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CAN ULTRASONOGRAPHY OR UROFLOWMETRY PREDICT WHICH CHILDREN WITH VOIDING DYSFUNCTION WILL HAVE RECURRENT URINARY TRACT INFECTIONS?

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ABSTRACT

Purpose: It has been suggested that in children with voiding dysfunction improper bladder emptying contributes to recurrent urinary tract infections (UTIs) and progressive renal scarring. Incomplete bladder emptying may be related to bladder-sphincter dyssynergia. Ultrasonography and uroflowmetry are used in the initial evaluation of many children with voiding dysfunction. We determine in children with voiding dysfunction whether incomplete bladder emptying has an important role in the pathogenesis of urinary tract infections and whether abnormal ultrasonography or uroflowmetry can predict which children are at increased risk of recurrent UTIs.

Materials and Methods: In this retrospective cohort study charts of 148 consecutive patients diagnosed with voiding dysfunction were reviewed for information regarding residual urine volumes on initial post-void ultrasound and the number of urinary tract infections on followup. Initial uroflowmetry curves were blindly reevaluated for this study.

Results: Considerable (greater than 10% predicted) post-void residual urine volumes were seen on 15% of ultrasounds, and 78% of uroflowmetry studies were characterized as abnormal. The volume of residual urine (corrected for age) showed a positive correlation with the number of UTIs occurring after the initial visit ($r = 0.3$, $p < 0.002$). There was no correlation between an abnormal uroflow pattern and number of subsequent UTIs.

Conclusions: Although increased residual urine on post-void ultrasound increases the risk of UTI recurrence in children with voiding dysfunction, it does not allow accurate identification of specific children at risk.

KEY WORDS: urinary tract infections, urination disorders, urodynamics

Some children with voiding dysfunction suffer from recurrent urinary tract infections (UTIs) and progressive renal scarring. It has been suggested that in these children improper bladder emptying is an important pathophysiological factor. Previous studies have produced conflicting results. In a study of children with neurogenic bladder undergoing intermittent catheterization those with increased volume of residual urine were more likely to be bacteriuric.[1] In 76 women referred to a nephrology clinic for UTIs increased residual urine volume correlated with subsequent UTIs.[2] In contrast, among children receiving biofeedback for voiding dysfunction the mean residual urine volumes were not significantly different between those with and without recurrent UTIs.[3]

Incomplete bladder emptying has been thought to be related to bladder-sphincter dyssynergia. Ultrasonography to detect incomplete emptying and uroflowmetry to detect bladder-sphincter dyssynergia are used in the initial evaluation of many children with voiding dysfunction. We determine in children with voiding dysfunction whether incomplete bladder emptying has an important role in the pathogenesis of urinary tract infections and whether abnormal ultrasonography or uroflowmetry can predict which children are at increased risk for recurrent UTIs.

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MATERIALS AND METHODS

Medical records of consecutive children diagnosed with voiding dysfunction between January 2001 and December 2002 at the urology clinic of the Children's Hospital of Pittsburgh were reviewed in July 2003. Children with voiding dysfunction secondary to neurological or anatomic abnormalities or those who had received prior treatment for voiding dysfunction were excluded from study. All children were toilet trained. A comprehensive clinical evaluation was performed in all children at the initial visit to the urology clinic. Post-void bladder imaging ultrasound was routinely ordered on all patients at the time of initial diagnosis. Volume of residual urine was calculated using the formula ht*breadth*width*0.72. Uroflowmetry including anal electromyography was performed using Laborie® urodynamic system equipment on select patients at the discretion of the attending urologist.

In this retrospective cohort study charts were reviewed for information regarding demographics (age, sex, race), clinical data (symptoms of voiding dysfunction, constipation, vesicoureteral reflux, previous treatment), number of UTIs between diagnosis of voiding dysfunction and the time of chart review (referred to as subsequent UTIs), followup duration (mean 19 months, range 7 to 30), number of previous UTIs as reported by the parent at the time of the initial urology evaluation, post-void bladder ultrasound results at the time of initial urology evaluation, initial uroflowmetry results and number of followup visits during the study period (for a random sample of 90 study children). The Human Rights Committee at the Children's Hospital of Pittsburgh approved the study.

Presenting symptoms

Symptom	Total No. Evaluable	No. (%)
Daytime incontinence	148	130 (88)
Urgency	148	128 (87)
Frequency	148	78 (53)
Encopresis	148	52 (35)
Constipation	146	114 (78)
Nighttime enuresis	147	97 (66)

Urinary tract infection was defined as growth of greater than 100,000 colony-forming units per ml of a single uropathogen in a clean catch specimen. Residual urine volumes obtained from the initial post-void ultrasound were converted to percentiles by dividing the actual volume by the expected bladder volume for age. Expected bladder volumes in ml for children 4 to 10 years old were calculated using the formula (age+2) × 30. Although there is no consensus as to which formula is most accurate for estimating bladder capacity in children,[4] the formula chosen has been used in most recent pediatric urology literature. To determine if use of a different formula could influence results, we also analyzed data using the formula (age/2)+6 = capacity in ounces.[5] A volume of 400 ml was used as the expected volume for children 11 years old or older.

For the purpose of this study clinically significant residual urine was defined using the International Children's Continence Society cutoff of greater than 10% of bladder capacity.[6] Uroflow curves were blindly reevaluated by a single investigator (SGD). Uroflow studies were characterized as inadequate if volume voided was insufficient to produce an acceptable study. The flow curves were categorized as normal (bell shaped) or abnormal (spiked, saw tooth or plateau). The presence or absence of dyssynergia (concurrent contraction of bladder and anal muscles) and peak urine flow rate were also recorded. All reported significance levels are 2-sided. Pearson's correlation was used to analyze the relationship between continuous variables and Spearman's correlation was used to analyze the relationship between ordinal variables. SPSS (SPSS, Inc., Chicago, Illinois) was used for the analysis of data.

RESULTS

The study included 148 patients with a clinical diagnosis of voiding dysfunction, of whom 46 (31%) were males and 102 (69%) were females. Of the children 120 (89%) were white, 19 (13%) were black and 9 (6%) were of unknown or other race. Mean patient age was 8.9 years (range 4 to 18). Voiding dysfunction symptoms were present for 6 months or longer in 137 (85%) children. Mean patient age at toilet training was 33.1 months. The number of previous UTI was 0 in 83 (56%) children, 1 to 2 in 14 (10%) and 3 or more in 51 (34%). Of the 104 children who had undergone voiding cystourethrography previously 17 (16%) demonstrated vesicoureteral reflux. Two children had a history of hydronephrosis. Among the children who underwent ultrasound at the initial visit 91% had at least 1 followup visit during the study period, 65% had 2 or more visits and 51% had 3 or more visits. Symptoms present at the time of initial evaluation are summarized in the table.

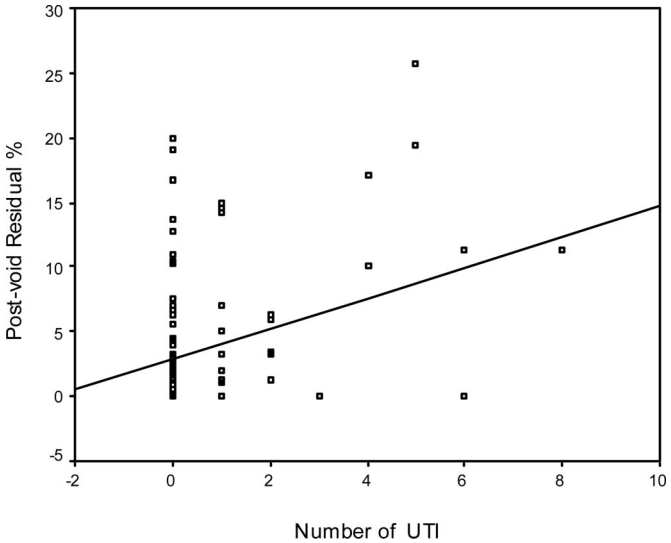
Residual urine and number of urinary tract infections. Of the patients 121 (82%) underwent a post-void ultrasound at the time of the initial visit. Mean post-void residual (PVR) urine volume calculated from initial ultrasound measurements was 15 ml and 18 (15%) children had a PVR greater than 10% of the expected bladder capacity for age. Six (4.8%) patients had bladder wall thickening.

The mean number of subsequent UTIs was 0.6. The number of subsequent UTIs was 0 in 112 (76%) children, 1 to 2 in 23 (16%) and 3 or more in 12 (8%). Information regarding number of subsequent UTIs was missing for 1 child who was excluded from this analysis. There was a positive correlation ($r = 0.3$, $p < 0.002$) between volume of residual urine on initial post-void ultrasound (corrected for expected bladder capacity) and number of subsequent UTIs (see figure).

Of the demographic and clinical variables only female gender, vesicoureteral reflux , and previous UTIs correlated with number of UTIs after the initial visit. The correlation between residual volume and number of subsequent UTIs did not change significantly after controlling for these 3 variables ($r = 0.33$, $p < 0.002$). Similarly, the results did not change significantly when we used a different formula for predicted bladder capacity,[5] absolute bladder volumes (without correcting for age) or a different cutoff (5% and 15% bladder capacity) for clinically significant residual volume. We also conducted ROC analysis to try to determine the diagnostic accuracy of increased PVR in predicting any subsequent UTI (1 UTI or more). The area under the ROC curve was 0.617, and there was no threshold above which risk of developing UTI increased appreciably. Of the 18 children with significant PVR (greater than 10% expected bladder capacity) 9 had no subsequent UTI. There was a similar correlation between residual volume on initial post-void ultrasound (corrected for expected bladder capacity) and the number of previous UTIs (Pearson's $r = 0.2$, $p = 0.01$).

Uroflow pattern and number of UTIs. Of the 78 cases evaluated with uroflowmetry at the time of the initial visit 17 (22%) were characterized as normal and 61 (78%) as abnormal. Flow pattern curve was saw shaped in 33 (54%) cases, plateau shaped in 20 (33%) and bell shaped in 8. No correlation was seen between an abnormal uroflow pattern and number of previous ($r = 0.05$, $p = 0.6$) or subsequent ($r = 0.02$, $p = 0.9$) UTIs. There was no correlation between an abnormal uroflow pattern and volume of residual urine on post-void ultrasound ($r = 0.09$, $p = 0.4$) even when the analysis was limited to studies performed on the same day.

Anal EMG was performed in 80 children at initial evaluation, which revealed dyssynergia in 20 (25%). Dyssynergia did not correlate with number of previous UTIs ($r = 0.02$, $p = 0.8$), volume of residual urine ($r = 0.17$, $p = 0.2$) or number of subsequent UTIs ($r = 0.07$, $p = 0.9$). Similarly, peak flow velocity did not correlate with the number of subsequent UTIs.



Correlation between post-void residual urine percent (post-void residual urine volume divided by expected bladder capacity for age) and number of UTIs.

DISCUSSION

Residual urine in the bladder has often been cited as a factor in the recurrence of urinary tract infections. Our findings suggest that post-void residual urine is a risk factor for UTI recurrence. Although children with higher PVR volumes have a higher risk than those with lower PVR, no threshold volume (above which risk of UTI increased dramatically) could be identified in our study. Furthermore, the weak correlation between the 2 variables is insufficient to allow accurate prediction of those children at risk for recurrent UTIs. While a child with increased residual volume is at increased risk for recurrent UTIs, most children with residual urine do not have recurrent UTIs, which is likely secondary to the multifactorial etiology of UTIs. Since multiple factors contribute to the development and recurrence of UTI in children with voiding dysfunction, no single factor is likely to correlate strongly with UTI recurrence.

The use of uroflowmetry in the initial evaluation of children with voiding dysfunction has not been extensively studied. Our findings suggest that uroflowmetry is not useful in the prediction of subsequent UTIs. To our surprise, there was no correlation between uroflow or electromyography results and volume of residual urine on ultrasound. In a recent study of asymptomatic children without a history of UTIs evaluated with ultrasonography and uroflowmetry there was also little agreement between post-void residual urine volumes and type of uroflow curve.[7] Perhaps the results of either the post-void ultrasound or uroflowmetry are influenced by the child's experience and comfort with the procedure and equipment. Further study into the reliability, accuracy and clinical significance of uroflowmetry is warranted.

The main limitation of our study is the possibility of selection bias, as not all patients who were prescribed a post-void ultrasound had one done, not all patients were evaluated using uroflowmetry and not all patients returned for planned followup visits. Nevertheless, since the majority (91%) of patients who underwent ultrasound returned for at least 1 followup visit, we do not suspect therapeutic adherence to be a significant confounder in the relationship between residual urine and UTIs. Our study did not have sufficient power to determine whether the correlation between residual urine volume and subsequent UTIs is present in important subgroups (for example, in those receiving anticholinergics, antibiotics or biofeedback). Larger prospective studies are needed to answer questions about such subgroups.

CONCLUSIONS

Although increased residual urine on post-void ultrasound increases risk of UTI recurrence in children with voiding dysfunction, it does not allow accurate identification of specific children at risk. Uroflowmetry is not useful in discriminating children at risk for recurrent UTIs.

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DISCUSSION

Dr. Walid Farhat. Which flow rates did you study? Did you use the first one or did you study all of the flow rates done in those patients?

Dr. Nader Shaikh. We used the initial uroflow rate at the time of diagnosis of voiding dysfunction.