatation that resolves spontaneously to severe obstruction requiring surgical correction. The condition's impact on renal development and long-term function underscores the importance of early detection, accurate diagnosis, and timely management. Advances in prenatal ultrasonography have revolutionized the early identification of congenital hydronephrosis, allowing clinicians to anticipate potential postnatal complications and plan individualized monitoring strategies. However, differentiating between obstructive and non-obstructive forms remains a diagnostic challenge, requiring the integration of multiple imaging modalities such as postnatal ultrasonography, diuretic renography, and magnetic resonance urography. Standardized grading systems like the SFU classification and measurement of the anteroposterior renal pelvic diameter provide valuable tools for assessing disease severity and determining the need for intervention. The management of congenital hydronephrosis must be carefully balanced between conservative observation and surgical correction. In many infants, mild hydronephrosis resolves naturally with urinary tract maturation, emphasizing the value of non-invasive follow-up. Conversely, persistent obstruction or progressive renal impairment mandates surgical intervention, with pyeloplasty whether open, laparoscopic, or robot-assisted remaining the gold standard. Modern minimally invasive techniques have greatly improved patient recovery, reduced postoperative morbidity, and ensured excellent long-term outcomes. A key determinant of prognosis is the timing of intervention. Early surgical correction before irreversible renal parenchymal damage occurs yields the best functional results. Nonetheless, overtreatment of cases that might resolve spontaneously should be avoided. Therefore, individualized care plans, guided by serial imaging and functional assessment, are essential for optimizing outcomes. Multidisciplinary collaboration among pediatric nephrologists, urologists, and radiologists is crucial for comprehensive management. Regular follow-up to assess renal growth, function, and blood pressure helps prevent late complications such as hypertension or chronic kidney disease. Furthermore, public health strategies emphasizing prenatal screening, parental education, and genetic counseling can enhance early detection and improve overall prognosis. Congenital hydronephrosis exemplifies how early diagnosis, evidence-based decision-making, and surgical innovation can preserve renal function and quality of life in affected children. Continued research into the molecular mechanisms of urinary tract development, refinement of diagnostic algorithms, and long-term outcome studies

will further enhance our ability to provide precise, patient-centered care for this common congenital anomaly.

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