Are we accurately predicting bladder capacity in infants?

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Abstract

Introduction: Estimating bladder capacity is an important component in the evaluation of many urological disorders. For estimates to be of clinical value, precise reference ranges are needed. While accepted reference ranges have been established in adults and older children, none have been validated in infants. We endeavour to determine the normal bladder capacity of children less than 1 year of age.

Methods: We retrospectively reviewed the charts of children aged 0 to 12 months with cutaneous stigmata of spinal dysraphism who were referred to the urology clinic to rule out tethered cord between October 2004 and July 2011. Patients with normal urologic assessment, who did not have surgery during the time they were followed, were included in the study cohort. Urodynamic studies were performed using the Laborie Medical Technologies UDS-600. Bladder filling occurred via a catheter at a rate of 10% of the expected total bladder capacity/minute. Bladder capacity was defined as the volume of filling when the child voided around the catheter. We collected data, including age at urodynamics, bladder capacity, detrusor pressure at capacity, bladder compliance and length of follow-up.

Result: In total, 46% (84/183) of patients had a normal urologic assessment and met the inclusion criteria. The median age was 9.0 months (interquartile range [IQR] 6.8-11.0). The average bladder capacity was 48.9 mL (standard deviation [SD] 32.8) and the mean detrusor pressure at capacity was 8.5 cmH_2O (SD 10.0). Mean compliance was 14.1 mL/cmH_2O (SD 13.6). The average length of follow-up was 40.7 months (SD 26.2) and during this interval no patients were found to have urologic or neurologic abnormalities and none underwent tethered cord release.

Conclusion: Bladder capacity in infants with a median age of 9.0 months was found to be 48.9 mL. This is less than half of the volume predicted by a commonly employed formula. A novel method of estimating bladder capacity in infants is required.

Introduction

Bladder capacity is a useful diagnostic parameter to evaluate many urologic diseases. Accurate estimates are essential to ensure reliable urodynamic assessments of infants. Furthermore, an abnormal bladder capacity in an otherwise normal child may be the first indication of significant underlying pathology. Knowledge of patients' estimated bladder capacity can be used to plan the volume of fluid instilled into the bladder during diagnostic tests. There have been case reports of bladder rupture secondary to overfilling during voiding cystourethrogram (VCUG)[1,2] in children, and this may reflect a poor understanding of the normal physiological bladder capacity of this age group. While formulas have been proposed for different patient populations, none of these have been validated in children under a year old. We assess the bladder capacity in normal children under a year old and compare our results to those predicted by the available formulas.

Methods

The study design was approved by the research ethics board at the Children's Hospital of Eastern Ontario (CHEO). We retrospectively reviewed charts of infants undergoing urodynamics. Bladder capacity was measured in children undergoing urodynamic testing at CHEO between October 2004 and July 2011. The study population consisted of patients with cutaneous stigmata of spinal dysraphism referred to rule out occult spina bifida. Patients with normal urologic assessment, defined as those not undergoing surgery for release of tethered cord, normal ultrasound of the abdomen and pelvis, and normal urodynamic testing, were included in the study cohort. All patients underwent a spinal ultrasound, magnetic resonance imaging or both and were assessed by the neurosurgery team. Studies were performed by a dedicated urodynamicist nurse using the Laborie Medical Technologies UDS-600 Urodynamics System. Following sterile catheter

placement, bladder filling was performed at 10% of the expected total bladder capacity per minute. Bladder capacity was determined at the time of spontaneous patient voiding around the catheter or when the child could not tolerate more volume. In addition to bladder capacity, patient data, including age, gender, detrusor pressure at capacity, bladder compliance and the presence of involuntary contractions, were recorded. Statistical analyses were performed using SAS software version 9.3 (SAS Institute, Cary, NC) and a *p* value of 0.05 was considered significant.

Results

Of the 183 consecutive patients who underwent urodynamic testing from October 2004 through July 2011, 84 (46%) patients had normal urologic assessments, had no surgery for tethered cord during the follow-up period and consequently met study inclusion criteria. The median age was 9.0 months (interquartile range [IQR] 6.8-11.0). The average bladder capacity was 48.9 mL (standard deviation [SD] 32.8). The mean detrusor pressure at capacity averaged 8.5 cmH_2O (SD 10.0), while the mean number of uninhibited detrusor contractions was 1.5 (SD 2.2). The mean bladder compliance was 14.1 mL/cmH_2O (SD 13.6). The average length of follow-up was 40.7 months (Table 1).

Discussion

Estimating bladder capacity is an important component in the evaluation of many urological disorders in children. Significant abnormal bladder capacity may suggest underlying pathology. Currently, no formula for predicting bladder capacity has been validated for infants under a year old. In this study, we reviewed data for infants who underwent urodynamic studies to rule out tethered cord and who were deemed free of urologic pathology. We found that children with a median age of 9.0 months had a mean bladder capacity of 48.9 mL. This is less than half of the volume calculated by many commonly employed formulas for a cohort of children with the same age (Fig. 1).

Critical work in this field was pioneered by Starfield and colleagues[3] and Koff and colleagues;[4,5] the latter group developed the formula [age + 2 (years)] for predicting bladder capacity in ounces. Koff's study was performed with children under anesthesia for hypospadias repair and has been subsequently shown to overestimate bladder capacity.[6] A revision was made to this formula by Rittig and colleagues who suggested that a more precise estimation would be obtained by using [age (years) + 1][7] bladder capacity in ounces. Kaefer and colleagues,[8] in an effort to improve the estimation in younger children, subsequently re-defined 2 linear equations for predicting bladder capacity and indicated that [2 × age (years) + 2] is appropriate for children under 2 years old for volume in ounces as well. Formulas that predict volume in ounces are often modified with a multiplier of 30 to achieve a value of millilitres. It is noteworthy that significant changes in children's growth and development occur during the first year of life, reflecting a quick increase in bladder capacity over this interval. For this reason, a formula derived specifically from a population of infants may yield a more accurate estimate.

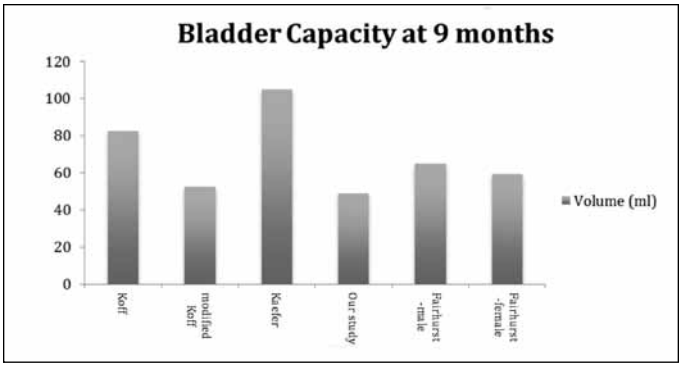

Fig. 1. Comparison of bladder capacity at 9 months: Study versus previously proposed formula.

Smaller studies have evaluated bladder capacity in a non-invasive fashion, such as a study by Holmdahl and colleagues. The authors reported on observational assessment of infants for 4 hours measuring the volume of spontaneous voids and subsequent post-void residuals using a suprapubic bladder scan.[9] While this approach attempts to simulate a natural environment, it is time consuming and relies strongly on the mother to monitor each child's void; however on the positive side, this method provides an assessment under a more physiological environment. This observational study may be affected by several factors, such as the amount of fluid the child drank during the study period and the assessor's skills in using suprapubic scan to evaluate capacity.

A similar observational approach was taken by Chung and colleagues.[10] Children aged 0 to 24 months were studied

Table 1. Study population demographic and urodynamic data

	Age (months) median/IQR	Capacity (mL)	Pdet at capacity (cmH2O)	Detrusor contractions, no	Compliance (mL/cmH2O)	Follow up (months)
Mean	9.0	48.9	8.5	1.5	14.1	40.7
SD		32.8	10.0	2.2	13.6	26.2
95% CI	6.8-11.0	41.9-55.9	6.4-10.7	1.1-2.0	11.2-17.0	

IQR: interquartile range; Pdet: detrusor pressure; SD: standard deviation; CI: confidence interval.

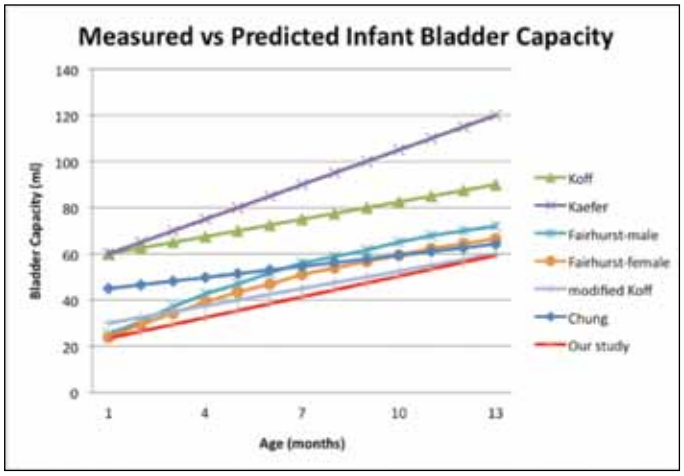

Fig. 2. Comparison of predicted and measured bladder capacity and age.[12]

for 2 days. Voided volumes were measured and the largest volume was considered the child's bladder capacity. These values were then used to create formulas using weight or age as the independent variable. Interestingly, the formula [1.6 × age (months) + 45] derived from this study overestimates the measured capacity in our study. Similarly to other study populations, this range of age may be too large to accurately predict bladder capacity in infants. As increasing weight in infants is a well-studied variable, Fairhurst and colleagues proposed the developed the formula [7 × weight (kg)] which gives a bladder capacity estimate in millilitres.[11] To define the weight of boys and girls at monthly intervals, the World Health Organiztion growth charts were used. The predicted 50th percentile weight at monthly intervals was employed to generate a bladder capacity estimate using the formula created by Fairhurst. Calculated values for bladder capacity from the formula proposed by Kaefer [age (years) + 2] are widely used by clinicians and researchers; however, our results demonstrate that it is not reliable in infancy. It generates volume estimates about 60 to 120 mL, which is greater than those found in our study using urodynamics, for neonates to 12 months of age, respectively. These values differ significantly from our study and this discrepancy may be due to the fact that this current study only considered a cohort of children in the first year of life (Fig. 2).[12]

As a consequence of formulas overestimating bladder capacity, congenital pathologies that would be recognized mainly on the basis of an increased capacity could be overlooked. Alternatively, children with no abnormalities may be deemed to have small bladder capacities when in fact they are in the normal range. In general, urodynamic testing provides a wide range of information, including bladder capacity, and many of these variables have a predefined range of normal values. The rapid growth rate in infants makes the "expected normal" value for bladder capacity difficult to ascertain and supports the need for a method of accurate estimation. As previously discussed, bladder rupture secondary to overfilling during a cystogram has been reported in children, and increasing prediction accuracy of bladder capacity is expected to increase patient safety. Our study determined bladder capacity in infants undergoing urodynamics. One previous study utilized values calculated with patients under anesthesia, which may alter the true bladder capacity. Others had significantly less subjects and did not specify the number of infants. The investigations in this study were performed by a dedicated urodynamics nurse in a consistent and systematic fashion. Normal abdominopelvic ultrasound, urodynamic parameters within the expected reference range and the absence of surgical intervention during the follow-up period were the endpoints used for normalcy. This allowed for objective inclusion/exclusion criteria of patients, as well as the exclusion of patients with subclinical disease at the time of the assessment. Our mean length of follow-up was substantial and approached 41 months.

Our study has its limitations. As this was a retrospective review, possible biases may have been introduced, such as a non-uniform decision on when to stop bladder filling during urodynamics (suprapubic discomfort, pain, excessive volume infused). Due to ethical constraints, a prospective evaluation of bladder capacity using urodynamic data from healthy infants would not be appropriate. As fluoroscopy is not used in regular urodynamics, we do not know if the presence of severe grade of vesicoureteric reflux has overestimated bladder capacity. Despite patients not having had surgery during the follow-up of this study, we do not know if some of these patients who had mild subclinical tethered cord at the time of the assessment are still asymptomatic and thus were not excluded.

Conclusion

We evaluated the urodynamic data of infants free of urologic pathology. Bladder capacity in this population with a median age of 9.0 months was 48.9 mL. This is less than half of the volume predicted by commonly employed formulas, which were developed based on an older population. This data show that the currently available formulas overestimate bladder capacity in infants. A novel method of estimating bladder capacity in infants is required.

Dr. Costa, Dr. Lavallée, Dr. Dubois, Dr. Leonard and Dr. Guerra all declare no competing financial or personal interests.

This paper has been peer-reviewed.

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