Categorization of Obstruction Using Noninvasive Pressure Flow Measurements: Sensitivity to Change Following Prostatectomy

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Purpose: We determined whether categorizing men with lower urinary tract symptoms using a noninvasive pressure flow nomogram is sensitive to change following the removal of obstruction.

Materials and Methods: A prospective cohort of men undergoing transurethral prostate resection was recruited, of whom 143 (69%) underwent noninvasive pressure flow study using the penile cuff technique before and 4 months following surgery. Cuff pressure required to interrupt voiding, estimated isovolumetric bladder pressure and maximum flow rate were recorded during a single void. Values were plotted on a nomogram categorizing cases as obstructed (upper left quadrant), not obstructed (lower right quadrant) or diagnosis uncertain (upper right and lower left quadrants). Changes in maximum flow rate, cuff pressure required to interrupt voiding and nomogram position following transurethral prostate resection were then analyzed.

Results: Transurethral prostate resection resulted in an improved flow rate for all diagnostic groups, which was highest for obstructed cases with a mean $\pm$ SD increase of 11 $\pm$ 6 ml second^{-1} ($p < 0.01$). Men categorized with obstruction and those placed in the upper right quadrant showed significant decreases in cuff pressure required to interrupt voiding following transurethral prostate resection with a mean decrease of -45 ± 35 and -48 ± 32 cm H_2O, respectively ($p < 0.01$). The number of cases classified as not obstructed increased from 28 (19%) preoperatively to 114 (80%) after transurethral prostate resection.

Conclusions: Sensitivity to change following the removal of obstruction further validates the usefulness of noninvasive measurement of bladder pressure by the penile cuff test and the categorization of obstruction by the noninvasive nomogram. Decreased isovolumetric bladder pressure following transurethral prostate resection may reflect a return to normal detrusor contraction strength.

Key Words: bladder, urodynamics, transurethral resection of prostate, bladder neck obstruction, prostatic hyperplasia

Urodynamic diagnosis of BOO using measurements of bladder pressure and urine flow is helpful for assessing men with bothersome LUTS. The disadvantages of invasive PFS have led to the development of noninvasive methods of pressure measurement, including the penile cuff test. This test involves automated inflation during micturition of a cuff placed around the penis until flow is interrupted, followed by deflation and repetition of the cycle until voiding is complete. The $p_{cuff.int}$ provides an estimate of $p_{ves.isv}$, which is an indicator of detrusor contraction strength.[1] A nomogram plot of maximum $p_{cuff.int}$ and $Q_{max.cuff}$ allows categorization of the void as obstructed, not obstructed or diagnostically uncertain,[2] which can be useful for predicting the outcome of TURP.[3]

A further key attribute of a useful diagnostic test is that it should return to normal following treatment of the detected condition. For BOO this principle has been applied to standard uroflowmetry and invasive PFS. The change in Q_{max} is used as an objective outcome measure following treatment for LUTS with increases of around 100% seen after TURP.[4] The $p_{det.Qmax}$ measured during invasive PFS also shows substantial change following TURP, decreasing an average of 50%.[4] These combined changes alter the categorization of an individual using the International Continence Society pressure flow nomogram typically from obstructed to unobstructed. Therefore, we determined 1) whether the categorization of individuals using the noninvasive pressure flow nomogram changes following the removal of obstruction by TURP and 2) whether isovolumetric bladder pressure, as measured by the cuff test ($p_{cuff.int}$), is altered following TURP.

METHODS

Subjects

This study was part of prospective project investigating the predictive value of penile cuff test measurements for the outcome of TURP from December 2003 until February

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Study received Local Research Ethics Committee and institutional approval.

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2005.[3] The study had Local Research Ethics Committee and institutional approval, and subjects provided informed written consent before entry. Of the 208 men recruited for the original study who underwent a penile cuff test before TURP 143 (69%) agreed to return for a repeat penile cuff test approximately 4 months postoperatively and they formed the current study cohort. Selection for TURP independent of the study was according to patient and surgeon preference, and it included the criteria of bothersome LUTS, decreased urinary flow rate (15 ml $second^{-1}$ or less) and recurrent urinary tract infection together with the exclusion of clinically apparent prostate cancer.

Penile Cuff Test

The cuff test was done in an identical manner at the preoperative and postoperative visits.[1–3] Before the test men were encouraged to have a full bladder, which was assessed by ultrasound volume measurement. After each subject reported a strong desire to void a penile cuff (Mediplus Ltd, High Wycombe, United Kingdom) was placed around the penis and the patient was asked to void into a standard uroflowmeter connected to a FM319 cuff machine (Regional Medical Physics Department, Freeman Hospital, Newcastle upon Tyne, United Kingdom). On initiation of voiding the penile cuff was automatically and linearly inflated at a rate of 10 cm H_2O $second^{-1}$ until flow was interrupted or a safety cutoff of 200 cm H_2O was attained. The cuff then rapidly deflated, allowing the resumption of flow. The process was repeated until voiding was complete.

Data Analysis

Patient classification. A continuous plot of flow rate and cuff pressure was produced for each void, from which $Q_{max.cuff}$, discounting the surge in flow usually seen following cuff deflation, and the highest $p_{cuff.int}$ reading were recorded from across the whole void irrespective of the number of inflation cycles.[3] These readings were plotted on the noninvasive nomogram and the diagnostic category was recorded as obstructed, not obstructed or diagnosis uncertain for each.[2]

Change in nomogram position following TURP. Descriptive statistics were calculated for the change between preoperative and postoperative values of $Q_{max.cuff}$ and $p_{cuff.int}$ for each patient together with summarized changes for each diagnostic group, as categorized by the preoperative nomogram position. When appropriate, significance was considered by the paired Student t test at $p < 0.05$ after confirming that the data were normally distributed.

Change in $p_{cuff.int}$ following TURP. We also performed ANOVA using $p_{cuff.int}$ readings from all interpretable cuff inflations during a void, as opposed to only the maximum reading, considering when the measurement was made during the voiding cycle. ANOVA included 4 factors, including individual subjects 1 to 143, the study type during which the measurement was made (pre-TURP or post-TURP), the percent of total volume voided at measurement (5 categories, including 0% to 20%, 20% to 40%, 40% to 60%, 60% to 80% and 80% to 100%) and the interaction between study type and volume. This analysis was designed to investigate the influence of 2 possible biases resulting from the increased flow rate and the subsequent decrease in voiding time following TURP, which may affect the magnitude of change in $p_{cuff.int}$. 1) A higher flow rate means that $p_{cuff.int}$ measurements tended to occur later in the voiding cycle, when isovolumetric pressure may be decreasing as bladder volume decreases.[5,6] 2) The same effect tends to result in fewer cuff inflation cycles per void, giving a decreased probability that a measurement of $p_{cuff.int}$ was made at peak pressure. These 2 factors may result in an underestimation of $p_{cuff.int}$.[5]

RESULTS

Subjects

The clinical characteristics of the cohort of 143 men were typical of patients undergoing TURP for LUTS (table 1). Of the men 123 (86%) had a Q_{max} of 15 ml $second^{-1}$ or less. The nomogram plot from the preoperative cuff test categorized 51 cases (36%) as obstructed (upper left quadrant), 64 (45%) as uncertain (LL in 24 and UR in 40) and 28 (19%) as not obstructed (lower right quadrant). This pattern of categorization and the response to treatment were similar to those of the complete group of 208 men recruited into the project.[3]

Change in Nomogram Position Following TURP

Overall mean ± SD $Q_{max.cuff}$ increased from 11 ± 4 to 19 ± 8 ml $second^{-1}$ following surgery ($p = 3 \times 10^{-26}$), while mean $p_{cuff.int}$ decreased from 138 ± 37 to 110 ± 29 cm H_2O ($p = 3 \times 10^{-13}$). These changes were reflected by a general movement in nomogram plot position to the not obstructed category following TURP (fig. 1). Figure 2 shows changes in nomogram category following surgery for the preoperative diagnostic groups, table 2 lists changes in pressure and flow readings, and figure 3 shows the mean change in nomogram position for each diagnostic group.

Changes in $p_{cuff.int}$ Following TURP

ANOVA for all $p_{cuff.int}$ measurements obtained across the preoperative and postoperative cuff tests, considering bladder volume at measurement, showed that it decreased from an average of 121 (95% CI 117-124) to 105 cm H_2O (95% CI 101-110), representing a mean decrease of 15.5 cm H_2O ($p = 1 \times 10^{-6}$). There was a highly significant effect due to voided volume at measurement ($p = 1 \times 10^{-18}$) for preoperative and postoperative readings with $p_{cuff.int}$ attaining its maximum in the mid part of the void (fig. 4). However, there was no additional statistically significant interaction between voided volume and study type (before/after TURP) affecting the $p_{cuff.int}$ measurement ($p = 0.4$).

TABLE 1. *Clinical characteristics of study cohort*

Variable	
No. pts	143
Mean age (range)	68 (47–88)
Mean ± SD preop International Prostate Symptom Score (max 35)	22 ± 6.7
Mean ± SD preop bother score (max 6)	4 ± 0.9
Mean ± SD preop Q_{max} (ml sec^{-1})	11 ± 5
Mean ± SD preop residual vol (ml)	160 ± 165
% Preop invasive PFS	42 (29)
Mean ± SD resected wt (gm)	16.4 ± 12.3
No. prostate Ca in resected tissue (%)	14 (10)
% Surgical success*	80

* Greater than 50% decrease in International Prostate Symptom Score 4 months following TURP.