Urodymanics

- Important role in understanding LUTS
- Defines and documents voiding pathophysiology causing symptoms
- LUTS subclassified as either irritative or obstructive, or storage or emptying
Lower Urinary Tract Symptoms (LUTS) Associated with BPH

Obstructive
- Hesitancy
- Weak stream
- Straining to pass urine
- Prolonged micturition
- Feeling of incomplete bladder emptying
- Urinary retention

Irritative
- Urgency
- Frequency
- Nocturia
- Urge incontinence

BPH and Bladder Outlet Obstruction

- Enlarged prostate causes urinary outflow obstruction
  - Rational treatment to improve symptoms for decades

Increased Outlet Resistance
- Increased Work Load

Muscle Hypertrophy
- Detrusor Overactivity
- Poor Compliance
- Decreased Volume
- Increased Tone

Muscle Decompensation
- Incomplete Emptying
- Retention
- Overstretched Muscle
- Endstage Muscle Dysfunction

Neural/Receptor Issue
- Increased Tone/Response
BPH and Bladder Outlet Obstruction

• Bladder outlet obstruction is a urodynamic defined condition
  – Can only be defined by urodynamics

• Detrusor overactivity is also a urodynamic detected activity
  – Similar symptoms and its irritative presence has a significant impact on quality of life
Pressure-Flow UDS Remain Best Method

- Documenting urodynamic pathology
  - Differentiate prostatic obstruction versus bladder dysfunction

- Some caveats:
  - Correlation of symptoms and UDS findings are complex and multifactorial
  - Direct relationship of symptoms severity to UDS not well established
  - Management not significantly altered by UDS

- Urodynamics not routine in clinical guidelines for BPH management

- Useful tool prior to interventional surgical therapy
  - Document bladder function
  - Assess bladder function
  - Confirm diagnosis
BPH, Progression and Bladder Outlet Obstruction

- Natural history evaluated in the placebo-controlled arm of multiple randomized placebo-controlled studies
- Untreated “urodynamic documented obstruction” not well studied and data lacking
- Poor correlation of symptoms with age, prostate size and urodynamic parameters
  - i.e., uroflow, post-void residual and detrusor pressure
- Influence of obstruction inferred from insight into urinary retention and surgery outcomes
  - End result of bladder outlet obstruction

Natural History of BPH

• Jacobsen et al. - The natural history of benign prostatic hyperplasia
• 2,000 randomly selected men aged 40-79 in Olmstead county, Minnesota
• Men with symptomatic BPH
  – Incidence of urinary retention was dramatically increased with age and symptoms.
  – Retention was 7/1000 person-years of follow-up
  – Over 70 years old, 1 in 10 chance of retention within 5 years
  – Greater risk if they had urinary symptoms

• Risk factors include:
  – Age greater than 70 years
  – AUA symptom index of 8 or greater
  – Prostatic size greater than 30 g

• Peak urinary flow rate (Qmax) of <12
  – 3.9-fold unadjusted or 2.1-fold adjusted relative risk of urinary retention

Can UDS Assist in Treatment Selection and Severity Assessment of BPH?

- Wasson et al. - Outcome of watchful waiting or TURP in a prospective multicenter trial

- Follow-up of 2.8 years, TURP superior to watchful waiting in regard to treatment failures and in eradicating moderate to severe LUTS

BPH and Urodynamics

• Relation between voiding symptoms and bladder function and outlet obstruction is not simple
  – Voiding symptoms are not directly diagnostic of inherent detrusor dysfunction and/or outlet obstruction
  – “Silent” obstructive uropathy can occur without significant voiding symptoms
  – Symptoms may not be “prostate specific”
  – May represent other “nonprostatic” etiologies such as impaired bladder contractility, detrusor instability, sensory urgency, urethral strictures and vesical neck obstruction.

• 25-50% of men undergoing urodynamic investigation for prostatism symptoms do not have urodynamic evidence of obstruction

Kaplan et al.

2500 consecutive men with symptomatic BPH with video UDS

February 1982 to July 1994

787 evaluable patients

39% prostatic obstruction and detrusor instability

23% isolated prostatic obstruction

64% had prostatic obstruction with 63% of them having detrusor instability

54% had detrusor instability and 23% as sole diagnosis

Impaired detrusor contractility 17% with 6% as their only diagnosis

0.4% had sensory urgency

Why the Poor Correlation Between Symptoms and UDS Findings?

- Differences in technique, equipment, operator interpretation, patient population and patient cooperation
- Controls or normal standards are lacking
- Standards developed by consensus panels (ICS) and not by studies

Donovan et al. J Urol 1994, 151: 294A
Kirchner-Hermanns et al. J Urol 1994, 151: 295A
UDS Still Useful Because:

• Only objective studies to provide understanding of bladder function and outlet obstruction

• Able to diagnose etiology of irritative and obstructive voiding symptoms, incontinence, urinary retention and the development of bladder outlet obstruction

• Greatest utility in elucidating voiding dysfunctional processes associated with neurological disease such as spina bifida, multiple sclerosis, diabetes, and others in the face of BPH

• Can potentially provide objective measurement of success in outcomes of BPH treatments

Griffiths et al. Neurourol Urodyn 1983, 2:27
Kaplan & Te Probl Urol 1992, 6: 659-68

Cystometry

- Two types, filling CMG and voiding CMG
- CMG refers to a filling CMG and can be performed with either a gas or liquid medium
  - Majority of studies utilize a liquid medium
- Two-lumen catheter
  - One lumen to fill the bladder and the other to measure intravesical pressure
- Assess bladder capacity, involuntary detrusor contractions (IDC), bladder compliance and contraction pressures
- Diagnosis of bladder outlet obstruction can not be made

- 60% of men with symptoms of prostatism have IDC
- Postoperatively the incidence is 25-30%
- IDC may be associated with higher treatment failures
- Not recommended by the AUA BPH guidelines

Cucchi et al. J Urol 1994; 51: 1342-4
Multichannel urodynamics are synchronous pressure-flow studies
Best to define bladder outlet obstruction in men
Simultaneous fluoroscopic video allows for visualization of location of obstruction (PO vs. VNO)
Diagnose impaired contractility, detrusor instability and sensory urgency
Clarify diagnosis with associated underlying neurological or postoperative surgical condition
Detect diverticula as well as vesicoureteral reflux on VCUG

Glemain et al. Eur Urol 1993, 24: 12-17
VCUG: VNO vs. PO

Vesical Neck Obstruction

Prostatic Obstruction
Technical Utility of Multichannel UDS

- Principal role is to analyze the act of micturition
- Examines the detrusor function as measured by its generation of pressure in relation to its outlet resistance as defined by its flow:
  - Bladder outlet obstruction is elevated, voiding pressure with low peak urinary flow
  - Impaired detrusor function is reduced, bladder pressure or contractility function identified as low voiding pressure in the presence of diminished flow (“low pressure, low flow”)
  - Can distinguish whether low urinary flow is secondary to obstruction and to impaired contractility
- Identify obstruction in normal urinary flow with high detrusor contraction pressure
- Measurement of capacity, filling pressure, parameters of a contraction and detect uninhibited contractions
- Identify detrusor sphincter synergy, anatomical function
- Assess and clarify bladder function in the neurological patient
- Provide pretherapeutic assessment of bladder function that enables one to infer outcome prediction better
- Objective physiological tool with which to study patients with BPH

Hald et al. Prostate 1989, 2(Suppl): 69-77
Haylen et al. Br J Urol 1989, 64: 30-8
Jensen et al. Neurourol Urodyn 1989, 8: 545
Multichannel UDS

Simultaneous synchronous real-time measurements

- Double lumen urethral catheter into bladder
  - Measures total vesical pressure
- Rectal catheter
  - Measures abdominal pressure
- Uroflometry
  - Measures urinary flow rate
- Detrusor pressure is calculated
  - Total vesical pressure – abdominal pressure

Other aspects:
- EMG monitoring
  - Pelvic floor or sphincter activity
- VCUIG imaging

Multichannel UDS of BOO

Low Flow

High Pressure
Quantitative Analytical Investigation of Prostatic Obstruction with UDS

- No standard well instituted
- Many urodynamic philosophies and operator preference in analytical studies
- Variations include catheter size, employment of suprapubic access, techniques of zeroing and type of EMG probe
- Basic concepts of diagnosis are the same
Early efforts emphasized theories based on rigid tube physics

Utilized a urethral resistance factor based on rigid tube hydrodynamic theory

If the calculated factor exceeded a certain value, obstruction would be diagnosed

However, not clinically applicable since urethra is not a rigid tube

Approach abandoned by the International Continence Society Standardization Committee

Griffiths et al. Urol Int 1975; 30: 28
Resistance Factors and Models

- Attempts to quantify “resistance” on advanced theoretical hydrodynamics
- Involved biophysical models and advanced analytical procedures
- Advance mathematical definitions of bladder outlet obstruction by calculating “resistance” coefficients
- Required a focus on techniques to assess the power of detrusor contractility
Assessing Power

- Griffiths describes a method to assess quantitatively the strength of detrusor contractions during any voiding where flow rate, detrusor pressure and residual urine are measured.

- Mathematically extrapolate a single point from the Hill curves, i.e., force versus contraction velocity.

- Parameters assessed include power [the product of detrusor pressure (Pdet) and flow rate] and work (power integrated over time).

- Griffiths developed WF, a factor dependent on detrusor pressure, uroflow, speed of detrusor contraction and bladder volume which uses two adjustable parameters – isovolumetric pressure and detrusor shortening velocity – which are volume independent.

Griffiths et al. Urol Int 1975, 30: 28
Models Used to Define Obstruction and Assess Resistance

- Utilizing the complex relationship between pressure, flow and outlet resistance during the dynamic function of voiding
- Multiple biophysical models and advanced quantitative analytical techniques have been developed to study this complex relationship
- These elegant models have sought to characterize and simplify this complex relationship to a quantitative value of comparison
### Methods of Quantitative Assessment of Bladder Outlet Obstruction

(adapted from ICS standardization committee 1997)

<table>
<thead>
<tr>
<th>Method</th>
<th>Aim</th>
<th>Number of p/Q points</th>
<th>Assumed shape of URR</th>
<th>Number of parameters</th>
<th>Number of grade severity or continuous</th>
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<tbody>
<tr>
<td>Abrams-Griffiths nomogram</td>
<td>diagnosis</td>
<td>1</td>
<td>n/a</td>
<td>n/a</td>
<td>3</td>
</tr>
<tr>
<td>Spangberg nomogram</td>
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<td>n/a</td>
<td>n/a</td>
<td>3</td>
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<td>URA linPURR</td>
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<td>curved</td>
<td>1</td>
<td>continuous</td>
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<tr>
<td>Schafer PURR</td>
<td>resistance</td>
<td>1</td>
<td>linear</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>CHESS</td>
<td>resistance</td>
<td>Many</td>
<td>curved</td>
<td>2</td>
<td>continuous</td>
</tr>
<tr>
<td>OBIS8</td>
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<td>Many</td>
<td>linear</td>
<td>1</td>
<td>continuous</td>
</tr>
<tr>
<td>Spangberg et al.</td>
<td>resistance</td>
<td>Many</td>
<td>linear or curved</td>
<td>3</td>
<td>continuous + 3 categories</td>
</tr>
<tr>
<td>DAMPF</td>
<td>resistance</td>
<td>2</td>
<td>linear</td>
<td>1</td>
<td>continuous</td>
</tr>
<tr>
<td>A/G number</td>
<td>resistance</td>
<td>1</td>
<td>linear</td>
<td>1</td>
<td>continuous</td>
</tr>
</tbody>
</table>

References:

- Spangberg et al. Neurol Urology 1997, 10: 139-67
- Griffiths et al. Neurol Urology 1997, 8: 17-27
- Schafer W. Urol Clin N Am 17: 553-66
Schafer’s Model and Nomogram

- Describes the urethra as a distensible tube with a flow-controlling zone in its proximal urethra
- Relationship between detrusor pressure and flow rate is described by the tube’s distensibility and the size of the flow-controlling zone
- PURR, the passive urethral resistance relationship, a graphical description
- From this graphical description, an index quantifying obstruction is derived, termed the LPURR, the linear passive urethral resistance relation
- LPURR is derived by looking up the position of a line segment that connects the point Qmax, p(Qmax) with the point of lowest pressure during flow in a nomogram

A Pressure Flow Plot
(ICS Standardization Committee 1997)

In the 1970s, Griffiths et al. introduced their urethral resistance relation, a graphical concept that analyzed the relationship between detrusor pressure and flow during voiding to define the lowest resistance when the bladder outlet was passive or relaxed.

Evolved to a pressure-flow nomogram in 1979 by Abrams and Griffiths with group-specific urethral resistance quantified.

Classified as obstructed, equivocal or unobstructed, and was modified by the International Continence Society in a provisional recommendation for standardization in 1997.

Abrams-Griffiths (AG) nomogram were similarly confirmed by Rollema and van Mastrigt in 1992.
ICS Provisional Modified Abrams-Griffith Nomogram
Defining Bladder Outlet Obstruction

Computer Modeling

- Van Mastrigt and Rollema developed a computer program, CLIM
  - Analyze detrusor pressure, flow rate signals during voiding and isometric detrusor pressure increase just before flow starts
  - U/L, the maximum extrapolated rate of increase of isometric pressure, as well as URA can be calculated
  - OBI, another quantification of urethral resistance can be calculated
    - OBI is the parameter that fits the lowest part of a pressure-flow rate relation with an orthogonal polynomial

- Spangberg et al. described a model based on computer analysis of pressure-flow data
- Model describes the flow-controlling zone in the urethra as it distends with increasing urethral pressure and calculates a urethral pressure/area relationship quantity
- Sarky and Blaivas described a series of computer-generated parameters that added a time factor to the pressure-flow curve

Sarky et al. Neurourol Urodyn 1988, 7: 221-22
Consensus Standards by the International Continence Society

- Provide a simple and reproducible method with high validity of diagnosing obstruction as well as a sensitive and reproducible method with high validity of measuring urethral resistance and changes in resistance.

- Provisional recommendations for obstruction assessment so as to standardize an approach to evaluation.

- One provisional diagnostic classification utilized classifications from calculated values to classify obstruction:
  - if \((P_{det}, Q_{max} – 2Q_{max}) > 40\), the pressure-flow study is obstructed;
  - if \((P_{det}, Q_{max} – 2Q_{max}) < 20\), the pressure-flow study is unobstructed;
  - if in between, then the study is equivocal.

- Modified Abrams-Griffith nomogram incorporating a compromise of various models resulted in a provisional ICS method of defining obstruction that was developed in 1997.

Griffiths et al. Neurourol Urodyn 1997, 16:521-532
Clinical Application of UDS Studies and BPH Treatments

- Jensen et al.
- Utilization of obstructive parameters
  - Lowered failure rate after surgery from as high as 20% to 8% and increased the exclusion from surgery from 5% to 9%.
  - BOO parameters (catheterized flow of less than 12 ml/s and a peak detrusor pressure of more than 45 cm H2O)

- However, no long-term follow-up pressure-flow analyses in symptomatic patients with prostatism who are left untreated, or those who are treated either surgically or pharmacologically have been studied in a randomized, placebo controlled long-term study

Clinical Application of UDS Studies and BPH Treatments

- Abrams et al.
- Examined 152 men who underwent prostatectomy for BPH based on urodynamic testing
- 86% of patients improved, on the basis of Qmax and a decrease in voiding pressure
- Subjectively, 88% of patients had improvement in their symptoms
- In an earlier study, inclusion of urodynamic testing in the operative criteria lowered the postoperative failure from 28% to 12%
- However, 28% is a higher surgical failure rate than that reported by others

Abrams et al. Urol 1979, 121: 640-2
Clinical Application of UDS Studies and BPH Treatments

- Kuo and Tsai
- Examined 50 patients with UDS and by a general symptom analysis before and after prostatectomy
- Subjective outcome analysis was divided into good, fair and worse
- Examined selected preoperative UDS parameters such as different levels of Qmax, and those with high-pressure obstruction, low-pressure obstruction and low-pressure/no obstruction (LPNOB)
- Concluded prostatectomy best for Qmax less than 15 ml/s and those with high-pressure obstruction
- Poor outcome noted in patients with a Qmax greater than 15 ml/s and those classified as LPNOB

- Since failure rate is this high, does this identify a population with flows greater than 15 ml/s who would benefit from multichannel urodynamic testing to identify them as LPNOB?

Kuo HC, Tsai TC. Taiwan I Hsueh Hui Tsa Chih 1988; 87: 323-30
Detrusor Overactivity, OAB and BPH Treatments

• Involuntary detrusor contraction (or detrusor overactivity) is a urodynamic entity that has been recognized as important, especially with the recent trend to treat and monitor irritative symptom concurrent with BPH

• The prognostic significance of its presence preoperatively and its risk for persistence postoperatively has impact, especially if the goal of treatment is to improve symptom score

• Currently, the presence of involuntary detrusor contractions on a urodynamic assessment does not have good predictive value for its presence postoperatively
Prostatectomy and OAB

- Olsson *et al.*
- Examined 129 consecutive men, after prostatectomy
- Mean age 72 years with voiding symptoms after prostatectomy
- Urodynamic findings were retrospectively analyzed with respect to symptoms, uroflow and synchronous video pressure-flow cystometry
- Obstruction was found in 38% of patients
- Impaired contractility in 25%
- Intrinsic sphincter deficiency in 8%
- 80 patients without neurological disorders
  - Involuntary bladder contractions were detected in 50%
- 49 patients with neurological disorders
  - Involuntary bladder contractions were detected in 76%
- Highlights significance of involuntary detrusor contractions as a potential cause of treatment failure after prostatectomy

Olsson et al. J Urol 1994, 151: 326A
Involuntary Detrusor Contractions and OAB in BPH
Evaluation of Risk of Retention

- Prevention to decrease the morbidities of BPH progression have been highlighted as goals for pharmaceutical and interventional therapies

- Can UDS identify those at highest risk and those not at risk?

Evaluation of Risk of Retention

• Te et al.
• Analyzed urodynamic parameters to predict the risk of urinary retention in men with BOO
• Retrospectively analyzed UDS of 944 consecutive men evaluated for LUTS
• 290 (30.7%) were diagnosed with BOO
  – BOO=Pdet@Qmax> 45 cm H2O and Qmax < 12 ml/sec
• Categorized into two groups
  – Group A (n=133): men with no history of retention
  – Group B (n=157): men with a history of retention
• Total prostate volume (PV), AUA Symptom Score (Sx), PSA and UDS parameters: Pmax, Pdet@Qmax, detrusor contraction length (DCL) and Qmax were analyzed.

### Evaluation of Risk of Retention

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pmax</td>
<td>58.9 ± 18.9 cm H2O</td>
<td>93.8 ± 27.9 cm H2O</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>DCL</td>
<td>126.5 ± 69.1 sec.</td>
<td>147.6 ± 78.7 sec.</td>
<td>&lt;0.018*</td>
</tr>
<tr>
<td>Qmax</td>
<td>8.5 ± 2.6 ml/sec.</td>
<td>4.2 ± 2.1 ml/sec.</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>PV</td>
<td>34 ± 11.2 cc.</td>
<td>43.4 ± 17.5 cc.</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Sx</td>
<td>14.2 ± 8.6</td>
<td>16.5 ± 9.7</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Statistical significance was demonstrated between group A and group B with regards to Pmax, DCL, Qmax and PV.
Symptom severity was not significant.

Evaluation of Risk of Retention

• ROC revealed that
  – Pmax @ 70 cm H2O had sensitivity and specificity of 73.9% and 82%, respectively, and an 82.8% and 72.8% positive and negative predictive value for urinary retention
  – DCL @ 100 sec had a sensitivity of 70% and specificity of 44% to predict retention
  – Novel nomogram created combining Pmax and DCL for PV >30 to maximize the sensitivity of predicting retention to 90%

• Suggest urodynamic pressure flow studies predict retention risk in men with BOO and the utility of urodynamics in BPH management

Summary

• Urodynamics is our best research tool to study detrusor and bladder outlet physiology

• Bladder outlet and detrusor interactions impact upon patient symptoms, response to therapy, and ultimate progression to complications

• This pathophysiology still requires further investigation and UDS provide objectivity to the study and treatment of BPH

• Since there are many different therapeutic options available for symptomatic BPH, and now more accurately described as lower urinary tract symptoms or LUTS, each therapy needs to find its appropriate indication based on its underlying urodynamic etiology

• Ultimately, urodynamic parameters that distinguish patient characteristics to allow guideline recommendations based on fact rather than the subjective assessments of both patients and urologists is a goal still to be attained