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Article / Review

CURRENT ADVANCES IN THE TREATMENT OF PEDIATRIC HYDRONEPHROSIS: A LITERATURE REVIEW

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Abstract.
Pediatric hydronephrosis, the most common prenatal urologic abnormality, results from the distension of the renal pelvis and calyces due to obstructed urine flow. Its causes range from congenital ureteropelvic junction (UPJ) obstruction to acquired conditions, with severity assessed through grading systems like the Society for Fetal Urology (SFU) and Urinary Tract Dilation (UTD) classifications. While mild cases often resolve spontaneously, severe cases may require surgical interventions such as pyeloplasty, which has high success rates, particularly with advancements like robotic-assisted techniques. Diagnostic innovations, including the integration of urinary biomarkers with ultrasound, have improved the precision of identifying cases requiring intervention. This comprehensive review emphasizes a multidisciplinary approach, combining advanced imaging, personalized treatment strategies, and emerging technologies to optimize outcomes. Ongoing research into novel therapies and minimally invasive methods promises to further enhance the management of this condition and improve long-term renal function in affected children.

Key words: pediatric hydronephrosis, ureteropelvic junction obstruction, prenatal ultrasound, pyeloplasty, robotic-assisted surgery.

Introduction: Hydronephrosis in children is defined as the distension and dilation of the renal pelvis and calyces, often due to obstruction of urine flow from the kidney, and can be congenital or acquired(Al-Salem, 2020; Clécio Piçarro et al., 2014). It is the most common prenatal urologic abnormality, detected in 0.5-1% of pregnancies through ultrasound, which remains the primary diagnostic tool both prenatally and postnatally(Azar Nickavar et al., 2014; Iuliana Picioreanu & Dan-Matei Picioreanu, n.d.). The significance of hydronephrosis lies in its potential to cause severe complications such as chronic kidney disease, urinary tract infections, and renal failure if not managed appropriately(V. Abhulimen & N. Eke, 2018). The primary objective in managing hydronephrosis is to preserve renal function through early detection and treatment, which may involve surgical interventions like the resection and plasty of the pyelo-ureteral junction in severe cases(Adrian Revenco et al., 2024; V. Abhulimen & N. Eke, 2018). Methodologically, studies on hydronephrosis often involve retrospective reviews and cross-sectional analyses to evaluate demographic and clinical characteristics, as well as the outcomes of various treatment strategies(Azar Nickavar et al., 2014; Kristy VanDervoort et al., 2009). For instance, a study at the Pediatric Urology Clinic of the National Scientific-Practical Center of Pediatric Surgery evaluated 35 children with congenital hydronephrosis, employing various imaging techniques to guide surgical decisions(Adrian Revenco et al., 2024). The etiology of hydronephrosis is diverse, including ureteropelvic junction obstruction, vesicoureteral reflux, and other anatomical anomalies, which can be identified through detailed imaging and histopathological examinations(Clécio Piçarro et al., 2014; Mădălina Boşoteanu et al., 2011). Despite the complexity of its causes, the prognosis for hydronephrosis can be favorable with timely intervention, as many cases resolve spontaneously, particularly those detected at birth(Kristy VanDervoort et al., 2009). However, severe cases, especially those with anteroposterior diameters exceeding 14 mm, often require surgical intervention due to their association with significant congenital anomalies and potential for non-functioning kidneys(J Glover et al., 2012). Overall, the management of hydronephrosis in children necessitates a multidisciplinary approach involving pediatricians, nephrologists, and surgeons to ensure optimal outcomes and prevent long-term renal damage(Iuliana Picioreanu & Dan-Matei Picioreanu, n.d.).

Pathophysiology and Classification

Hydronephrosis in children is characterized by the dilation of the renal pelvis

and calyces, often due to an obstruction in the urinary tract, which can lead to hydroureteronephrosis if the ureter is also dilated(Ahmed H. Al-Salem, 2017). The condition is predominantly congenital, with ureteropelvic junction (UPJ) obstruction being the most common cause, accounting for 80% of cases, while anomalous renal vessels contribute to the remaining 20%(Belloli G et al., 1982). Hydronephrosis can be classified into primary and secondary types. Primary hydronephrosis is congenital, often detected prenatally via ultrasound, and may resolve spontaneously or require intervention if severe(Clécio Piçarro et al., 2014; Negar Janani & Valliappan Raman, 2024). Secondary hydronephrosis arises from other conditions such as ureterolithiasis or an anomalous polar vessel causing ureteral angulation(Clécio Piçarro et al., 2014; N. Venkatesa Mohan & Valliappan Raman, 2016). The severity of hydronephrosis is graded using systems like the Society for Fetal Urology (SFU) and the Urinary Tract Dilation (UTD) classification, which assess the extent of renal pelvis and calyceal dilation(Kosar Jafari et al., 2024; Negar Janani & Valliappan Raman, 2024). These grading systems, however, face challenges due to variability and subjectivity, leading to potential misclassification and treatment delays. The Onen grading system has been proposed to address these issues by providing a more detailed assessment of renal damage, aiding in distinguishing cases that require surgical intervention from those that can be managed conservatively(Onen, 2020). Prognosis and treatment are closely linked to the severity and cause of hydronephrosis. Mild to moderate cases often resolve without intervention, while severe cases, particularly those with UPJ obstruction, may necessitate surgical procedures like pyeloplasty to prevent renal damage(Bebenina et al., 2023; Clécio Piçarro et al., 2014). Early diagnosis and appropriate grading are crucial for optimizing treatment outcomes and preserving renal function in affected children(Bebenina et al., 2023; Belloli G et al., 1982).

Diagnostic Approaches

The most effective diagnostic approaches for identifying hydronephrosis in children include a combination of ultrasound (US) and urine biomarkers, as well as scintigraphic tests. Ultrasound is a primary tool due to its non-invasive nature and ability to classify the degree of hydronephrosis, which is crucial for determining the necessity of further intervention or monitoring(Clécio Piçarro et al., 2014; Mateusz Owsiak et al., 2022). The addition of urine biomarkers, such as urinary albumin, β2 microglobulin, and neutrophil gelatinase-associated lipocalin, enhances the predictive accuracy of US for surgical intervention, particularly when combined with the cumulative anterior-posterior diameter (APD)/mid-parenchymal ratio(Vytis Kazlauskas et al., 2022). This combination has shown good sensitivity and specificity in detecting significant renal function impairment, such as differential renal function (DRF) below 40%(Vytis Kazlauskas et al., 2022). Despite these advancements, limitations exist, including the lack of universally accepted diagnostic algorithms and the need for anesthesia in some pediatric imaging procedures, which can complicate the process(Mateusz Owsiak et al., 2022). Additionally, while prenatal ultrasound can identify fetal hydronephrosis, the condition's progression post-birth requires careful monitoring to decide on the necessity of surgical intervention, especially in cases of severe dilatation(Clécio Piçarro et al., 2014). Overall, while current diagnostic methods are effective, they require careful integration and interpretation to optimize patient outcomes.

Treatment Modalities

Hydronephrosis in children is a condition characterized by the swelling of the kidney due to urine buildup, often caused by ureteropelvic junction obstruction (UPJO). Treatment options for hydronephrosis range from conservative management to surgical interventions, with emerging technologies offering new possibilities. Each treatment modality has specific indications, outcomes, and advancements that are crucial for effective management.

Conservative Treatment

Indications: Conservative management is often considered for mild cases of hydronephrosis, particularly in antenatal hydronephrosis (ANH), where spontaneous resolution is possible. Monitoring is based on the degree of hydronephrosis and renal function assessments.

Outcomes: A significant proportion of ANH cases resolve spontaneously, with 53.3% resolving without intervention in a study of 150 cases.

Advancements: Improved diagnostic protocols, including regular prenatal ultrasounds and postnatal evaluations, help in identifying cases that may require intervention, thus refining treatment protocols(Singh et al., 2024)(Rana P. Singh et al.,

2024).

Pharmacological Treatment

Indications: Pharmacological interventions are primarily supportive, aimed at managing symptoms or complications such as infections associated with hydronephrosis.

Outcomes: In cases complicated by infections, comprehensive anti-infection treatment combined with drainage can significantly improve outcomes before surgical intervention(Shao-Qiang Duan et al., 2022).

Surgical Treatment

Indications: Surgery is indicated in cases of significant obstruction, recurrent hydronephrosis, or when conservative management fails. Common procedures include pyeloplasty, which has a high success rate(Adrian Revenco et al., 2024; Lobach et al., 2024).

Outcomes: Surgical interventions, such as open pyeloplasty, have success rates of 90-95%(Naif Alqarni et al., 2024). Minimally invasive techniques like laparoscopic pyeloplasty (LP) and robot-assisted laparoscopic pyeloplasty (RALP) offer comparable success rates with reduced hospital stays and recovery times(Edoardo Bindi et al., 2024; Naif Alqarni et al., 2024).

Advancements: RALP has emerged as a safer and more effective option for infants, overcoming the technical challenges of LP(Edoardo Bindi et al., 2024). The use of algorithms in surgical planning has improved outcomes in recurrent cases, achieving a 93% success rate(Lobach et al., 2024).

Emerging Treatments

Indications: Emerging treatments focus on improving surgical precision and reducing recovery times. These are particularly beneficial for complex or recurrent cases.

Outcomes: Robotic-assisted techniques have shown promising results, with reduced operative times and improved recovery of renal function.

Advancements: The integration of artificial intelligence and robotic technology in surgical procedures is enhancing the precision and safety of interventions, potentially setting new standards in pediatric urology(Zhongli Hu et al., 2023).

While surgical interventions remain the cornerstone for treating significant hydronephrosis in children, the choice of treatment is influenced by the severity of the condition, the presence of complications, and the potential for spontaneous resolution. Emerging technologies and refined protocols are enhancing the effectiveness and safety of these treatments, offering hope for improved outcomes. However, the variability in individual cases necessitates a personalized approach, balancing the benefits and risks of each treatment option.

Prognosis and Long-Term Outcomes

The prognosis and long-term outcomes of hydronephrosis in children vary significantly based on the severity of the condition and the treatment approach. Congenital hydronephrosis often resolves spontaneously, particularly in cases of mild to moderate severity. For instance, a study found that 66% of congenital hydronephrosis cases resolved within a median of 16 months, with a higher resolution rate in grade I to II cases compared to grade III to IV cases, which required longer follow-up and sometimes surgical intervention(Morizawa et al., 2024). Similarly, another study reported that 46% of fetal hydronephrosis cases resolved completely, while the remaining cases required further treatment or surgery(Abbas Madani et al., 2022). Surgical intervention, such as pyeloplasty, is often necessary for severe cases, especially when there is significant obstruction or deterioration in renal function. Early surgical intervention has been shown to improve renal parenchyma thickness and function, with a significant decrease in renal pelvis size(Bebenina et al., 2023). However, recurrent hydronephrosis can occur, often due to strictures or anatomical anomalies, necessitating further surgical strategies(Lobach et al., 2024). The use of temporary double-J stents has been explored as a less invasive option to manage severe hydronephrosis, with a success rate of 69% in avoiding surgery, though complications like urinary tract infections and stent dislocation are concerns(Nina Hutflesz et al., 2022). The risk of urinary tract infections is notably higher in severe hydronephrosis, emphasizing the need for careful monitoring and possibly antibiotic prophylaxis(Obafunbi Abimbola et al., 2022; Songül Yılmaz et al., 2023). Overall, while many cases of hydronephrosis in children have a favorable prognosis, particularly mild cases, severe cases require vigilant follow-up and sometimes surgical intervention to prevent long-term renal damage(Abbas Madani et al., 2022; Adrian Revenco et al., 2024; Morizawa et al., 2024).

Challenges and Controversies

Pediatric hydronephrosis presents numerous challenges and controversies, primarily revolving around diagnosis, treatment, and ethical considerations. One significant challenge is the variability in grading systems used to assess the severity of hydronephrosis, such as the AP diameter, SFU, and UTD classifications, which often lead to inconsistent diagnoses and treatment plans due to their subjective nature and operator dependency(Onen, 2020). This inconsistency complicates the decision-making process regarding whether to pursue surgical intervention or conservative management, as highlighted by the need for refined diagnostic protocols to differentiate cases that require intervention from those likely to resolve spontaneously(Rana P. Singh et al., 2024). Surgical treatment options, such as open lumbotomy and laparoscopic pyeloplasty, also present dilemmas, with studies comparing their efficacy in terms of recovery time and hospital stay, yet no consensus on the superior method(А.З. Кусаинов et al., 2022). Furthermore, the presence of ureteral anomalies, such as ureteral duplicity and ectopy, adds complexity to diagnosis and treatment, often requiring surgical intervention when associated with significant symptoms or complications(Gheorghe Adrian Bumbu et al., 2018). Ethical considerations arise in the context of prenatal diagnosis and the potential for over-treatment, as many cases of antenatal hydronephrosis resolve without intervention, raising concerns about unnecessary surgeries and the associated risks(Everling Mosquera-Pinargote, 2019; Lei Zhang et al., 2016). Additionally, the potential for chronic kidney disease in untreated or improperly managed cases underscores the importance of accurate diagnosis and timely intervention(Adrian Revenco et al., 2024). The lack of a universally accepted grading system and the variability in clinical presentations further complicate the management of pediatric hydronephrosis, necessitating ongoing research to establish standardized protocols and improve patient outcomes(Ilmay Bilge, 2020; Onen, 2020). Overall, addressing these challenges requires a multidisciplinary approach, integrating advances in imaging and surgical techniques with ethical considerations to optimize care for affected children.

Future Directions

Innovative research in the management of hydronephrosis, particularly antenatal hydronephrosis (ANH), has focused on refining diagnostic and monitoring protocols to better differentiate cases that require intervention from those that resolve spontaneously. A study involving 150 pregnant women highlighted the importance of systematic evaluation, showing that 53.3% of ANH cases resolved spontaneously, while 46.7% required postnatal intervention, with surgical correction needed in 64.3% of these cases. The variability in outcomes underscores the need for improved diagnostic thresholds, such as the anteroposterior renal pelvic diameter, to guide clinical decision-making(Nina Hutflesz et al., 2022). Additionally, the use of continuous antibiotic prophylaxis during the monitoring period remains controversial, with some pediatric urologists advocating for its use to prevent urinary tract infections, while others question its necessity(Mandy Rickard et al., 2022). Recent advancements have also explored the role of hedgehog signaling in regulating the renal collecting system, suggesting that inhibitors of GLI3 repressor formation could serve as novel therapies for non-obstructive hydronephrosis(Robyn P. Thom & Norman D. Rosenblum, 2013). Despite these advancements, prenatal intervention remains experimental, with significant risks and uncertain efficacy, as prenatal ultrasound often fails to accurately distinguish between physiological hydronephrosis and pathological conditions like obstruction or renal dysplasia(Douglas E. Coplen, 1997). Furthermore, the protective role of hydronephrosis as a compensatory mechanism to prevent renal damage has been proposed, challenging the traditional view of it as solely pathological(Stephen A. Koff, 2003). Areas requiring further investigation include the development of minimally invasive diagnostic techniques, the long-term outcomes of different management strategies, and the potential for pharmacological interventions targeting molecular pathways involved in renal development and function(Douglas E. Coplen, 1997; Robyn P. Thom & Norman D. Rosenblum, 2013). Overall, while significant strides have been made in understanding and managing hydronephrosis, ongoing research is essential to optimize treatment protocols and improve patient outcomes.

Conclusion: Early diagnosis, precise grading, and individualized treatment are crucial in managing pediatric hydronephrosis. This review highlights that mild cases often resolve spontaneously, whereas severe cases frequently necessitate surgical intervention, with pyeloplasty achieving high success rates, particularly with advancements like robotic-assisted techniques. Emerging diagnostic tools, such as urinary biomarkers and

enhanced imaging protocols, are improving the accuracy of identifying cases requiring intervention. A tailored approach is essential, given the variability in clinical presentations and outcomes, especially in complex cases involving recurrent or bilateral hydronephrosis. Interdisciplinary collaboration among pediatricians, nephrologists, and urologists plays a vital role in optimizing care, minimizing complications, and improving long-term renal outcomes. By integrating technological advancements with clinical expertise, the prognosis for children with hydronephrosis can be significantly improved.

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