Journal of Pediatric Urology (2014) 10, 982—999

Journal of Pediatric urology

Multidisciplinary consensus on the classification of prenatal and postnatal urinary tract dilation (UTD classification system)

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Received 26 August 2014; accepted 8 October 2014
Available online 15 November 2014

KEYWORDS
Hydronephrosis;
Classification;
Prenatal;
Postnatal;
Evaluation;
Ultrasonography

Abstract *Objective:* Urinary tract (UT) dilation is sonographically identified in 1—2% of fetuses and reflects a spectrum of possible uropathies. There is significant variability in the clinical management of individuals with prenatal UT dilation that stems from a paucity of evidence-based information correlating the severity of prenatal UT dilation to postnatal urological pathologies. The lack of correlation between prenatal and postnatal US findings and final urologic diagnosis has been problematic, in large measure because of a lack of consensus and uniformity in defining and classifying UT dilation. Consequently, there is a need for a unified classification system with an accepted standard terminology for the diagnosis and management of prenatal and postnatal UT dilation.

DOI of original article: http://dx.doi.org/10.1016/j.jpurol.2014.10.001.
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http://dx.doi.org/10.1016/j.jpurol.2014.10.002

Methods: A consensus meeting was convened on March 14—15, 2014, in Linthicum, Maryland, USA to propose: 1) a unified description of UT dilation that could be applied both prenatally and postnatally; and 2) a standardized scheme for the perinatal evaluation of these patients based on sonographic criteria (i.e. the classification system). The participating societies included American College of Radiology, the American Institute of Ultrasound in Medicine, the American Society of Pediatric Nephrology, the Society for Fetal Urology, the Society for Maternal-Fetal Medicine, the Society for Pediatric Urology, the Society for Pediatric Radiology and the Society of Radiologists in Ultrasounds.
Results: The recommendations proposed in this consensus statement are based on a detailed analysis of the current literature and expert opinion representing common clinical practice. The proposed UTD Classification System (and hence the severity of the UT dilation) is based on six categories in US findings: 1) anterior-posterior renal pelvic diameter (APRPD); 2) calyceal dilation; 3) renal parenchymal thickness; 4) renal parenchymal appearance; 5) bladder abnormalities; and 6) ureteral abnormalities. The classification system is stratified based on gestational age and whether the UT dilation is detected prenatally or postnatally. The panel also proposed a follow-up scheme based on the UTD classification.
Conclusion: The proposed grading classification system will require extensive evaluation to assess its utility in predicting clinical outcomes. Currently, the grading system is correlated with the risk of postnatal uropathies. Future research will help to further refine the classification system to one that correlates with other clinical outcomes such as the need for surgical intervention or renal function.

Introduction

Prenatal diagnosis of urinary tract (UT) dilation occurs in 1—2% of all pregnancies. Based on an estimated birth rate in the United States of 4 million per year [1], approximately 40—80,000 children are diagnosed annually with this condition. The prenatal sonographic identification of UT dilation reflects a spectrum of potential etiologies and uropathies. The rationale of prenatal detection is to identify pathology prior to the development of complications such as urinary tract infection (UTI), urinary stone formation, and renal dysfunction. In the majority of the cases, the prenatal finding of UT dilation is transient or physiologic and has no clinical significance. In other cases, it represents obstructive conditions such as posterior urethral valves (PUV) that have significant morbidities and even mortalities (Table 1). In many of the cases, the etiology of UT dilation is unable to be determined before birth and is diagnosed postnatally with additional imaging including ultrasound (US) and voiding cystourethrogram (VCUG).

Clinical practice patterns vary considerably regarding recommendation for the follow-up evaluation of fetuses and children who have been diagnosed with prenatal UT dilation. This stems from the challenge of predicting which children will have a clinically significant uropathy and would benefit from postnatal imaging. Evaluating every child with prenatal UT dilation results in the expenditure of significant healthcare resources and could cost over $90 million annually (1—3 prenatal US scans at $500; antibiotics at $25; 1—3 postnatal US scans at $400; 1 VCUG at $1200 per child). This does not factor in the cost associated with travel, time off from work for the parents, unnecessary parental anxiety, childhood radiation, and antibiotic exposure. Alternatively, not evaluating any child with prenatal UT dilation could avoid these initial costs but might delay the diagnosis of significant uropathies such as PUV and consequently, incur higher long-term health and financial costs.

Evidence correlating the severity of prenatal UT dilation with postnatal urological pathologies is lacking for several reasons. First, there is no uniformity on how to define, classify, and grade UT dilation both within and between the prenatal and postnatal periods. As a result, several different classification systems have evolved, leading to varying nomenclature. Second, different terminologies with overlapping meanings are used to describe UT dilation, and different clinicians may use the terms to mean different things. This causes misunderstanding, which further leads to confusion as to the specific US findings identified. For example, the term hydronephrosis is often used by imagers to describe even mild degrees of UT dilation, while clinicians (especially among primary care providers) consider the term hydronephrosis to mean distension of the renal pelvis and calyces from obstruction of urine flow that, if left untreated, results in progressive renal deterioration. Thus, the communication of the findings, which is transmitted between the imager and the clinician, may be misinterpreted. Third, UT dilation is a dynamic process, which can fluctuate over time and with varying conditions. The distension of the renal pelvis and calyces may vary depending on factors such as hydration status, degree of bladder filling, and patient position. Finally, uropathies present in a spectrum of severity. As an example, not all cases of PUV present with a severe UT dilation. Therefore, minimal UT dilation does not necessarily exclude the diagnosis of PUV. Given the lack of

Table 1 Etiology of urinary tract dilation detected on antenatal ultrasound.

Etiology	Incidence (%)
Transient/physiologic	50—70
Ureteropelvic junction obstruction	10—30
Vesicoureteral reflux	10—40
Ureterovesical junction obstruction/megaureter	5—15
Multicystic dysplastic kidney disease	2—5
Posterior urethral valves	1—5
Ureterocele, ectopic ureter, duplex system, urethral atresia, Prune belly syndrome, polycystic kidney diseases, l cysts	Uncommon

Adapted from Nguyen et al. 2010 [16].

uniformity in the description of the sonographic findings and paucity of evidence on which to base clinical management, our goal is to develop a unified classification system with an accepted standard terminology for the diagnosis and management of prenatal and postnatal UT dilation.

Methods and conference preparations

Eight societies with a special interest in the diagnosis and management of fetuses and children with UT dilation (The American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), the American Society of Pediatric Nephrology (ASPN), the Society for Fetal Urology (SFU), the Society for Maternal-Fetal Medicine (SMFM), the Society for Pediatric Urology (SPU), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasounds (SRU)) agreed to collaborate on the development of a unified grading system for perinatal UT dilation and propose a standardize scheme for follow-up evaluation.

The panel consisted of a director (HTN) and 12 panelists who each have specialized clinical and research experience with the perinatal diagnosis of UT dilation. The panel members were appointed by their respective societies and were representative of several medical disciplines including obstetrics (maternal fetal medicine, MFM), radiology, pediatric radiology, pediatric urology, and pediatric nephrology. Prior to the conference, specific aspects of prenatal and postnatal diagnosis of UT dilation were assigned to society representatives, based on his/her area of expertise. The current literature was reviewed and summarized for presentation (see References).

The consensus conference took place on March 14—15, 2014, in Linthicum, MD. An audience consisting of clinicians and researchers from the various specialties observed the proceedings in person or via webinar. The first day of the conference was devoted to presentations and discussion regarding the current classification systems for prenatal and postnatal UT dilation, correlation of prenatal US findings with postnatal outcomes, current recommendations for postnatal evaluation and follow-up, and long-term renal outcomes in children with prenatal UT dilation. At the end of the first day, the panelists spent the evening drafting a consensus statement. The following day, this statement was presented to the audience and discussed until the entire group arrived at a consensus.

Background and summary of the literature

Correlation between prenatal and postnatal US findings and the ultimate urological diagnosis has been problematic, partly because of the lack of uniformity in defining and grading urinary tract (UT) dilation. Currently, there are several grading systems utilized. Some are descriptive (e.g. mild-moderate-severe [2]); others are quantitative (e.g. numeric value of the anterior-posterior renal pelvic diameter (APRPD) [3]) or semi-quantitative (e.g. SFU [4], European Society of Pediatric Radiology (ESPR), Uroradiology Task Force [5], and Onen grading system [6]). Certain grading systems are preferentially used in prenatal evaluation while others are preferred for postnatal evaluation. Based on a survey regarding prenatal diagnosis, MFM physicians overwhelmingly preferred using the APRPD, while pediatric urologists were equally divided between using the APRPD and the SFU grading system [7]. Pediatric radiologists were not included in the survey study results because most who were surveyed did not perform prenatal evaluation. For postnatal evaluation, pediatric radiologists preferred using the descriptive grading system, while urologists preferred using the quantitative (APRPD) or semi-quantitative (SFU) grading system [7]. Moreover, Swenson et al. (publication in progress) demonstrated that even when the same grading system was utilized, there was significant inter-rater variability as to which grade a specific sonographic image represented. All the current grading systems have less than ideal inter-observer reproducibility (kappa ranging from 0.2 to 0.6 [5,8,9]), and there are no defined correlations between grading systems.

A single grading system that can be used across the prenatal and postnatal time period to describe UT dilation would be beneficial to promote communication between different specialists. In the majority of the cases, oral communication or the report of the findings is not dependable. Although providing the actual US images would be optimal, non-imagers may not be familiar with interpreting gray-scale images, and, in practice, actual images are often not available. Developing a common grading system would allow for information transfer without the ambiguities of interpretation by different providers. Additionally, by having a consistent grading system utilized in both the prenatal and postnatal evaluation, more rigorous outcomes research could be performed to correlate the prenatal sonographic findings to specific consequences such as resolution of renal dilation, specific uropathies, risks for urinary tract infection, surgery, or renal dysfunction.

Prenatal imaging

In the United States, US evaluation is routinely performed during pregnancy with an average of two scans for low-risk

patients and four scans for high-risk patients [10]. National practice guidelines for obstetrical imaging include evaluation of the fetal kidneys and bladder as a required component of a complete survey [11]. The kidneys and bladder can be reliably seen on US by the end of the first trimester [12]. The incidence of detecting UT dilation prenatally after the first trimester is 1–2%, but is reported to be as high as 5% in some studies [13]. The majority of MFM specialists (91%) favor measuring the APRPD to characterize the severity of the renal dilation [7]. Several studies have evaluated the APRPD of the renal pelvis in normal fetuses as a function of gestational age to establish normative data [13,14]. The threshold used for diagnosing UT dilation based on APRPD typically varies depending on the gestational age of the fetus. The gestational age ranges used for various cut-off values were not consistent across studies, such that the number of gestational age groups and what cut-off values are applied to each group, is highly variable and erratic. The most common clinical practice is to use two gestational age groups, with the first typically starting in the second trimester (16–20 weeks) and the second in the third trimester (28–32 weeks). An APRPD of $\geq$4 mm is the most common threshold for diagnosing UT dilation in the earlier gestational age range, and $\geq$7 mm in the older age range [13,14].

Additional US findings that are important for defining the severity and clinical significance of the prenatal UT dilation include: laterality, extent of calyceal dilation, parenchymal abnormalities, bladder and ureteral abnormalities, gender, amniotic fluid volume (AFV), and other organ system abnormalities. Dilation of the calyces is an important predictor of clinically significant UT dilation [15]; consequently, some grading systems incorporate the degree of dilation of the calyces in characterizing the severity of UT dilation. Grignon et al. [3] proposed five grades of UT dilation that take into account the measurement of the APRPD, the degree of calyceal dilation, and parenchymal thickness. The SFU grading system [4] is composed of five grades that subjectively evaluate the dilation of the renal pelvis, distinguish between central (major) and peripheral (minor) calyceal dilation, and assess parenchymal thickness with different diagnostic criteria for second trimester and again for third trimester findings [16]. During the second trimester, the SFU system defined APRPD as mild for 4 to $<$7 mm, moderate 7 to $\leq$10 mm, and severe $>$10 mm. During the third trimester, mild is defined as APRPD of 7 to $<$9 mm, moderate as 9 to $\leq$15 mm, and severe as $>$15 mm.

Correlation with outcomes

Several studies have assessed outcome based on prenatal APRPD measurements, and most have found that the larger the APRPD, the more likely it is to be caused by obstructive uropathies [17–19], the greater the risk of requiring surgery postnatally [18,20–22], and the lower the spontaneous resolution rate [18,23]. However, it should be noted that these studies varied widely, applying different APRPD cut-offs, different gestational age ranges, and different outcome measures. Looking at the SFU grading system, a meta-analysis of the literature found that the severity of UT dilation based on the SFU criteria correlated with urological pathologies, except for vesicoureteral reflux (VUR) [19,24]. Postnatal pathology (including VUR) was detected in only 12% of children with isolated second trimester UT dilation, but in 40% of those with dilation observed in both the second and third trimester [25]. Progressive UT dilation observed during pregnancy, rather than lack of progression or regression, is more often associated with uropathies [26]. In the diagnosis of lower urinary tract obstruction (such as from PUVs), oligohydramnios, renal cortical abnormalities, and early gestational age at diagnosis (e.g. $<$24 weeks) were found to be independent predictors of poor postnatal renal function [27].

Follow-up fetal imaging

In evaluating the need for follow-up US evaluation, it has been observed that prenatal UT dilation can resolve during pregnancy, remain stable, or may progress. The likelihood of resolution is related to the severity of the APRPD at initial diagnosis. Prenatal resolution occurred in approximately 80% of the cases when APRPD was between 4 and 7–8 mm during the second trimester [28–30], but less than 15% when APRPD was greater than 9 mm at that stage [28]. Consequently, follow-up US during the third trimester to assess interval change is usually recommended. For fetuses in which the UT dilation is mild (4–6 mm prior to 28 weeks gestation and 7–9 mm after 28 weeks onward), follow-up US during the third trimester detects those in which resolution has occurred and hence, those that do not require further prenatal or postnatal evaluation. In cases of moderate UT dilation (7–10 mm prior to 28 weeks and 10–15 mm 28 weeks onward) and severe cases ($>$10 mm prior to 28 weeks and $>$15 mm 28 weeks onward), US is warranted to evaluate for progression of UT dilation [16,28,30,31]. For the vast majority of cases, follow-up prenatal US evaluation is sufficient. In a few unique situations, prenatal MRI may provide additional information in diagnosis of UT dilation [32–34].

Fetal pyelectasis on mid-trimester US is associated with an increased risk of trisomy 21 [35–39]. The sonographic finding should prompt a targeted anatomic evaluation of the fetus, and as an isolated finding, carries a likelihood ratio of 1.5–1.6 for Down syndrome [36]. The finding of isolated fetal pyelectasis must be interpreted in the context of the *a priori* risk of trisomy 21 based on an accepted screening protocol. In addition, there are monogenic syndromes with congenital renal anomalies, some of which are associated with UT dilation [40].

Postnatal imaging

In current clinical practice, it is common that the prenatal US findings are not available to the physicians taking care of infants postnatally. Often, it is only mentioned that there is a history of prenatal kidney problems, without any additional details characterizing the extent and severity of the UT dilation. Postnatally, US is often the first imaging modality to evaluate these patients. In a recent survey of 284 pediatric radiologists with experience in interpreting postnatal US of UT dilation, 66% utilize the mild-moderate-severe grading system, while others routinely measure the APRPD or use the SFU grading system to characterize the

severity of the UT dilation (Swenson et al., publication accepted *Pediatric Radiology*) Based on intravenous pyelogram (IVP) [41] and magnetic resonance imaging (MRI) measurements (Swenson et al., publication accepted *Pediatric Radiology*), the normal APRPD in children is commonly considered to be 3 mm at 1 year of age and 6 mm at 18 years with the 99th percentile for children <5 years of age being <10 mm. It is important to recognize that these normative values are based on MRI, while most postnatal studies are performed with US. Furthermore, the distension of the urinary tract can be affected by the degree of bladder distension, hydration, and the position of the patient in which the US is performed. Furthermore, the accuracy of these measurements may be dependent on the US image resolution, the site of measurement, the technical skill of the sonographer, and the supervising physician.

It has been long recognized that the timing of the first postnatal US is important. Up to 48 h after birth, there is a tendency to underestimate the severity of hydronephrosis, in part because of dehydration [41,42]. It is generally recommended that the first postnatal US be delayed for at least 48 h after birth, except for cases of oligohydramnios, urethral obstruction, bilateral high-grade dilation, and concerns about patient compliance with postnatal evaluation [43]. Hydration can increase the size of a normal renal pelvis by increasing the volume of excreted fluid and also by affecting the bladder volume [44—48]. Consequently, it is recommended that in the presence of UT dilation, the patient should be rescanned after bladder emptying to accurately assess the severity of UT dilation. Patient position can also affect the accurate measurement of UT dilation, as in many cases the APRPD decreases when measured in the prone position [49]. As there are pros and cons to imaging the kidneys in either the prone or supine position, the current recommendation is that the same position be used in the same patient during each follow-up measurement to make for more accurate comparisons.

Multiple methods of grading UT dilation postnatally have been utilized. The descriptive grading system assesses the degree of renal pelvis dilation, calyceal dilation, and parenchymal thickness, categorizing variations as mild, moderate, or severe. This grading system was developed by correlating US with IVP grading [2]. The SFU grading system emphasizes the importance of intrarenal calyceal dilatation rather than the size of renal pelvis [4]. Consequently in this grading system, the APRPD is not measured. The intra-rater reliability is good and the inter-rater reliability is modest using this grading system [8,50]. A meta-analysis of the literature indicated that the SFU grading system is the most widely used with the best consistency (11/25 studies) [51]. In an attempt to improve further the accuracy of the grading system, ESPR proposed a modification of the SFU grading system in which APRPD was incorporated [5]. Onen proposed an alternative grading system in which Grade 1 represents pelvic dilation alone, Grade 2 with calyceal dilation, Grade 3 with less than 50% loss of the renal parenchyma, and Grade 4 with severe loss of renal parenchyma [6]. Compared with the SFU grading system, the Onen system has increased intra-rater reliability but decreased inter-rater reliability [9].

Alternative US parameters used to evaluate the severity of the UT dilation include pelvicalyceal area [52], hydronephrosis index (parenchymal to pelvicalyceal area [53], calyx to parenchymal ratio [54], and pelvicalyceal volume using 3D US [55]. These methods are more complicated to perform and therefore less commonly used in routine clinical practice.

In addition to US, IVP and static MR urography (MRU) can provide additional information on morphology. Diuretic urosonography, radionuclide renography (NUC), and functional MR urography (MRU) can provide functional information. Diuretic urosonography is not widely used. The assessment of VUR can be performed by radionuclide cystography (RNC), voiding cystourethrography (VCUG), or contrast enhanced voiding urosonography (VUS).

Correlation with outcomes

Similar to APRPD measured on prenatal US, the APRPD measured on the first postnatal US correlates with the risk of uropathies [56]. Multivariate analysis demonstrated that the severity of renal pelvic dilation, ureteral dilation, parenchymal thinning, renal hyperechogenicity, and thickened bladder were independently predictive of uropathies. An APRPD >16 mm (sensitivity = 99.8%, specificity = 89.5%, and OR 106) has been correlated with the child undergoing pyeloplasty [21]. Recent studies have attempted to combine several grading systems to improve correlation with outcomes. Based on multivariate analysis, Longpre et al. observed that the larger initial APRPD and SFU Grade 4 both independently predicted lower likelihood of resolution [57].

Postnatal management

Follow-up US evaluation. An initial normal postnatal US may be misleading. Aksu et al. observed that 21—28% of children with prenatal UT dilation had a normal initial postnatal US [58]; 45% of these children with an initial normal first postnatal scan had an abnormal US at follow-up [58]. In another study, 5% of those requiring surgery for obstructive uropathies had a normal US at 1 week of age but an abnormal US at 1 month of age [26]. It has been reported that approximately 15% of children with prenatal UT dilation develop later worsening or recurrent hydronephrosis after an initial normal postnatal US [59]. Consequently, many advocate that, in children with prenatal UT dilation, a second postnatal US should be performed even if the first postnatal US is normal.

It is generally agreed that those with moderate and severe hydronephrosis (SFU Grade 3 and 4) require earlier and more frequent postnatal US evaluation than those with mild (SFU Grade 1 and 2) UT dilation [16]. In a meta-analysis, SFU Grade 2 resolved in 70% of the cases and SFU Grade 1 and 2 stabilized in 98% of the cases [51]. Sencan et al. observed in their study population of children with a history of prenatal UT dilation and mild (SFU Grade 1 and 2) hydronephrosis on the first postnatal US, that subsequent follow-up US demonstrated resolution of UT dilation in 67%, improvement in 13%, stabilization in 16%, and worsening in 3% [60].

Evaluation for vesicoureteral reflux. In children with a history of prenatal UT dilation, the incidence of reflux

ranges from 12% to 38% [24,56]. When UT dilation is observed on the postnatal US, approximately 40% of the children have VUR, compared with less than 5% when two postnatal US evaluations are normal [25]. Similarly, in children with SFU grade 1 and 2 (mild), the incidence of VUR was 3% [60]. Notably, VUR is the only uropathy in which the degree of UT dilation observed on the prenatal and postnatal US does not correlate with increasing risk of pathology. Moreover, there is poor correlation between VUR grade and severity of UT dilation [61–64]. Controversies remain over the management of VUR. This raises the question as to the utility of diagnostic evaluation for VUR in this population, but this was outside the scope of this consensus conference.

Functional imaging. It is generally recommended that children with mild hydronephrosis (SFU Grade 1 and 2) do not need any functional imaging studies such as nuclear renography. With moderate (SFU Grade 3), the risk for surgical intervention was greater in those with differential renal function (DRF) $<$ 40% (33% vs. 3%) [65]. Most clinicians recommend that severe hydronephrosis (SFU Grade 4) be evaluated with functional studies.

Risk for UTI. Systematic review of the literature suggests benefit of selective use of prophylactic antibiotics in children with a prenatal diagnosis of UT dilation [66]. The incidence of UTI in children with SFU Grade 1–2 was approximately 5%, compared with 23% in those with SFU Grade 3–4 [60]. The risk of UTI with and without antibiotic prophylaxis in children with SFU Grade 1 and 2 or APRPD $<$ 15 mm was similar (2.2% vs. 2.8%), but was significantly different in those with SFU Grade 3 and 4 or APRPD $\geq$15 mm (14.6% (95% CI: 9.3–22) vs. 28.9% (95% CI: 24.6–33.66), $p < 0.01$) [66]. The estimated number needed to treat to prevent one UTI in patients with SFU Grade 3 and 4 was seven. The risk for UTI is also significantly higher in those with ureteral dilation [67]. Several studies have suggested that circumcision appears to be an equally effective alternative to antibiotic prophylaxis in preventing UTI in children with UT dilation [66,68,69].

Long-term renal function. Many of the uropathies that manifest UT dilation prenatally (known collectively as the Congenital Abnormalities of the Kidney and Urinary Tract or CAKUT) have concomitant renal developmental anomalies. In fact, CAKUT is the most frequent cause of chronic kidney disease (CKD) and end stage renal disease (ESRD) in children [70]. How these uropathies affect long-term GFR is determined by: 1) the extent of renal developmental injury and its impact on nephrogenesis; 2) the integrity of the nephron mass that develops and its ability to maintain renal reserve in the face of normal glomerular obsolescence and any new insults that may adversely impact the reserve; and 3) the ability to decrease the tempo of loss of GFR over time by blunting any hyperfiltration injury that ensues from reduced renal reserve.

Nephron development begins early in fetal life and reaches completion by 35 weeks of gestation. With morphologically normal kidneys, there are on average approximately 600 000–1,000,000 nephrons present at birth [71]. For most individuals, such a nephron endowment provides enough renal reserve to maintain renal function throughout life. Developmental or genetic abnormalities affecting nephron development or integrity, as well as acquired conditions or renal trauma or surgeries resulting in nephron loss, can lead to a reduced renal reserve with an ensuing increased risk of CKD or even ESRD. Children who are born with a reduced reserve, or who are left with a significantly reduced reserve early in life, are particularly at risk for manifesting renal functional abnormalities, as normal somatic growth places ever-increasing demands on their already compromised kidneys, in addition to the effect of hyperfiltration injury.

An individual's overall GFR reflects the sum of the filtration that occurs in all of that individual's functioning nephrons. As physiologically it is important to maintain GFR, a compensatory process termed hyperfiltration can occur when there is a reduced number of functioning nephrons. In hyperfiltration, the remaining nephrons try to maintain overall GFR by increasing their single nephron GFR, essentially increasing their filtration burden to take over for the absence or loss of normal nephron mass [72,73]. This process can accelerate normal obsolescence in these nephrons, leading to glomerular and tubular dysfunction and in many cases, the ultimate loss of enough overall function that effective GFR wanes.

As serum creatinine levels are maintained or even appear better than expected in the early phases of hyperfiltration, this process may initially present with what looks like a picture of functional renal adequacy. Over time, however, with ongoing nephron loss, there can be the development of proteinuria, hypertension, and renal insufficiency. In other words, although hyperfiltration may begin as a compensatory mechanism to maintain function in a variety of congenital or acquired conditions in which nephron mass is reduced, the accelerated glomerular obsolescence that ensues is often a final common pathway to advanced kidney disease.

In children with CAKUT, high grade obstructing lesions and diffuse anomalies in development such as hypoplasia and dysplasia are associated with earlier onset of CKD and progression to ESRD; however, any prenatally diagnosed CAKUT increases the risk of CKD substantially. In the general pediatric population, CKD is very rare, with a prevalence of about 75 cases/million children [74]. On the other hand, in children with any prenatally diagnosed CAKUT, up to 6% may manifest CKD by 10 years of age, an 800-fold increased risk over normal rates [75].

Minimizing new or ongoing insults to the kidney when there is already pre-existing CKD improves long-term renal survival and slows down progression to ESRD [76]. Importantly, recurrent UTI in children is associated with the risk of new renal scarring and accompanying nephron loss in children, from 10% with two UTIs to 60% after five UTIs [77]. In addition to addressing any necessary urologic issues such as obstruction or vesicoureteral reflux, medical management of associated sequelae of CKD may have significant implications for both renal survival and the child's overall long-term health. For example, in infants with prenatally diagnosed CAKUT, the incidence of hypertension increases

from <5% in children under 5 years of age to nearly 20% in older adolescents [75], and uncontrolled hypertension is certainly a co-factor for accelerating renal dysfunction. Along these same lines, high-grade proteinuria also portends poorer outcomes such as poorer blood pressure control [78].

The role of angiotensin blockade in dampening the progression of chronic kidney disease has been a focus of attention for many years, especially since the ready availability of angiotensin converting enzyme inhibitors or angiotensin receptor blockers. These therapies are well tolerated, making such intervention attractive to both clinicians and patients [79]. The beneficial role of angiotensin blockade in CKD is thought to stem not only from antihypertensive effect, but also by general renoprotection as a result of decreasing intraglomerular filtration pressure, proteinuria, and profibrogenic cytokines [80].

All of these factors are, in turn, thought to play a role in the development and progression of hyperfiltration injury and the loss of renal reserve in CAKUT and other clinical entities with CKD. There is indeed clinical evidence that in some populations angiotensin blockade can slow down the progression from hyperfiltration to albuminuria and can stabilize proteinuria once present [81].

Accordingly, angiotensin blockade serves at present as an important adjunctive therapy to blunt disease progression in children with CKD. As other therapies are developed to impede disease progression or even to induce disease regression, accurate risk stratification for children with abnormal renal development and abnormal urinary tracts will be of utmost importance to help determine potential efficacy.

Consensus discussion and statement

The goals of the Consensus Panel

The principal goals for the Consensus Panel were:

1. To propose a unified description of UT dilation that can be applied both prenatally and postnatally with consistent terminology. This grading system should be simple but detailed enough to be meaningful for both clinical use and future research endeavors. It should also allow for communication of information between specialists who care for these patients, both as fetuses and children.
2. To propose a standardized scheme for the perinatal evaluation of these patients based on sonographic criteria; this is intended to be a starting point for observation and study and will likely require modification over time based on the accumulated evidence.

There are several important caveats that the Consensus Panel considered in developing the following recommendations. First, this grading system is not designed with the intent of developing a definitive final classification system for prenatal UT dilation. The proposed grading system is expected to be validated and/or modified with clinical experience and evidence-based research results. Second, it is based on the current available literature, which is inconsistent and limited. Third, the grading system is designed to be used in cases of isolated UT dilation and not to be applied to unique situations or anomalous kidneys such as solitary, ectopic, multicystic dysplastic kidneys (MCDK) or other cystic diseases of the kidney. Finally, while the grading system can be used for post-surgical evaluation, the proposed scheme for subsequent evaluation is not intended for application to patients who have undergone urinary tract surgery.

Recommendations

Recommendation #1: terminology

Because of the apparent confusion associated with the implied meanings of various terminologies for UT dilation, the Consensus Panel recommended avoiding the use of nonspecific terms in describing UT dilation (e.g. hydronephrosis, pyelectasis, pelviectasis, uronephrosis, UT fullness or prominence, and pelvic fullness). The panel recommends the consistent use of the term "UT dilation." Further determination of the severity of UT dilation is characterized by specific sonographic findings, delineated by the UTD classification system below.

Table 2 US parameters included in the Urinary Tract Dilation Classification System.

US parameters		Measurement/findings	Note
Anterior-Posterior Renal Pelvic Diameter (APRPD)		(mm)	Measured on transverse image at the maximal diameter of intrarenal pelvis
Calyceal dilation	Central (major calyces)	Yes/No	
	Peripheral (minor calyces)	Yes/No	
Parenchymal thickness		Normal/Abnormal	Subjective assessment
Parenchymal appearance		Normal/Abnormal	Evaluate echogenicity, corticomedullary differentiation, and for cortical cysts
Ureter		Normal/Abnormal	Dilation of ureter is considered abnormal; however, transient visualization of the ureter is considered normal postnatally
Bladder		Normal/Abnormal	Evaluate wall thickness, for the presence of ureterocele, and for a dilated posterior urethra

Table 3 Normal values for Urinary Tract Dilation Classification System.

Ultrasound findings	Time at presentation		
	16–27 weeks	≥28 weeks	Postnatal (>48 h)
Anterior-Posterior Renal Pelvis Diameter (APRPD)	<4 mm	<7 mm	<10 mm
Calyceal dilation			
Central	No	No	No
Peripheral	No	No	No
Parenchymal thickness	Normal	Normal	Normal
Parenchymal appearance	Normal	Normal	Normal
Ureter (s)	Normal	Normal	Normal
Bladder	Normal	Normal	Normal
Unexplained oligohydramnios	No	No	NA

Recommendation #2: consultation and communication of information

Communication of prenatal findings to physicians taking care of the infant postnatally is essential for clinical care as well as for future outcomes research. The sonographic findings should be described in accordance with the recommended grading system, and if feasible, representative images should be included with the final US report. The panel recommends that when it is feasible, the parents of fetuses with prenatal UT dilation and/or the eventual primary care provider should be provided with the actual US images. When this is not practical, the panel recommends providing the family and/or treating physician with the necessary US findings as delineated by the UTD classification system. When the prenatal findings are concerning enough for a potential need for surgical intervention or risk for renal compromise, the panel recommends that consultation prior to delivery with a pediatric urologist and/or pediatric nephrologist be undertaken to help outline the care that the child may require postnatally.

Recommendation #3: classification system

The panel concluded that the following sonographic features are important factors in characterizing the severity of the UT dilation (Table 2). The ideal technique for APRPD measurement is based on images of the kidney obtained with the fetus or the child in an anterior-posterior plane. For optimal visualization of the fetal kidneys and measurement of the APRPD, the spine should be demonstrated at the 12 or 6 o'clock positions. In addition, the measurement should be taken at the maximal diameter of intrarenal pelvis dilation. In postnatal evaluation, imaging in the transverse plane at the hilum and in the prone position is encouraged, although consistency of position (prone or supine) at the time of measurement should take precedence in serial evaluations.

Additional sonographic features that should be evaluated include: 1) calyceal dilation, making a distinction between central and peripheral location (recognizing that this may be difficult to evaluate prenatally, especially before the third trimester); 2) parenchymal thickness (a subjective assessment); 3) parenchymal appearance with respect to echogenicity (subjectively determined by comparison with the adjacent liver or spleen), the presence or absence of cortical cysts and corticomedullary differentiation (the latter finding on postnatal imaging only); 4) ureteral dilation (transient visualization of the ureter is considered normal postnatally); 5) bladder abnormalities such as increased wall thickness, the presence of ureterocele or dilated posterior urethra; and 6) the presence of otherwise unexplained oligohydramnios on prenatal imaging. We acknowledge that ureteroceles are part of the ureter and not the bladder, but for simplicity we consider them as an abnormality in the bladder.

The threshold values for the diagnosis of UT dilation based on sonographic imaging are stratified based on gestational age at presentation (Table 3). The renal pelvis is considered not to be dilated (normal) when the APRPD

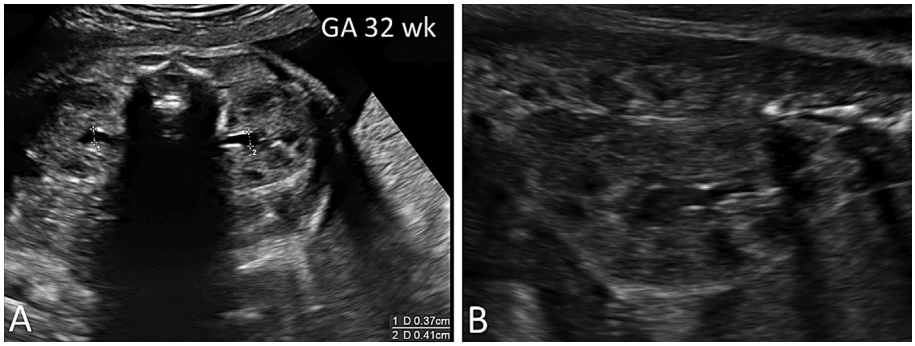

Figure 1 Ultrasound appearance of normal fetal kidneys at 32 weeks gestation. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) measuring < 7 mm, which is within the normal range for this gestational age. The measurement is taken with the spine at the 12 o'clock position and the calipers are placed at the widest part of the intrarenal fluid collection. B: Imaging in the sagittal plan demonstrates normal appearing parenchyma and no peripheral calyceal dilation. This fetus has a normal appearing bladder (not shown) and the ureters are not visualized.

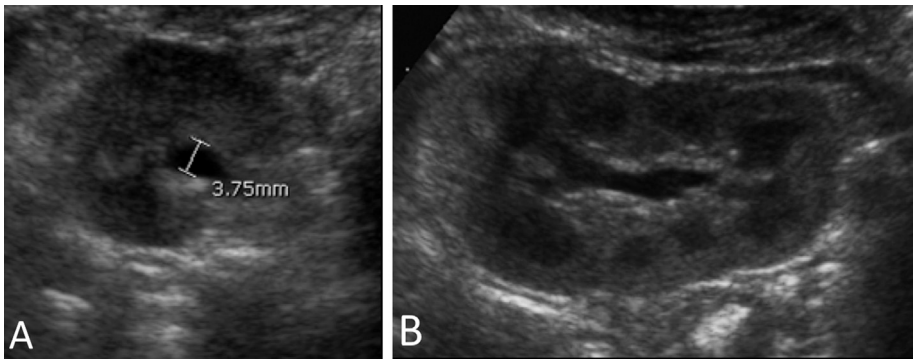

Figure 2 Appearance of normal kidneys on postnatal ultrasound. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) < 10 mm, which is normal for age. Note that the APRPD is measured at the maximal diameter of intrarenal pelvis dilation rather than that of extrarenal pelvis dilation. B: Imaging in the sagittal plane demonstrates normal renal parenchyma without any calyceal dilation. The bladder is normal (not shown), and the ureters are not visualized.

measures <4 mm at <28 weeks gestation, <7 mm at ≥28 weeks (Fig. 1A and B), and <10 mm postnatally (Fig. 2A and B). In the normal fetus, calyceal dilation is absent, the renal parenchyma has normal thickness and appearance, the ureter is not seen, and the bladder is normal. Additionally, there is no unexplained oligohydramnios.

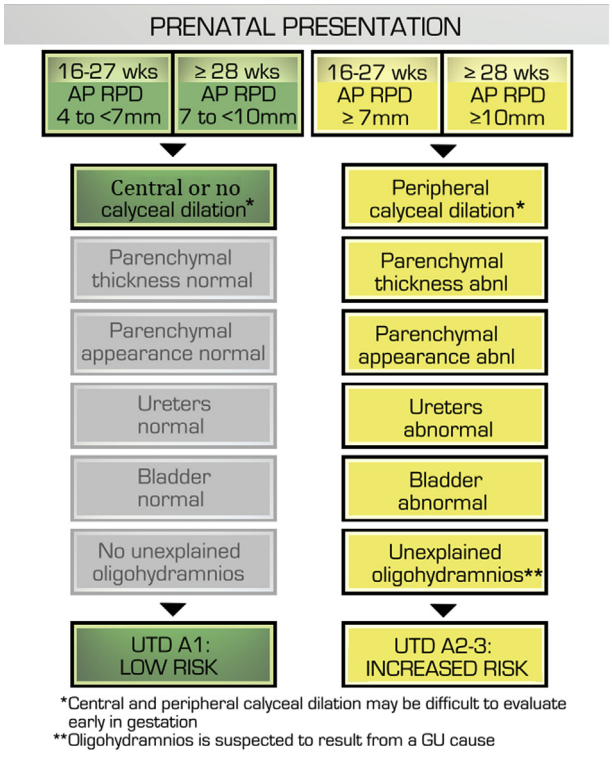

Figure 3 Urinary Tract Dilation (UTD) Risk Stratification - Prenatal Presentation for UTD A1 (low risk) and UTD A2—3 (increased risk). Note: Classification is based on the presence of the most concerning feature. For example, a fetus with an anterior-posterior renal pelvis diameter (ARPRD) within the UTD A1 range but with peripheral calyceal dilation would be classified as UTD A2—3 (as illustrated in Fig. 5C and D).

When the UT dilation is detected prenatally (denoted as A for antenatally), we suggest stratifying the findings into a low risk group (UTD A1) and an increased risk group (UTD A2—3) (Fig. 3). With UTD A1 the APRPD considered to be low risk for postnatal uropathies is 4 to <7 mm at <28 weeks (Fig. 4A and B), and 7 to <10 mm at ≥28 weeks (Fig. 4C and D). Fetuses in the low-risk category UTD A1 may also have central calyceal dilation but the presence of peripheral calyceal dilation is considered to increase risk. The renal parenchyma has normal thickness and appearance, the ureter is not seen, and the bladder is normal. There should not be unexplained oligohydramnios. Fetuses with UTD A2—3, are considered at increased risk for postnatal uropathy, based on an APRPD ≥7 mm at <28 weeks (Fig. 5A and B) and ≥10 mm at ≥28 weeks, or any one of the following findings: dilation of peripheral calyces (Fig. 5C and D); abnormal parenchymal thickness or appearance (Fig. 5E and F); visibly dilated ureter (Fig. 5G, H, and I); an abnormal bladder; or the presence of oligohydramnios suspected to be related to the urinary tract.

Initially, the panel intended to create low (A1), intermediate (A2), and high-risk (A3) groups to parallel the postnatal classification system, with the distinction between the intermediate and high-risk groups being dilation of the central versus the peripheral calyces. However, the panel noted that based on the literature and clinical experience, it was often difficult to distinguish between central and peripheral calyceal dilation on prenatal US. Consequently, the panel recommends combining the intermediate and high-risk groups to create one category of increased risk (A2—3).

When UT dilation is detected postnatally (denoted as P), we recommend stratification of risk into three groups: low risk (UTD P1); intermediate risk (UTD P2); and high-risk (UTD P3) groups (Fig. 6). With UTD P1, the APRPD considered to be low risk for postnatal uropathies is 10 to <15 mm (Fig. 7A and B). Again it should be emphasized that the first postnatal US should be done more than 48 h after birth to ensure it does not underestimate dilation, and be repeated once to ensure the appropriate management. In the low-risk group, central calyceal dilation may be present, but again, peripheral calyceal dilation is considered to increase

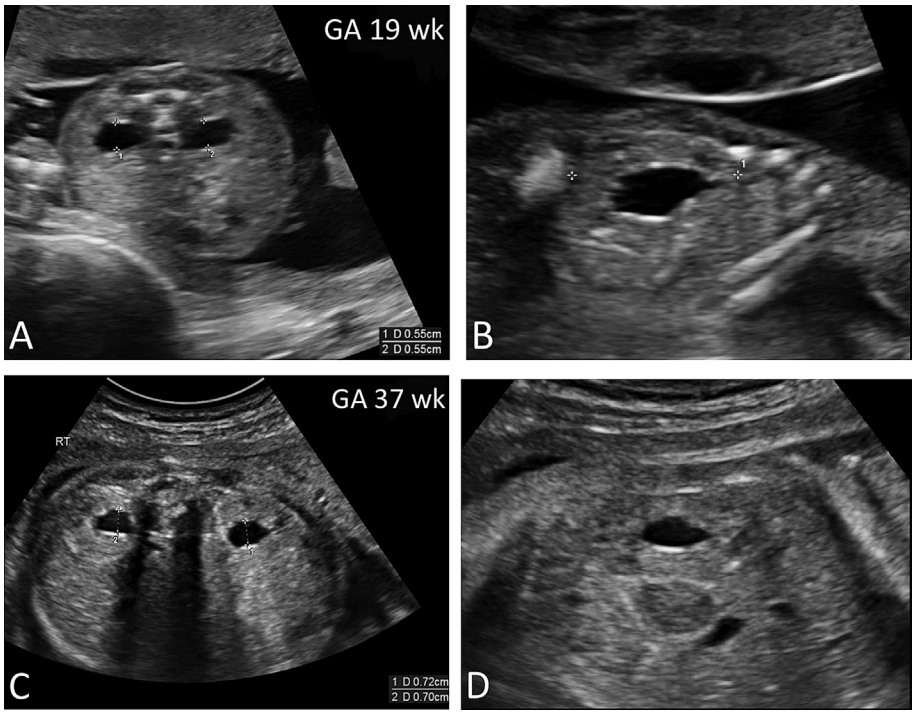

Figure 4 Ultrasound appearance of UTD A1. A and B: Fetal kidneys at 19 weeks gestation. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) measuring less than 7 mm, which is within the UTD A1 range for this gestational age. B: Imaging in the sagittal plane demonstrates normal appearing parenchyma and no peripheral calyceal dilation. C and D: Fetal kidneys at 37 weeks gestation. C: Imaging the transverse plane demonstrates an APRPD measuring less than 10 mm, which is within the UTD A1 range for this gestational age. D: Imaging in the sagittal demonstrates normal appearing parenchyma and no peripheral calyceal dilation. In each case, the bladder is normal, and the ureters are not visualized (not illustrated).

risk. The renal parenchyma should have normal thickness and appearance, the ureter is not seen, and the bladder is normal. If there is central calyceal dilation but the APRPD is less than 10 mm, it is still considered UTD P1 (Fig. 7C and D). With UTD P2, which is considered to be intermediate risk for postnatal uropathies, the APRPD is $\geq$15 mm (Fig. 8A and B). The calyces may be dilated centrally and peripherally or a dilated ureter is visible. For this classification, the parenchymal thickness and appearance as well as the bladder are normal. Cases in which there is peripheral calyceal dilation but the APRPD is less than 15 mm are still classified as UTD P2 (Fig. 8C and D). Finally, with UTD P3, the sonographic findings for APRPD, calyceal dilation, and the ureter are the same as those in UTD P2. However, in UTD P3, the renal parenchymal is thinned, has increased echogenicity and/or has decreased corticomedullary differentiation, or the bladder is abnormal (wall thickening, ureterocele, posterior urethral dilation) (Fig. 9A and B). Cases in which there are parenchymal abnormalities but the APRPD is $<$15 mm, are still classified as UTD P3.

Recommendation #4: proposed management scheme

Based on the suggested UTD classification system's risk stratification, the panel proposed a follow-up management scheme. For UTD A1 diagnosed before 32 weeks, a follow-up prenatal US is recommended at $\geq$32 weeks (Fig. 10). If the US at $\geq$32 weeks reveals resolution of the UT dilation with normal renal parenchyma, bladder and ureters, no further prenatal or postnatal follow-up is necessary. If there is persistent UTD A1 or UTD A2—3 (Fig. 3), evaluation after birth is recommended. Postnatal evaluation should include two US evaluations: the first at $>$48 h but less than 1 month after birth; and the second 1—6 months later. In fetuses considered at increased risk for postnatal uropathy (UTD A2—3), a follow-up prenatal US is recommended within 4—6 weeks of the initial diagnosis of UT dilation. Because of the variability of US findings on prenatal US in these cases, recommendations for subsequent interval assessment are at the discretion of the clinician. Prenatal consultation with a pediatric urologist and/or pediatric nephrologist is recommended in situations where there is substantial risk for surgery or renal dysfunction. After birth, a follow-up US is recommended at $>$48 h of life but before 1 month. Follow-up should be performed sooner for obstructive uropathies, such as suspected PUV (as suggested by the finding of a thick-walled bladder with persistent dilation and a fusiform appearance and/or posterior urethral dilation on prenatal US) or for bilateral conditions.

For UTD P1, a follow-up US is recommended in 1—6 months (Fig. 11). As there is significant controversy regarding the clinical importance of diagnosing VUR and the effectiveness of prophylactic antibiotics, recommendations for evaluation with VCUG and the use of prophylactic

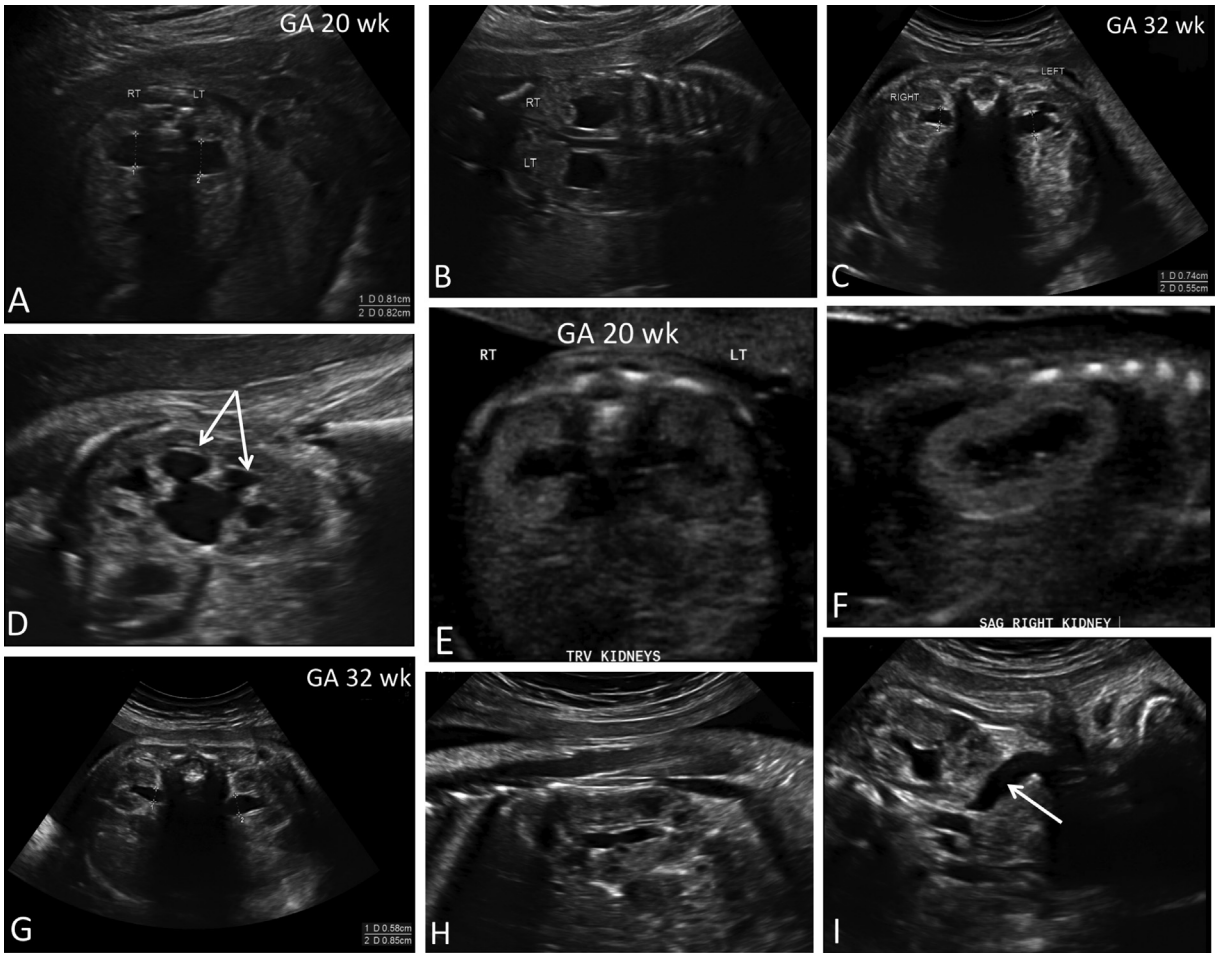

Figure 5 Ultrasound appearance of UTD A2—3. A and B: Fetal kidneys at 20 weeks gestation. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) measuring greater than 7 mm, which is within the UTD A2—3 range for this gestational age. B: Imaging in the coronal plane demonstrates normal appearing parenchyma. C and D: Fetal kidneys at 32 weeks gestation. C: Imaging in the transverse plane demonstrates an APRPD measuring 7 mm, which is below the UTD A2—3 range for gestational age; however, note the presence of peripheral calyceal dilation. D: Imaging in the sagittal plane demonstrates normal appearing parenchyma but clear peripheral calyceal dilation leading to the classification as UTD A2—3. E and F: Fetal kidneys at 20 weeks gestation. E: Imaging in the transverse plane demonstrates fluid within the renal pelvis (not measured). F: Imaging in the sagittal plane demonstrates abnormal appearing parenchyma that is more echogenic than adjacent liver, prompting classification UTD A2—3. G, H, and I: Fetal kidneys at 32 weeks. G: Imaging in transverse plane demonstrates an APRPD of 8 mm, which is below the usual range for UTD A2—3 classification. H: Imaging in the sagittal plane demonstrates normal renal parenchyma and no calyceal dilation. I: However, imaging in the modified sagittal plane demonstrates a clear hypoechoic tubular structure that has peristalsis in real time, characteristic of a hydroureter. Consequently, the urinary tract classification in this case is UTD A2—3 based on the presence of a visualized ureter on prenatal US imaging.

antibiotics are left to the discretion of the clinician. For UTD P2, a follow-up US is recommended in 1—3 months. As with UTD 1, recommendations for evaluation with VCUG and the use of prophylactic antibiotics are left to the discretion of the clinician. There is significant variability in the practice of performing functional scans in children with SFU Grade 3. Consequently, recommendations for functional scans in patients with UTD P2 are left to the discretion of the clinician. For UTD P3, a follow-up US is recommended within 1 month. Evaluation with VCUG and the use of prophylactic antibiotics is recommended in this group, depending in part on the pathology suspected. As with UTD P2, recommendation for functional scans in patients with UTD P3 is left to the discretion of the clinician.

Recommendation #5: modifiers of UTD classification system

Worsening findings on serial prenatal or postnatal US are associated with increased risk of genitourinary pathology. With regards to fetal gender, the panel feels there is insufficient evidence to suggest that the risk for postnatal uropathies is significantly different, the exception being the diagnosis of PUV in males. With regards to unilateral vs. bilateral UT dilation, there is insufficient evidence to

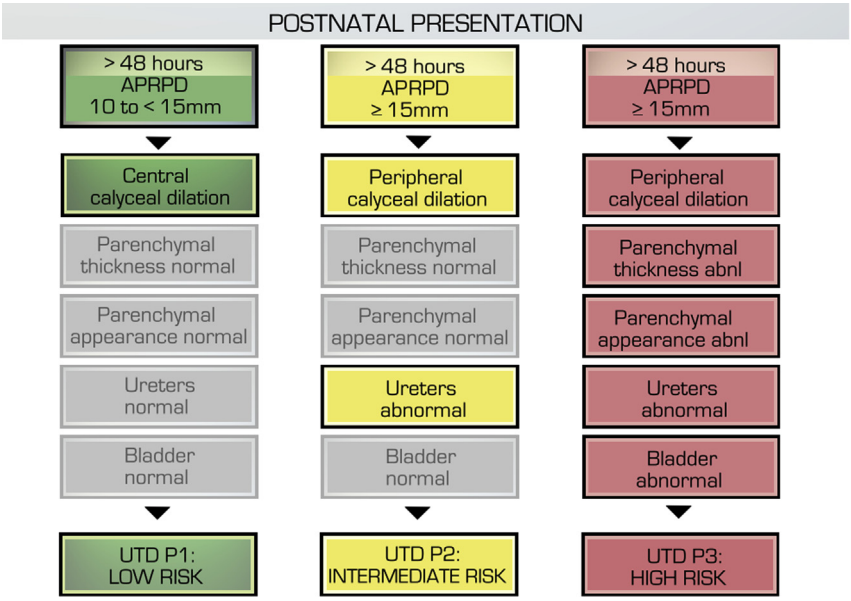

Figure 6 Urinary Tract Dilation (UTD) Risk Stratification — Postnatal Presentation for UTD P1 (low risk), UTD P2 (intermediate risk), and UTD P3 (high risk). Note: Stratification is based on the most concerning ultrasound finding. For example, if the anterior-posterior renal pelvis diameter (APRPD) is in the UTD P1 range, but there is peripheral calyceal dilation, the classification is UTD P2. Similarly, the presence of parenchymal abnormalities denotes UTD P3 classification, regardless of APRPD measurement.

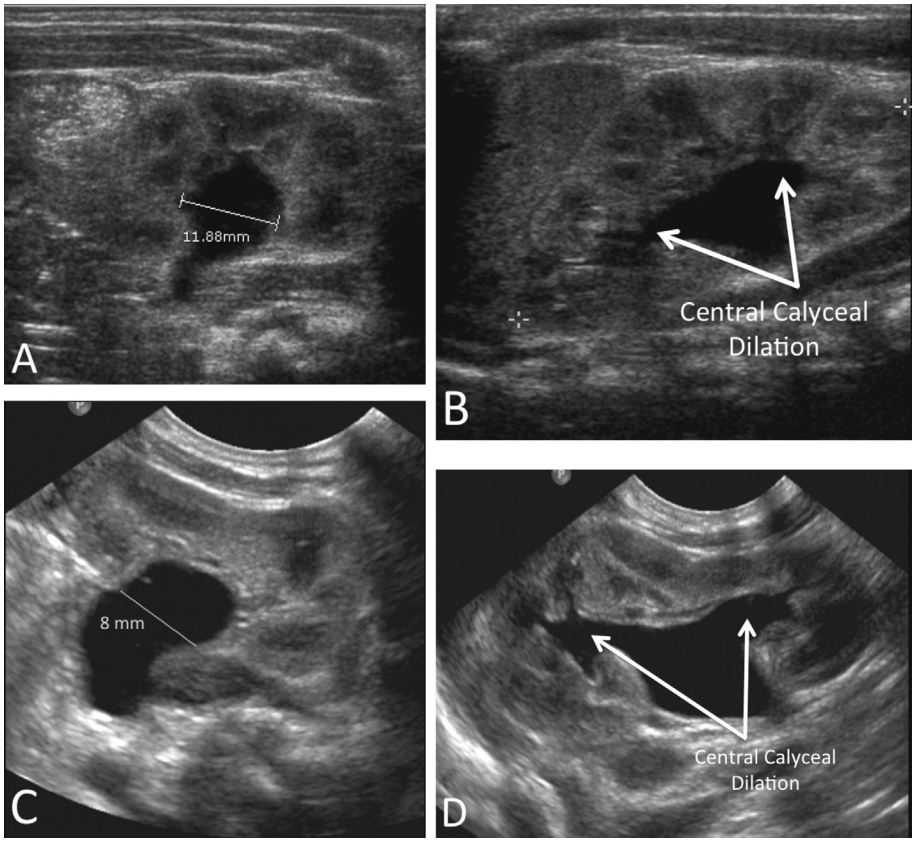

Figure 7 Appearance of UTD P1 on postnatal ultrasound. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) 10 to <15 mm. B: Imaging in the sagittal plane demonstrates central but no peripheral calyceal dilation. The renal parenchyma is otherwise normal. The bladder is normal (not shown), and the ureters are not visualized. Another example of UTD P1 on postnatal US. C: Imaging in the transverse plane demonstrates an APRPD <10 mm. D: However, imaging in the sagittal plane demonstrates central calyceal dilation.

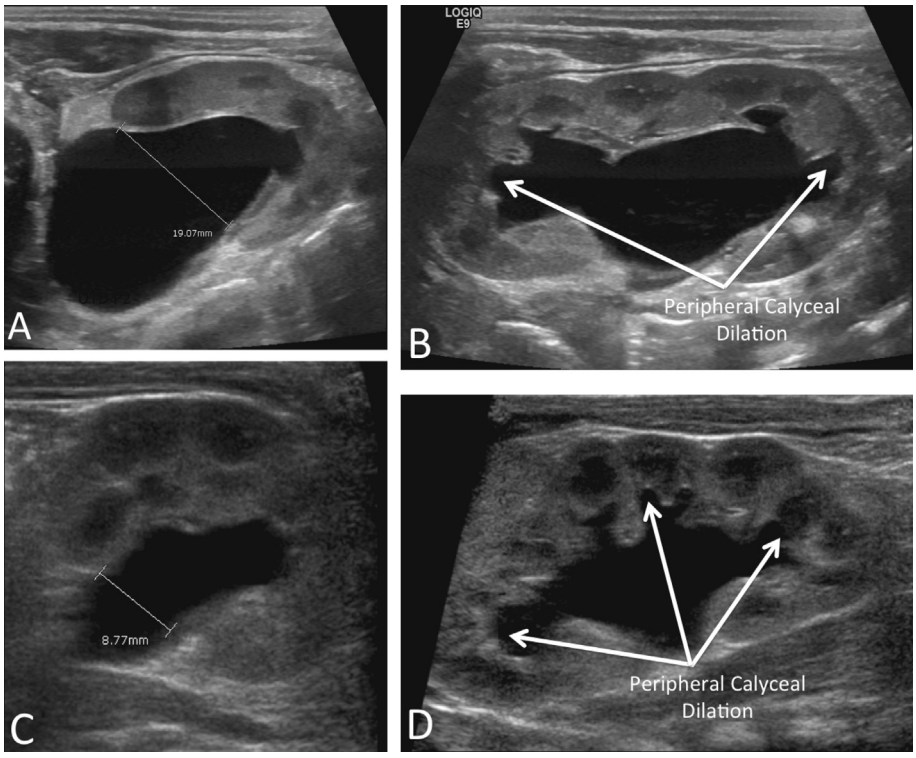

Figure 8 Appearance of UTD P2 on postnatal ultrasound. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) $\geq$15 mm. B: Imaging in the sagittal plane demonstrates peripheral calyceal dilation but normal renal parenchymal thickness and appearance. In addition, there are no bladder abnormalities (not shown). Another example of UTD P2 on postnatal US. C: Imaging in the transverse plane demonstrates an APRPD $<$10 mm. D: However, imaging in the sagittal plane demonstrates peripheral and central calyceal dilation.

suggest that the risks for postnatal uropathies are significantly different. The panel recommends that stratification of risk should be based on the grading of UT dilation in the most severely affected side.

Recommendation #6: reporting

When reporting UT dilation, the panel recommends that a description of the above seven imaging parameters (Table 3, Figs. 3 and 6) be reported in the written report. In the Impression section, the specific UTD category (Normal, UTD A1, UTD A2—3, UTD P1, UTD P2, or UTD P3) should be reported along with the suggested management scheme. Ideally, representative images should be provided with the report.

Discussion

In this consensus statement, the panel integrated existing grading systems and recommendations and attempted to

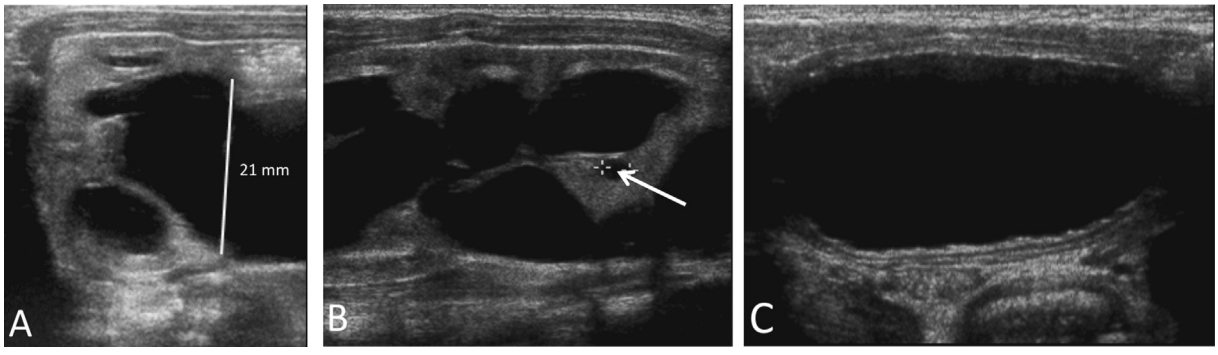

Figure 9 Appearance of UTD P3 on postnatal ultrasound. A: Imaging in the transverse plane demonstrates an anterior-posterior renal pelvis diameter (APRPD) $\geq$15 mm with peripheral calyceal dilation. B: Imaging in the sagittal plane demonstrates parenchymal thinning and cysts (arrow). C: Imaging of the bladder demonstrates increased wall thickness.

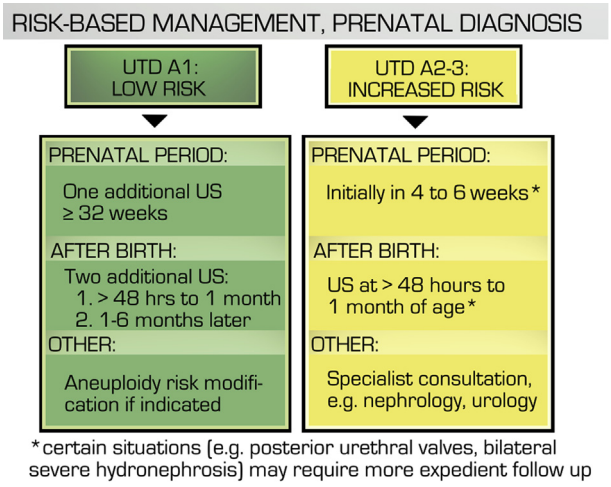

Figure 10 Management schema based on UTD classification system's risk stratification of UTD A1 and UTD A2—3.

adapt them to current clinical care. The UTD classification system incorporates three broad categories of sonographic findings — degree of UT dilation, parenchymal quality, and associated anomalies. Specific aspects of the existing grading systems have been simplified and incorporated into a single unified system. Consequently, conversion from existing grading systems to the UTD classification system should be relatively uncomplicated. For example, SFU Grade 1—2 would be equivalent to UTD P1, SFU Grade 3 to UTD P2, and SFU Grade 4 to UTD P3.

In categorizing the severity of the UT dilation, the panel felt that it was appropriate to correlate the sonographic findings to postnatal urological pathology (not transient or physiologic hydronephrosis) because it was the most objective and best-characterized outcome identified in the literature. Further research will be needed to correlate the UTD classification system risk stratification to other specific clinical outcomes such as surgical intervention, renal function, urinary tract infection, and others.

In addition, the panel recognized that not all urinary tract dilation is associated with renal pelvic dilation as in some cases of primary megaureter or reflux where there is ureteral dilation, but there may be little to no pelvic or calyceal dilation. The classification system proposed is primarily for different degrees of renal pelvic dilation and is thus the main criteria for the UTD classification system with ureteral dilation as a modifier of renal pelvic dilation. The visualization of dilated ureter(s) categorizes the UT dilation as either UTD A2—3 or UTD P2, regardless of the APRPD measurements.

The panel recommendations are in agreement with the Executive Summary on Fetal Imaging by NICHD [82]. Specifically, an abnormal APRPD is defined as $\geq$ 4 mm in the second trimester and $\geq$7 mm at $\geq$32 wk. We concur with the Executive Summary that UT dilation is most often transient and carries an increased risk of Trisomy 21, warranting a detailed US and correlation with accepted aneuploidy-screening protocols. In addition, we agree that follow-up US evaluation should be performed at 32 weeks to rule out persistent UT dilation. If the APRPD is $\geq$7 mm at 32 weeks, we agree with the recommendation of postnatal radiological evaluation.

Future research directions

The Consensus Panel identified several important areas that require future research evaluation.

1. The proposed grading classification system will require extensive evaluation to assess its utility in predicting clinical outcomes. Currently, the grading system is correlated with the risk of postnatal uropathies. Future research will help to further refine the classification system to one that correlates with other clinical outcomes such as the need for surgical intervention or renal function.
2. The seven sonographic parameters utilized in the UTD classification system were selected based on the current

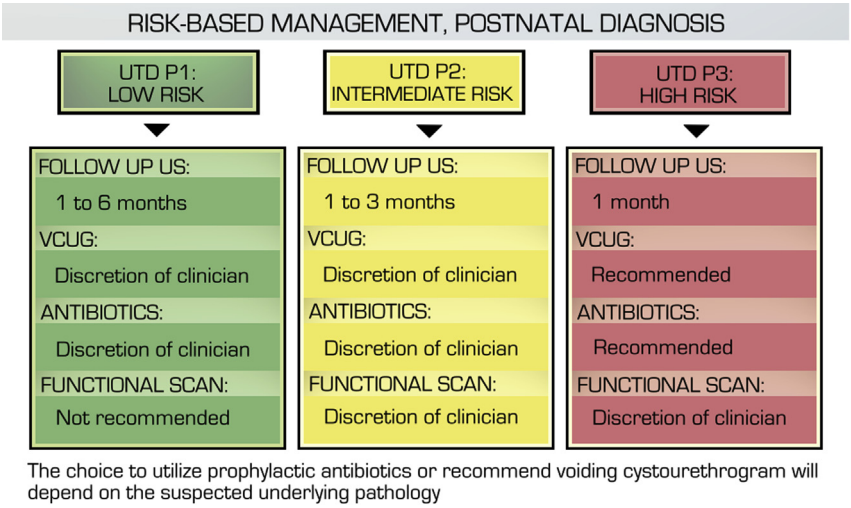

Figure 11 Management schema based on Urinary Tract Dilation (UTD) classification system risk stratification of UTD P1, UTD P2, and UTD P3.

literature. Further research may help to identify other US findings that may be more predictive of uropathies and clinical outcomes.

3. While it is beyond the scope of this consensus statement, the panel identified that the issue of UTI and the evaluation of VUR in children with prenatal UT dilation is controversial. Prospective studies in this area are needed to define the role of prophylactic antibiotic or circumcision and the clinical significance of identifying VUR in this patient population.

Conflict of interest

None.

Funding

None.

Acknowledgments

We would like to thank the American Urological Association (represented by Beverly Mannion, Kristin Pichon, and Drew Shifflet) for sponsoring and defraying the cost of the meeting, Dr. Barry A. Kogan for critically reviewing the article, and Dr. Matthew D. Timberlake for the figure illustration. The respective societies provided travel and hotel expenses for their representatives to attend this conference. None of the participants received any honorarium.

References

[1] Hamilton BE, Martin JA, Ventura SJ. Births: preliminary data for 2012. Natl Vital Stat Rep 2013;62:1—20.
[2] Ellenbogen PH, Scheible FW, Talner LB, Leopold GR. Sensitivity of gray scale ultrasound in detecting urinary tract obstruction. Am J Roentgenol 1978;130:731—3.
[3] Grignon A, Filion R, Filiatrault D, Robitaille P, Homsy Y, Boutin H, et al. Urinary tract dilatation in utero: classification and clinical applications. Radiology 1986;160:645—7.
[4] Fernbach SK, Maizels M, Conway JJ. Ultrasound grading of hydronephrosis: introduction to the system used by the Society for Fetal Urology. Pediatr Radiol 1993;23:478—80.
[5] Riccabona M, Avni FE, Blickman JG, Dacher JN, Darge K, Lobo ML, et al. Imaging recommendations in paediatric uroradiology: minutes of the ESPR workgroup session on urinary tract infection, fetal hydronephrosis, urinary tract ultrasonography and voiding cystourethrography, Barcelona, Spain, June 2007. Pediatr Radiol 2008;38:138—45.
[6] Onen A. An alternative grading system to refine the criteria for severity of hydronephrosis and optimal treatment guidelines in neonates with primary UPJ-type hydronephrosis. J Pediatr Urol 2007;3:200—5.
[7] Zanetta VC, Rosman BM, Bromley B, Shipp TD, Chow JS, Campbell JB, et al. Variations in management of mild prenatal hydronephrosis among maternal-fetal medicine obstetricians, and pediatric urologists and radiologists. J Urol 2012;188:1935—9.
[8] Keays MA, Guerra LA, Mihill J, Raju G, Al-Asheeri N, Geier P, et al. Reliability assessment of Society for Fetal Urology ultrasound grading system for hydronephrosis. J Urol 2008; 180:1680—2. discussion2—3.
[9] Kim SY, Kim MJ, Yoon CS, Lee MS, Han KH, Lee MJ. Comparison of the reliability of two hydronephrosis grading systems: the Society for Foetal Urology grading system vs. the Onen grading system. Clin Radiol 2013;68:e484—90.
[10] Siddique J, Lauderdale DS, VanderWeele TJ, Lantos JD. Trends in prenatal ultrasound use in the United States: 1995 to 2006. Med Care 2009;47:1129—35.
[11] American Institute of Ultrasound in M. AIUM practice guideline for the performance of obstetric ultrasound examinations. J Ultrasound Med 2013;32:1083—101.
[12] Whitlow BJ, Economides DL. The optimal gestational age to examine fetal anatomy and measure nuchal translucency in the first trimester. Ultrasound Obstetr Gynecol 1998;11: 258—61.
[13] Odibo AO, Marchiano D, Quinones JN, Riesch D, Egan JF, Macones GA. Mild pyelectasis: evaluating the relationship between gestational age and renal pelvic anterior-posterior diameter. Prenat Diagn 2003;23:824—7.
[14] Chitty LS, Altman DG. Charts of fetal size: kidney and renal pelvis measurements. Prenat Diagn 2003;23:891—7.
[15] Bassanese G, Travan L, D'Ottavio G, Monasta L, Ventura A, Pennesi M. Prenatal anteroposterior pelvic diameter cutoffs for postnatal referral for isolated pyelectasis and hydronephrosis: more is not always better. J Urol 2013;190: 1858—63.
[16] Nguyen HT, Herndon CD, Cooper C, Gatti J, Kirsch A, Kokorowski P, et al. The Society for Fetal Urology consensus statement on the evaluation and management of antenatal hydronephrosis. J Pediatr Urol 2010;6:212—31.
[17] Coplen DE, Austin PF, Yan Y, Blanco VM, Dicke JM. The magnitude of fetal renal pelvic dilatation can identify obstructive postnatal hydronephrosis, and direct postnatal evaluation and management. J Urol 2006;176:724—7. discussion 7.
[18] Duin LK, Willekes C, Koster-Kamphuis L, Offermans J, Nijhuis JG. Fetal hydronephrosis: does adding an extra parameter improve detection of neonatal uropathies? J Matern Fetal Neonatal Med 2012;25:920—3.
[19] Psooy K, Pike J. Investigation and management of antenatally detected hydronephrosis. Can Urol Assoc J 2009;3: 69—72.
[20] Barbosa JA, Chow JS, Benson CB, Yorioka MA, Bull AS, Retik AB, et al. Postnatal longitudinal evaluation of children diagnosed with prenatal hydronephrosis: insights in natural history and referral pattern. Prenat Diagn 2012;32: 1242—9.
[21] Dias CS, Silva JM, Pereira AK, Marino VS, Silva LA, Coelho AM, et al. Diagnostic accuracy of renal pelvic dilatation for detecting surgically managed ureteropelvic junction obstruction. J Urol 2013;190:661—6.
[22] Dicke JM, Blanco VM, Yan Y, Coplen DE. The type and frequency of fetal renal disorders and management of renal pelvis dilatation. J Ultrasound Med 2006;25:973—7.
[23] Coelho GM, Bouzada MC, Pereira AK, Figueiredo BF, Leite MR, Oliveira DS, et al. Outcome of isolated antenatal hydronephrosis: a prospective cohort study. Pediatr Nephrol 2007; 22:1727—34.
[24] Lee RS, Cendron M, Kinnamon DD, Nguyen HT. Antenatal hydronephrosis as a predictor of postnatal outcome: a meta-analysis. Pediatrics 2006;118:586—93.
[25] Ismaili K, Avni FE, Hall M, Brussels Free University Perinatal Nephrology Study G. Results of systematic voiding cystourethrography in infants with antenatally diagnosed renal pelvis dilation. J Pediatr 2002;141:21—4.
[26] Signorelli M, Cerri V, Taddei F, Groli C, Bianchi UA. Prenatal diagnosis and management of mild fetal pyelectasis:

implications for neonatal outcome and follow-up. Eur J Obstet Gynecol Reprod Biol 2005;118:154—9.
[27] Morris RK, Malin GL, Khan KS, Kilby MD. Antenatal ultrasound to predict postnatal renal function in congenital lower urinary tract obstruction: systematic review of test accuracy. BJOG 2009;116:1290—9.
[28] Feldman DM, DeCambre M, Kong E, Borgida A, Jamil M, McKenna P, et al. Evaluation and follow-up of fetal hydronephrosis. J Ultrasound Med 2001;20:1065—9.
[29] Podevin G, Mandelbrot L, Vuillard E, Oury JF, Aigrain Y. Outcome of urological abnormalities prenatally diagnosed by ultrasound. Fetal Diagn Ther 1996;11:181—90.
[30] Sairam S, Al-Habib A, Sasson S, Thilaganathan B. Natural history of fetal hydronephrosis diagnosed on mid-trimester ultrasound. Ultrasound Obstet Gynecol 2001;17:191—6.
[31] Odibo AO, Raab E, Elovitz M, Merrill JD, Macones GA. Prenatal mild pyelectasis: evaluating the thresholds of renal pelvic diameter associated with normal postnatal renal function. J Ultrasound Med 2004;23:513—7.
[32] Abdelazim IA, Abdelrazak KM, Ramy AR, Mounib AM. Complementary roles of prenatal sonography and magnetic resonance imaging in diagnosis of fetal renal anomalies. Aust N Z J Obstet Gynaecol 2010;50:237—41.
[33] Hayashi S, Sago H, Kashima K, Kitano Y, Kuroda T, Honna T, et al. Prenatal diagnosis of fetal hydrometrocolpos secondary to a cloacal anomaly by magnetic resonance imaging. Ultrasound Obstet Gynecol 2005;26:577—9.
[34] Stathopoulos L, Merrot T, Chaumoitre K, Bretelle F, Michel F, Alessandrini P. Prenatal urinoma related to ureteropelvic junction obstruction: poor prognosis of the affected kidney. Urology 2010;76:190—4.
[35] Benacerraf BR, Mandell J, Estroff JA, Harlow BL, Frigoletto Jr FD. Fetal pyelectasis: a possible association with Down syndrome. Obstet Gynecol 1990;76:58—60.
[36] Bromley B, Lieberman E, Shipp TD, Benacerraf BR. The genetic sonogram: a method of risk assessment for Down syndrome in the second trimester. J Ultrasound Med 2002;21:1087—96. quiz 97—8.
[37] Carbone JF, Tuuli MG, Dicke JM, Macones GA, Odibo AO. Revisiting the risk for aneuploidy in fetuses with isolated pyelectasis. Prenat Diagn 2011;31:566—70.
[38] Liao AW, Sebire NJ, Geerts L, Cicero S, Nicolaides KH. Megacystis at 10—14 weeks of gestation: chromosomal defects and outcome according to bladder length. Ultrasound Obstet Gynecol 2003;21:338—41.
[39] Nyberg DA, Souter VL, El-Bastawissi A, Young S, Luthhardt F, Luthy DA. Isolated sonographic markers for detection of fetal Down syndrome in the second trimester of pregnancy. J Ultrasound Med 2001;20:1053—63.
[40] Rasouly HM, Lu W. Lower urinary tract development and disease. Wiley Interdiscip Rev Syst Biol Med 2013;5:307—42.
[41] Dejter Jr SW, Gibbons MD. The fate of infant kidneys with fetal hydronephrosis but initially normal postnatal sonography. J Urol 1989;142:661—2. discussion 7—8.
[42] Laing FC, Burke VD, Wing VW, Jeffrey Jr RB, Hashimoto B. Postpartum evaluation of fetal hydronephrosis: optimal timing for follow-up sonography. Radiology 1984;152:423—4.
[43] Wiener JS, O'Hara SM. Optimal timing of initial postnatal ultrasonography in newborns with prenatal hydronephrosis. J Urol 2002;168:1826—9. discussion 9.
[44] Angell SK, Pruthi RS, Shortliffe LD. The urodynamic relationship of renal pelvic and bladder pressures, and urinary flow rate in rats with congenital vesicoureteral reflux. J Urol 1998;160:150—6.
[45] Evans ED, Meyer JS, Harty MP, Bellah RD. Assessment of increase in renal pelvic size on post-void sonography as a predictor of vesicoureteral reflux. Pediatr Radiol 1999;29:291—4.
[46] Hvarness H, Jakobsen H, Hermansen F, Marving J, Meyhoff HH. Effect of a full bladder on urine production in humans. Scand J Urol Nephrol 1999;33:386—91.
[47] Jones DA, Lupton EW, George NJ. Effect of bladder filling on upper tract urodynamics in man. Br J Urol 1990;65:492—6.
[48] Peerboccus M, Damry N, Pather S, Devriendt A, Avni F. The impact of hydration on renal measurements and on cortical echogenicity in children. Pediatr Radiol 2013;43:1557—65.
[49] Sharma G, Sharma A, Maheshwari P. Predictive value of decreased renal pelvis anteroposterior diameter in prone position for prenatally detected hydronephrosis. J Urol 2012;187:1839—43.
[50] Marks A, Maizels M, Mickelson J, Yerkes E, Anthony Herndon CD, Lane J, et al. Effectiveness of the computer enhanced visual learning method in teaching the society for fetal urology hydronephrosis grading system for urology trainees. J Pediatr Urol 2011;7:113—7.
[51] Sidhu G, Beyene J, Rosenblum ND. Outcome of isolated antenatal hydronephrosis: a systematic review and meta-analysis. Pediatr Nephrol 2006;21:218—24.
[52] Cost GA, Merguerian PA, Cheerasarn SP, Shortliffe LM. Sonographic renal parenchymal and pelvicaliceal areas: new quantitative parameters for renal sonographic followup. J Urol 1996;156:725—9.
[53] Shapiro SR, Wahl EF, Silberstein MJ, Steinhardt G. Hydronephrosis index: a new method to track patients with hydronephrosis quantitatively. Urology 2008;72:536—8. discussion 8—9.
[54] Imaji R, Dewan PA. Calyx to parenchyma ratio in pelviureteric junction obstruction. BJU Int 2002;89:73—7.
[55] Riccabona M, Fritz GA, Schollnast H, Schwarz T, Deutschmann MJ, Mache CJ. Hydronephrotic kidney: pediatric three-dimensional US for relative renal size assessment—initial experience. Radiology 2005;236:276—83.
[56] Passerotti CC, Kalish LA, Chow J, Passerotti AM, Recabal P, Cendron M, et al. The predictive value of the first postnatal ultrasound in children with antenatal hydronephrosis. J Pediatr Urol 2011;7:128—36.
[57] Longpre M, Nguan A, Macneily AE, Afshar K. Prediction of the outcome of antenatally diagnosed hydronephrosis: a multivariable analysis. J Pediatr Urol 2012;8:135—9.
[58] Aksu N, Yavascan O, Kangin M, Kara OD, Aydin Y, Erdogan H, et al. Postnatal management of infants with antenatally detected hydronephrosis. Pediatr Nephrol 2005;20:1253—9.
[59] Matsui F, Shimada K, Matsumoto F, Takano S. Late recurrence of symptomatic hydronephrosis in patients with prenatally detected hydronephrosis and spontaneous improvement. J Urol 2008;180:322—5. discussion 5.
[60] Sencan A, Carvas F, Hekimoglu IC, Caf N, Sencan A, Chow J, et al. Urinary tract infection and vesicoureteral reflux in children with mild antenatal hydronephrosis. J Pediatr Urol 2014 May 9. http://dx.doi.org/10.1016/j.jpurol.2014.04.001 [Epub ahead of print], pii:S1477-5131(14)00113-2.
[61] Herndon CD, McKenna PH, Kolon TF, Gonzales ET, Baker LA, Docimo SG. A multicenter outcomes analysis of patients with neonatal reflux presenting with prenatal hydronephrosis. J Urol 1999;162:1203—8.
[62] Nepple KG, Arlen AM, Austin JC, Cooper CS. The prognostic impact of an abnormal initial renal ultrasound on early reflux resolution. J Pediatr Urol 2011;7:462—6.
[63] Preda I, Jodal U, Sixt R, Stokland E, Hansson S. Value of ultrasound in evaluation of infants with first urinary tract infection. J Urol 2010;183:1984—8.
[64] Tibballs JM, De Bruyn R. Primary vesicoureteric reflux—how useful is postnatal ultrasound? Arch Dis Child 1996;75:444—7.

[65] Ulman I, Jayanthi VR, Koff SA. The long-term followup of newborns with severe unilateral hydronephrosis initially treated nonoperatively. J Urol 2000;164:1101—5.
[66] Braga LH, Mijovic H, Farrokhyar F, Pemberton J, DeMaria J, Lorenzo AJ. Antibiotic prophylaxis for urinary tract infections in antenatal hydronephrosis. Pediatrics 2013;131:e251—61.
[67] Gimpel C, Masioniene L, Djakovic N, Schenk JP, Haberkorn U, Tonshoff B, et al. Complications and long-term outcome of primary obstructive megaureter in childhood. Pediatr Nephrol 2010;25:1679—86.
[68] Davenport MT, Merguerian PA, Koyle M. Antenatally diagnosed hydronephrosis: current postnatal management. Pediatr Surg Int 2013;29:207—14.
[69] Kose E, Yavascan O, Turan O, Kangin M, Bal A, Alparslan C, et al. The effect of circumcision on the frequency of urinary tract infection, growth and nutrition status in infants with antenatal hydronephrosis. Ren Fail 2013;35:1365—9.
[70] Wong CJ, Moxey-Mims M, Jerry-Fluker J, Warady BA, Furth SL. CKiD (CKD in children) prospective cohort study: a review of current findings. Am J Kidney Dis 2012;60:1002—11.
[71] Nyengaard JR, Bendtsen TF. Glomerular number and size in relation to age, kidney weight, and body surface in normal man. Anat Rec 1992;232:194—201.
[72] Hostetter TH, Olson JL, Rennke HG, Venkatachalam MA, Brenner BM. Hyperfiltration in remnant nephrons: a potentially adverse response to renal ablation. Am J Physiol 1981; 241:F85—93.
[73] Remuzzi G, Ruggenenti P, Perico N. Chronic renal diseases: renoprotective benefits of renin-angiotensin system inhibition. Ann Int Med 2002;136:604—15.
[74] Ardissino G, Dacco V, Testa S, Bonaudo R, Claris-Appiani A, Taioli E, et al. Epidemiology of chronic renal failure in children: data from the ItalKid project. Pediatrics 2003;111: e382—7.
[75] Quirino IG, Diniz JS, Bouzada MC, Pereira AK, Lopes TJ, Paixao GM, et al. Clinical course of 822 children with prenatally detected nephrouropathies. Clin J Am Soc Nephrol 2012;7:444—51.
[76] Carlstrom M. Causal link between neonatal hydronephrosis and later development of hypertension. Clin Exp Pharmacol Physiol 2010;37:e14—23.
[77] Jodal U. The natural history of bacteriuria in childhood. Infect Dis Clin North Am 1987;1:713—29.
[78] Kogon AJ, Pierce CB, Cox C, Brady TM, Mitsnefes MM, Warady BA, et al. Nephrotic-range proteinuria is strongly associated with poor blood pressure control in pediatric chronic kidney disease. Kidney Int 2014;85:938—44.
[79] Navis G, Faber HJ, de Zeeuw D, de Jong PE. ACE inhibitors and the kidney. A risk-benefit assessment. Drug Saf 1996;15: 200—11.
[80] Ruster C, Wolf G. Renin-angiotensin-aldosterone system and progression of renal disease. J Am Soc Nephrol 2006;17: 2985—91.
[81] Martens DH, Rake JP, Navis G, Fidler V, van Dael CM, Smit GP. Renal function in glycogen storage disease type I, natural course, and renopreservative effects of ACE inhibition. Clin J Am Soc Nephrol 2009;4:1741—6.
[82] Reddy UM, Abuhamad AZ, Levine D, Saade GR, Fetal Imaging Workshop Invited P. Fetal imaging: executive summary of a joint Eunice Kennedy Shriver National Institute of Child Health and Human Development, Society for Maternal-Fetal Medicine, American Institute of Ultrasound in Medicine, American College of Obstetricians and Gynecologists, American College of Radiology, Society for Pediatric Radiology, and Society of Radiologists in Ultrasound Fetal Imaging Workshop. J Ultrasound Med 2014;33:745—57.

Commentary to 'Multidisciplinary consensus on the classification of prenatal and postnatal urinary tract dilation (UTD classification system)'

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Appropriate management of neonatal urinary tract dilation is a challenge to clinicians in various medical specialties. One initial obstacle to good care, or even to high-quality clinical evidence to guide care, is the lack of a widely accepted method of categorizing this problem. The development of standardized classification criteria for chronic kidney disease [1] and acute kidney injury [2,3] has allowed for large-scale studies [4,5] that have greatly advanced our understanding of these diseases. Currently, many classification schemes exist for neonatal urinary tract dilation, none of which are widely accepted by all medical specialties involved in the care of patients with this condition.

A new classification and management strategy for neonatal urinary tract dilation is proposed in this issue of the *Journal of Pediatric Urology*. It represents a multidisciplinary consensus among radiologists, urologists, maternal-fetal medicine practitioners, and nephrologists. This has great appeal. It allows for all clinicians caring for neonates with urinary tract dilation to have a common language for communication. Representatives from all interested parties participated in the development of this document. There are explicit criteria for classification that are clear and (for the most part) objective. There are a small number of categories for classification, which lends itself to outcomes-oriented research as well as to communication with patients.

While this consensus statement is useful, it does not resolve all the obstacles to excellent care of patients with neonatal urinary tract dilation. It will be meaningful only if its classification system is widely adopted. As the authors acknowledge, management recommendations are vague. This reflects both the lack of conclusive evidence to guide management and the wide variability in current clinical practice. As with any guideline, there will be isolated clinical situations where application will not be appropriate.