Basic Principles of Urodynamics

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The Standardisation of Terminology of Lower Urinary Tract Function

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Uroflowmetry, Filling Cystometry, and Pressure-Flow Studies

Paul Abrams
Urodynamics
Third Edition
Springer

Chapter 6: Urodynamic Testing (pp 429-506)

Distributor: ICUD-EAU
www.ics.org

Topics covered
- Pressure
- Transducers
- Different types of transducer
- Issues with bladder pressure
- Flow measurement
- Pressure-flow tests

What is pressure?
Force per unit area

Note the level of fluid in the tube is higher than the balloon.

Why is level of fluid in the tube higher than the balloon?
The pressure inside the balloon is transmitted up the tube and supports a column of water.

What, apart from pressure, dictates the height of fluid in the tube?
Diameter of tube does not matter

Pressures on holiday

Does the density of the fluid determine the height to which the fluid goes?

Density matters

Thus we need to state pressure both in terms of a height and also in terms of a particular fluid

Unit of pressure

**cm H₂O**

- 1 cm H₂O = 0.74 mm Hg
- 100 cm H₂O = 74 mm Hg

Measuring bladder pressure
Topics covered

• Pressure
• Transducers
• Different types of transducer
• Issues with bladder pressure
• Flow measurement
• Pressure-flow tests

Pressure transducers

External pressure transducer with dome and taps

External pressure transducer without dome

Strain Gauge

External transducer specifications

<table>
<thead>
<tr>
<th>General Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressure range:</strong></td>
</tr>
<tr>
<td><strong>Sensitivity:</strong></td>
</tr>
<tr>
<td><strong>Resonant frequency:</strong></td>
</tr>
<tr>
<td><strong>Max. electrical excitation:</strong></td>
</tr>
<tr>
<td><strong>Bridge resistance:</strong></td>
</tr>
<tr>
<td><strong>Input and output:</strong></td>
</tr>
<tr>
<td><strong>Zero balance:</strong></td>
</tr>
<tr>
<td><strong>Thermal sensitivity:</strong></td>
</tr>
<tr>
<td><strong>Thermal zero drift:</strong></td>
</tr>
<tr>
<td><strong>Operating temperature range:</strong></td>
</tr>
<tr>
<td><strong>Storage temperature range:</strong></td>
</tr>
<tr>
<td><strong>Insulation resistance:</strong></td>
</tr>
<tr>
<td><strong>Leakage current:</strong></td>
</tr>
<tr>
<td><strong>Weight:</strong></td>
</tr>
<tr>
<td><strong>Connector:</strong></td>
</tr>
</tbody>
</table>
Transducer characteristics

- Good linearity
- Minimal hysteresis
- Minimal zero shift
- Minimal sensitivity shift

Topics covered

- Pressure
- Transducers
- Different types of transducer
- Issues with bladder pressure
- Flow measurement
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Transducer types

- Catheter tip
- Air filled
- Water filled

Catheter-tip pressure transducers

- Catheter-tip pressure transducers
- Catheter-mounted pressure transducers
- Microtip transducers
- Solid state transducers
Catheter-mounted pressure transducers

- No fluid connecting the patient to the equipment – only wires
- No flushing
- No need to set anything at a reference level

Air-charged catheters

- No water connecting the patient to the equipment – only air
- No flushing
- No need to set anything at a reference level
- No substantial comparisons with water-filled lines

“No water” pressure measurement

- No fluid connecting the patient to the equipment – only wires

Water-filled pressure lines

- Water-filled pressure lines
Issues in filling cystometry

- Do you use external pressure transducers connected to the patient via water-filled lines or do you use catheter-mounted pressure transducers?

External pressure transducer

![Diagram of external pressure transducer](image)

Fig. 3.31 External pressure transducers measure pressure according to their position (outside the body) in relation to the bladder: the lower position (dotted line) also records the 8 cm pressure head of the bladder itself. The position of the catheter in the bladder does not change the pressure measurement.

Catheter-mounted pressure transducer

![Diagram of catheter-mounted pressure transducer](image)

Fig. 3.32 Catheter tip transducers measure pressure according to the position of the transducer within the bladder. When the transducer is high in the bladder (solid lines) the pressure is lower (20 cmH₂O); when the transducer is lower in the bladder the pressure is higher (26 cmH₂O = 20 cm H₂O plus the 6 cm column of urine on top of the transducer).

Recommendation - Pressure

- It is recommended that for intravesical and abdominal pressure recording, external pressure transducers connected to water-filled tubes and catheters should be used.
- If microtip or air-filled catheters are used, any deviation from standard zero and reference level should be minimised and taken into account at the time of analysis.

Measuring bladder pressure with a water-filled line

![Diagram of bladder pressure measurement](image)

Position of the bladder relative to the transducer

![Image of bladder measurement setup](image)

Bristol Urological Institute
**Recommendation - Pressure**

- We need to know the reference height of the transducers
- Compare readings on the same patient
- Check for realistic pressures
- Equal reference for $p_{abd}$, $p_{ves}$ relative to bladder
- The ICS standard reference height is the upper edge of the symphysis pubis

**Calibration**

- Urodynamic equipment is not perfect and its accuracy can alter with time. Therefore, regular checks of its calibration are essential
- 0 to 50 cmH$_2$O before clinic

**Measurement issues with water-filled lines**

- Reference height
- Movement artefact
- Pump artefact

**Pump artefact**

- The effect of air in the system

- Reference height
- Movement artefact
- Pump artefact
- Air in the system
Effect of air in the system

Effect of air in the system

Effect of air in the system

Effect of air in the system

Flushing a water-filled line

Flushing a water-filled line

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Measuring bladder pressure

What route is used for inserting pressure sensors in the bladder?

- Transurethral
- Suprapubic

Suitable sites for measuring abdominal pressure

- Rectum
- Vagina (upper part)
- Abdominal stoma

Symbol of pressure

\( p \)
(p not P)
Qualifiers

- det – detrusor
- ves – intravesical
- abd – abdominal
- ura – urethral

\[ P_{\text{det}}, P_{\text{ves}}, P_{\text{abd}}, P_{\text{ura}} \]

Definition of detrusor pressure

\[ P_{\text{det}} = P_{\text{ves}} - P_{\text{abd}} \]

Why subtract?

Why not just display detrusor?

Rectal artefact

Why then display all three?
Quality control

Normal cystometry
A BIG issue in filling cystometry

- Do you zero your transducers inside the patient, outside the patient, to atmospheric pressure or to resting bladder pressure?

Recommendation - Pressure

- It is recommended that there is strict adherence to the ICS standardisation of zero pressure and reference height
  - Zero pressure is the surrounding atmospheric pressure

Reasons to zero to atmospheric pressure

- It produces a scientifically meaningful parameter
- Has a role in quality control
- When comparing with other centre’s data, it is necessary to compare like with like
- Some measurements (e.g. VLPP) are made on the intravesical or abdominal pressure not detrusor pressure

Reasons to zero to atmospheric pressure

- It produces a scientifically meaningful parameter
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Pressures at beginning of filling cystometry

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{ves}$ ($cm H_2O$)</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>$P_{abdo}$ ($cm H_2O$)</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>$P_{det}$ ($cm H_2O$)</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
**Reasons to zero to atmospheric pressure**

- It produces a scientifically meaningful parameter.
- Has a role in quality control.
- When comparing with other centre's data, it is necessary to compare like with like.
- Some measurements (e.g., VLPP) are made on the intravesical or abdominal pressure not detrusor pressure.

**Zeroing to atmosphere**

**A BIG issue in filling cystometry**

- Do you zero your transducers inside the patient, outside the patient, to atmospheric pressure or to resting bladder pressure?

**Zeroing while connected**

**Issues in filling cystometry**

- Do you zero your transducers inside the patient or to atmospheric pressure?
- What rate should you fill the patient?
**Detrusor overactivity & filling**

**Issues in filling cystometry**

- Do you zero your transducers inside the patient or to atmospheric pressure?
- What rate should you fill the patient?
- What temperature should the filling medium be at?

**Urodynamic equipment**

**Hardware**

[Image of urodynamic equipment]

[Image of hardware diagram with links to buyers' guide and evaluation report]

[nhscep.useconnect.co.uk]
Topics covered

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Free flow rate measurement

Uroflowmetry

Flowmeters

- Load cell (gravimetric)
- Rotating disc
- Capacitive dipstick
- Pressure sensor
- Air displacement

Load cell flowmeter

Change in weight with time is related to change in volume with time

Differentiate

Flow rate (Q)

Rotating disc flowmeter

Urine hits disc and slows it down

Electronics puts more energy in to get disc back to original speed

If stream hits disc perpendicularly, this amount of energy a flow rate Q

Disc rotating at constant speed

Integrate Q

Volume
Free flow rate measurement

Max flow rate: $Q_{\text{max}}$
Voided volume: $V$
Average flow: $Q_{\text{ave}}$

Flow time = $a + c + e$
Voiding time = $a+b+c+d+e$

Free flow rate measurement

Patient Identification
Surname
Firstname
DOB
Hospital ID
Sex
Female

Free-Flow Results
Maximum Flow Rate, after 3sec.
Flow time 83sec., voiding time 15sec.
Voided volume 214mls.
Average Flow rate 18ml/s.
Free flow rate measurement

Wag artefact

Lag artefact
Free flow rate measurement

- Voided volume
- Patient apprehension
- Patient position

What does it tell us?

- Whether there is a problem with voiding
- It DOES NOT tell us whether any problem is due to outflow obstruction or poor detrusor contractility

Topics covered

- Pressure
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Normal pressure-flow

\[ P_{\text{detQmax}}: 40-60 \text{ cm H}_2\text{O (male)} \]

\[ P_{\text{detQmax}}: 20-40 \text{ cm H}_2\text{O (female)} \]

Normal pressure-flow (female)
Outflow obstruction (female)

Normal pressure-flow plot

Obstructed pressure-flow plot

ICS nomogram

BOOI (Abrams-Griffiths number)

\[ p_{\text{det}Q_{\text{max}}} - 2Q_{\text{max}} \]

- < 20  non obstructed
- > 40  obstructed

Female pressure-flow nomogram
Topics covered - summary

• Pressure
• Transducers
• Different types of transducer
• Issues with bladder pressure
• Normal cystometry
• Flow measurement
• Pressure-flow tests

Types of flow

Transducer characteristics

- Non-linearity
- Electrical signal does not change in proportion to the pressure put on it

Non-linearity

Linearity

Transducer characteristics

- Hysteresis
- Electrical signal for a given pressure is different when that pressure is reached from a lower pressure than when it is reached from higher pressure
**Hysteresis**

**No hysteresis**

**Transducer characteristics**

- **Zero shift**
  - Electrical signal when no pressure is applied to the transducer changes if the temperature of the transducer changes

**Zero drift**

**Transducer characteristics**

- **Sensitivity shift**
  - Electrical signal for a given pressure changes if the temperature of the transducer changes

**Sensitivity drift**