The role of ultrasound in investigating paediatric urinary tract infections for urinary structural defects at Chris Hani Baragwanath Academic Hospital

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Background. The number of paediatric genitourinary ultrasounds performed with an indication of urinary tract infection (UTI) is abundant. However, there are minimal data regarding whether UTI is an appropriate indication for determining whether urinary structural defects (USD) will be identified.
Objectives. To quantify structural urinary tract defects identified in the paediatric population presenting with a UTI. Furthermore, diagnoses will be assessed according to sex and age group.
Methods. A retrospective review of 180 cases of paediatric ultrasounds was done, with an indication of UTI. Data were collected at Chris Hani Baragwanath Academic Hospital (CHBAH) from March 2022 to November 2022. USDs, as well as the normal ultrasounds, were identified and quantified.
Results. Twelve different structural urinary tract defects were found in this study. The most common being hydroureteronephrosis. Duplex collecting system and pelviureteric junction obstruction were the second most common. USDs were more common in males than females, but the incidence was equal in all age groups.
Conclusion. There was no statistical relationship between a diagnosis of UTI in children and the presence of a USD. Furthermore, once a urinary structural tract defect was identified, there was no statistical relationship between the diagnosis and age or sex.

Keywords. urinary tract infection; paediatric; ultrasound; structural urinary tract defects; duplex collecting system; pelviureteric junction obstruction; hydroureteronephrosis; posterior urethral valves.

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Urinary tract infections (UTIs) are prevalent in the paediatric population and can lead to serious complications if not treated properly. UTIs are common in the paediatric population – ~8% of girls and 2% of boys will develop a UTI by the age of seven.[1] Urinary structural defects (USDs) commonly cause recurrent UTIs in children but the appropriate approach to investigation remains controversial and differs between regional and institutional guidelines.[1] Ultrasound investigation can be used to detect urinary structural abnormalities – it is a non-invasive and cost-effective imaging modality.[2]

The primary role of ultrasound in the paediatric setting is to identify and locate structural urinary tract defects to prevent short- and long-term sequelae, including chronic kidney disease and early-onset hypertension.[3] Fifty-five percent of children with posterior urethral valves (PUVs) develop urinary incontinence-associated bladder dysfunction.[4] Pelviureteric junction (PUJ) obstruction may lead to complete loss of functioning of the affected kidney, and one study determined that 26% of children with vesicoureteric reflux (VUR) developed permanent kidney damage.[5,6] These complications further highlight the need for early detection to initiate prompt management of these conditions. The detection of a urinary structural abnormality and subsequent treatment will prevent recurrence of UTIs, which will aid in the prevention of antibiotic resistance.[7]

This study aims to assess the number of structural urinary tract defects identified in the paediatric population presenting with UTIs, quantify the defects noted, and see if certain defects have an increased prevalence in certain age groups or if the defects are more prevalent based on sex.

Methods

A retrospective, cross-sectional study was performed in a single tertiary hospital. The study population included patients from birth to the age of 12 years who presented for an ultrasound of the kidneys, ureters and bladder (KUB) with an indication of UTI. The sample was taken from March 2022 until November 2022. The total number of cases that met the inclusion criteria was 180. The patients included in the study were either born at CHBAH, presented directly to CHBAH or met criteria for referral to CHBAH from other hospitals or clinics.

Ultrasounds were performed by doctors with varying levels of expertise, including radiology registrars and consultants in the Department of Radiology. The main objective of the ultrasounds was to identify structural defects in the urinary system. The ultrasounds were reported according to pre-existing templates and protocols implemented by the department. The ultrasound machine used was a single Canon Aplio 400 (Canon Medical Systems Corp., Japan). Portable ultrasound reports uploaded onto

CHBAH's Picture Archiving and Communication System (PACS) from various paediatric wards and intensive care units were also used. Upon diagnosing a structural defect or symptoms suggestive of a structural defect, patients were evaluated for associated complications, and additional study modalities were suggested where necessary. Certain pathologies, such as PUVs and PUJ obstruction, revealed secondary signs on ultrasound, and further studies were obtained to confirm the diagnosis. Pathologies such as hydronephrosis, hydroureter, duplex collecting systems, kidney agenesis and duplex kidneys were diagnosed using the initial ultrasound.

Data were collected from the previous PACS at CHBAH. The indication for the study was then confirmed by assessing the patient history provided by the clinician and noted on the ultrasound report. Collected data included the age of the patient, sex, presence of a structural defect and the name of the structural defect identified. These structural defects were then grouped based on pathology noted, age distribution and sex.

The data were analysed using SPSS Statistics (version 29; IBM Corp., USA). Descriptive statistics were presented as frequencies. Patients' age and sex were profiled, and the nature and prevalence of urinary tract infections and structural urinary tract abnormalities within the study sample were quantified. Pearson's chi-squared test was used to compare urinary tract infections and structural urinary tract abnormalities findings within the different age groups, i.e. neonates (0 - 4 weeks), infants (4 weeks - 1 year) and children (1 - 12 years). The Fisher's exact test was used for similar comparisons based on the patients' sex. Statistical significance testing was set at the 95% confidence level, and therefore, *p*-values lower than 0.05 denoted statistical significance.

Ethics

Approval was obtained from the University of the Witwatersrand Human Research Ethics Committee (ref. no. M230974) and the National Health Research Database (ref. no. GP_202307_041). Further approval to conduct the present study at CHBAH, including permission to access and use their PACS database, was granted by the Head of Radiology and Chief Executive Officer of CHBAH. No identifiable information was collected from the patients' reports. No informed consent was required as this was a retrospective study. All efforts to ensure patient anonymity and confidentiality were implemented.

Results

USDs were identified in children from birth until 12 years of age. Of the 180 patients who presented with a UTI, 22 had a USD identified (12.2%). Significantly (p=0.00002), of the study population presenting with UTI for an ultrasound, the males represented almost double the number of females (118 males v. 61 females) with a ratio of 1.9:1.

Forty-three percent of the USDs were present in patients between birth and 1 year of age, and 57% of the identified structural urinary defects were present between 1 and 12 years of age. Seventy-six percent of the diagnosed USDs were male, with a male-to-female ratio of 3.2:1. Furthermore, 13% of males presenting with a UTI had a USD compared with 8% of females presenting with a UTI. The most common USD identified was hydroureteronephrosis without an ultrasound-discernible cause. A duplex collecting system and PUJ obstruction were the next most prevalent USDs identified (Fig. 1).

Of the 37 neonates, two patients had USDs, which included a duplex collecting system and PUJ obstruction with resultant hydronephrosis. Of the 59 patients who presented during their infancy period, 5 patients had USDs identified (8%) and in the 1 - 12-year group, 12 (14%; n=12/82) of the children had USDs identified. The patients' age was statistically insignificant (p=0.76), possibly owing to a limited sample size.

Duplex collecting systems and PUJ obstructions were identified within each age group, with one case of PUJ obstruction and one case of a duplex collecting system identified in the neonatal, infancy and childhood period (1 - 12 years of age). Only one case of PUV was identified (in a 2-year-old male). VUR was found in one male infant. Hydroureteronephrosis, however, was seen in five cases between the ages of 1 and 12 years, with only one case each seen in a neonate and infant. The prevalence of different urinary tract structural defects varied between the age groups, with no statistically significant age predilection for any defect.

A total of 118 males and 61 females were included in the study, with 13.5% (n=16/118) of the males and 8.1% (n=5/61) of the females diagnosed with USDs, respectively. The distribution of diseases, which included duplex collecting system, hydroureteronephrosis and PUJ obstruction, were no different between the two sexes. Kidney agenesis and VUR were identified in one case each, both in males. The patients' sex, however, was also found to be statistically insignificant when predicting the identification of USDs in children presenting with UTIs (p=0.33).

In the isolated case of a suspected cystic partially differentiated nephroblastoma, the patient had a subsequent computed tomography (CT) scan of the abdomen, which further suggested the kidney pathology suspected. The patient was, however, subsequently lost to follow-up.

Of the 180 patients with a UTI presenting for an ultrasound, 87.8% of the ultrasounds were normal, with no concerning features for USDs or other incidental pathological or variant findings.

Discussion

Ultrasound is, and should remain, the primary investigative or screening modality when evaluating for USDs in children who present with a UTI. Although the incidence of pathology identified in this study remained low, the modality is non-invasive and does not expose the child to ionising radiation.[7] The benefit of ultrasound is that it can depict differing kidney sizes, structural anomalies or variants, positional anomalies, hydronephrosis, hydroureter and bladder abnormalities.[8] The major disadvantages of using ultrasound alone in detecting structural urinary tract defects are that there is poor anatomical detail of the lower urinary tract, it is operator-dependent, and no information on kidney function or detection of VUR is gathered.[9]

Our findings align with previous research indicating that while UTIs are common in the paediatric population, the incidence of patients presenting with a UTI and having structural urinary tract defects identified is relatively low.[10]

Duplex collecting systems were the second equal most prevalent primary pathology in this population group, with four cases identified and one case of a duplex kidney, but the numbers are small and thus should be treated cautiously. This finding was in keeping with a retrospective analysis by Visuri *et al.*,[11] who found that a duplex collecting system is high-risk for the development of a UTI despite prophylactic antibiotics. A duplex kidney refers to two separate pelvicalyceal systems draining a single kidney parenchyma (Fig. 2). Symptomatic UTIs are most commonly caused by a duplex collecting system, with a duplex kidney draining into a completely duplicated ureter (double ureter).[12] Ultrasound is helpful in identifying this pathology when hydronephrosis is present.[12]

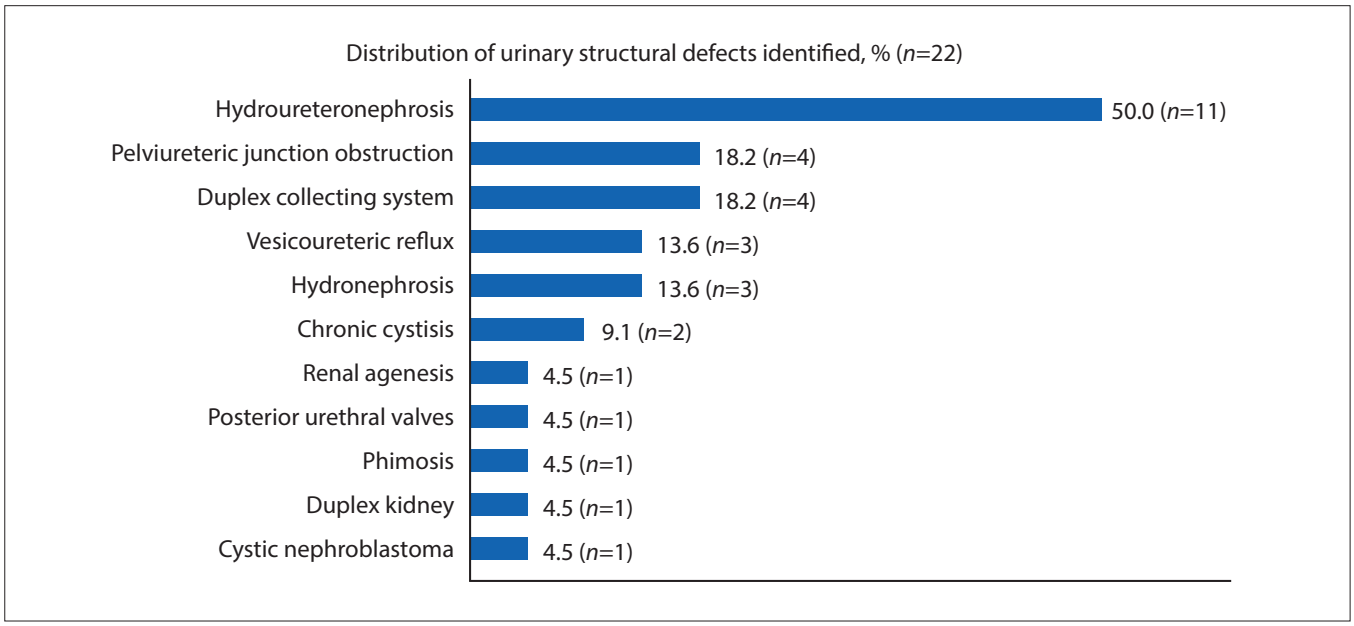

Fig.1. Percentage distribution (with frequency) of identified urinary structural defects.

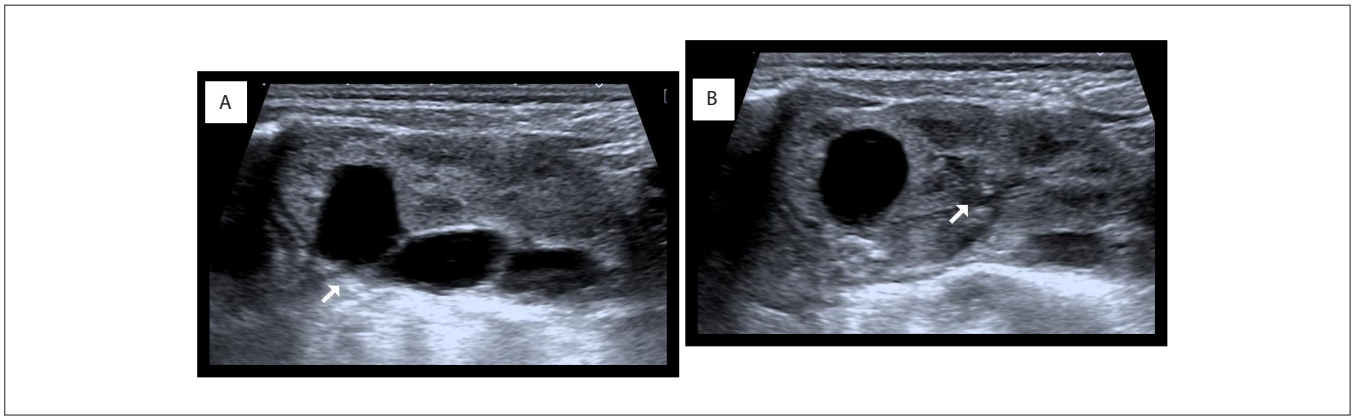

Fig. 2. Ultrasound images of a left duplex collecting system with a dilated upper moiety (A) and an undilated lower moiety (B) of the left kidney.

The other equally common USD identified in this study was PUJ obstruction. PUJ obstruction can be acquired or congenital, with congenital being one of the most common causes of hydronephrosis.[13] Out of the four PUJ obstruction cases, three presented with hydronephrosis and one with an isolated dilated renal pelvis. The consequences of this pathology are significant, especially with its association with UTIs.

Only one case of PUV was identified in the present study. This may be because ultrasound can only identify secondary signs, such as hypertrophy with significant distention of the bladder, hydroureter with (or without) hydronephrosis, kidney dysplasia (in severe cases) or a visible keyhole sign (Fig. 3), which is the proximal dilated urethra with a thick-walled, distended bladder.[14] The PUV of our single patient was confirmed on a subsequent voiding cystourethrogram (VCUG), the best imaging technique to diagnose this condition.[15]

VUR was identified in 3 of the 180 patients. Secondary features of VUR were visualised on ultrasound, which led to a high index of suspicion of the diagnosis. A unilateral dilated ureter or kidney prompted the radiologists to perform a VCUG, which subsequently confirmed VUR as an isolated abnormality in each case. The incidence of VUR in children presenting with UTIs is between 25% and 40% worldwide.[16]

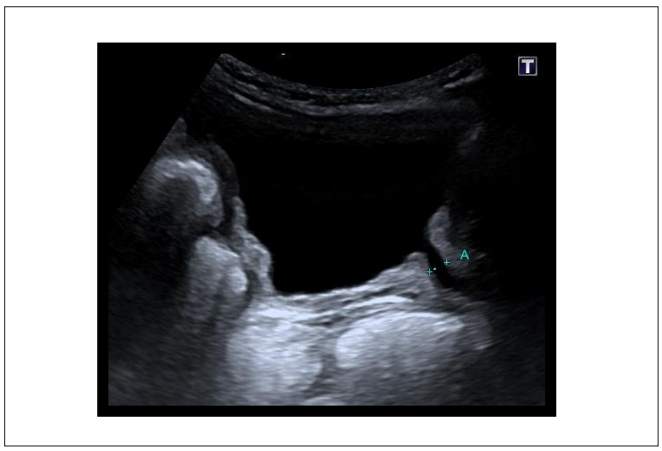

Fig. 3. Ultrasound of secondary signs of posterior urethral valves, with an elongated and dilated posterior urethra demonstrating the 'keyhole sign'.

One case of right kidney agenesis was identified. This refers to the congenital absence of one or both kidneys. If bilateral, the condition is fatal; however, if unilateral, patients typically have a normal life expectancy.[17] Even though our patient presented with a UTI, identifying this anomaly was thus thought to be purely incidental

but remained a significant finding. The gold standard for kidney agenesis diagnosis is ultrasound, which can now be identified *in utero* on antenatal imaging.[17]

An extremely rare case of cystic partially differentiated nephroblastoma was suspected in one of the study patients. These tumours are multilocular and exclusively cystic and are indistinguishable from paediatric nephromas.[18] Patients may present with an abdominal mass, haematuria or a UTI.[18] In our case, a subsequent CT scan strengthened the suspicion of the diagnosis. However, the patient was subsequently lost to follow-up.

In our study population, only 12.2% of the patients presenting with a UTI were found to have a USD or features suggestive of a USD. Ultrasound is considered a cost-effective and safe investigative modality, successfully identifying defects in 22 of the 180 patients assessed in this study.

Study limitations and recommendations

The patients included in the study presented to CHBAH. This excluded a large population of paediatric patients who may have had their UTI treated at clinics and/or other healthcare facilities. As UTIs are not an indication for admission to a hospital, a large proportion of patients were not represented in the study. Handwritten results of portable ultrasounds were not included in the present study if they were not uploaded onto PACS. This inherent bias may account for the limited amount of USDs identified, thus limiting the statistical significance of the results.

The ultrasound findings are operator-dependent and ultrasounds were performed by radiologists of varying levels of expertise, ranging from senior radiology registrars to paediatric radiology consultants. Findings thus became dependent on ultrasound technique, ability and the user's experience.

As mentioned, certain USDs are not diagnosed with ultrasound as the gold standard. If there is a high suspicion of a specific USD with a normal ultrasound, specific protocols need to be implemented to perform other investigative modalities with a higher sensitivity and specificity. Examples include a Tc-99m DMSA scan for kidney scarring or pyelonephritis or VCUG for VUR, in which ultrasound is not as sensitive.[19,20] These modalities tend to have a much higher cost burden than ultrasound, which is especially relevant in resource-limited settings like South Africa. Another vital consideration is adherence to the ALARA (as low as reasonably achievable) principle, which serves as a standard for minimising radiation exposure in children. This principle limits how much radiation paediatric patients can safely receive during radiological investigations. While radiation exposure carries inherent risks, each case should be evaluated by weighing the benefits of obtaining a diagnosis against these risks.

Conclusion

There was no statistical relationship between a diagnosis of UTI in children and the presence of a USD. Furthermore, once a urinary structural tract defect was identified, there was no statistical relationship in diagnoses based on age or sex. In most cases, UTIs in children were spontaneous, which was in keeping with the international literature; however, there were a number of cases in which an ultrasound did prove useful to identify an underlying USD.

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Author contributions. SS was the principal investigator, involved in ethics approval, literature review, data collection, statistical analysis, article write-up and image selection. NCC and HMB were the principal supervisors and assisted with review of the work throughout the protocol development and research write-up.

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