Basic principles
of the
cuff test

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Newcastle upon Tyne
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Basic urology - the flow measurement
The single most obvious and objective symptom of most men's urodynamic complaints is a hesitant flow or a poor flow rate, and so the most basic tool of the prostate assessment clinic is the flow meter. In its most basic mode, the **Cuff Machine** will act as a urine flow meter.

Measurement of flow rate and voided volume
A flow meter provides measurements of flow rate (Q) and voided volume (V_{void}). V_{void} is usually measured in millilitres (ml), while Q is measured in millilitres per second (ml/s). Flow rate and voided volume are clearly related:

\[ Q = \frac{dV}{dt} \]

*If V_{void} can be measured, Q can be calculated.*

\[ V = \int Q \, dt \]

*If Q can be measured, V_{void} can be calculated.*

There are a few different types of flow meter, but they all measure either flow or volume, and then calculate the other parameter. The **Cuff Machine** uses a load-cell flow meter, so it's worth mentioning it in some more detail.

The load cell flow meter
This is currently the most common type of flow meter, and is used by the majority of flow or cystometry measurement systems on the market, including the **Cuff Machine**. The load cell is essentially a weighing scale - since the density of urine is (to within 3%) the same as water, the weight of the urine can be converted directly to volume, and then to flow rate.

This type of flow meter is simple and easy to clean, and works with any shape and size of collecting vessel. However, the load-cell measures weight, and not volume. It therefore needs calibration for use with contrast medium, which is heavier than water or urine.

In most cases, this will not be a problem in the prostate assessment clinic, and **Cuff Machine** assumes that volume (in millilitres) is equal to weight (in grammes).

Since the load cell in the **Cuff Machine** (effectively) measures volume, it then deduces the flow by determining the rate of change of volume. In contrast the spinning disk flow meter, also widely used, measures flow and then obtains volume by integration.
Limitations of the flow test

Why is the measurement of pressure important?
An abnormal urine flow is a key symptom of a urological complaint, but does not indicate the cause. In very general terms, the flow rate is affected by two factors:

- The driving pressure from the bladder;
- The opposition to flow presented by the outlet.

Therefore, symptoms of hesitancy or a poor flow rate might be due to:

- a weak bladder contraction.

Or equally, due to:
- an enlarged prostate producing a large obstruction to flow.

The need for bladder contraction information
Clearly, a flow rate alone is not enough to distinguish these conditions. You need to measure bladder pressure as well. The picture shows the constituents of a basic urodynamics system.

The general idea is to fill the patient using a bladder line, and then ask him to void. Meanwhile, you record flow rate, and the bladder pressure required to generate the measured flow. In men, a low flow with a high bladder pressure is indicative of prostatic obstruction.

But...
This measurement (cystometry) is time-consuming, unpleasant, and carries some risk for the patient. Some centres believe these negative factors outweigh the usefulness of the information gained from the test, and would proceed to treatment without a definite diagnosis of obstruction (van Mastrigt & Pel, 1999).
Basic principle of the cuff test

The new cuff test is intended as an adjunct to a conventional flow study. While it is not a replacement for cystometry (which still remains the best gold standard), the cuff test gives some information on bladder contraction pressure. We believe it can therefore be used in some cases to confirm the likely diagnosis of obstruction, while avoiding the need for full cystometry.

The principle of the test is similar to blood pressure measurement. When the patient is ready to void, a small pneumatic cuff is fitted round the penis. When voiding has commenced, the cuff is inflated under automatic control until the stream is interrupted. The cuff pressure required to interrupt flow should equal bladder pressure at the time of interruption (Griffiths et al, 2002; Drinnan et al, 2003a).

Then cuff pressure is quickly released, allowing flow to resume. The cycle is repeated until voiding is complete.

We therefore plot a graph of flow rate versus cuff pressure, to enable the cuff pressure to be determined at the moment when flow stopped (right). This forms our estimate of bladder pressure - 120-125 cm H\(_2\)O in the example.

Because the measurement is made when flow is zero, the test measures *isovolumetric* bladder pressure.
Principles underlying the cuff test

To work properly, the cuff test depends on three key principles:

**Inflation pressure in the penile cuff is transmitted to the penile urethra**

First, pressure in the cuff must be transmitted to the penile urethra so that when cuff pressure exceeds the fluid pressure, flow stops. To this end, we have made simultaneous measurements of cuff and urethral pressure for a range of cuff materials and sizes (Drinnan et al., 2001a). The figure shows this relationship for the two cuff widths finally used - 38mm (left) and 48mm (right).

**The bladder maintains its contraction throughout the test**

When the flow stops, it is important that the bladder contraction be maintained during the interruption. To test this hypothesis, we used conventional cystometry lines to measure the detrusor pressure immediately before and after the cuff test (left) in 135 cuff measurements from 31 subjects (McIntosh et al., 2003a).

There was a detectable but clinically insignificant mean decrease of 4 cm H$_2$O, which was probably due to the expected decline in bladder pressure through the void.

**The urethra acts as a fluid-filled catheter**

Finally, when the flow stops, there must be a continuous column of fluid between the bladder and the urethra next to the cuff so that the urethra serves as a fluid filled catheter for the purpose of the test.

In 11 patients we used a triple-lumen catheter to measure cuff and urethral pressures at the time of flow interruption (Drinnan et al., 2001b). This figure shows that the three pressure measurements were closely related, giving evidence that the pressure in the bladder is transmitted along an open urethral lumen.

In addition, we have conducted simultaneous video cystometry in a limited number of subjects. We have yet to observe a subject where the urethra closed during the test.
The cuff machine printout

The Cuff Machine instrument produces a printout like the one shown below. In the top half of the page are the original cuff pressure (green), flow rate (orange) and voided volume (magenta) signals. The shaded grey areas correspond to periods when the cuff was actively inflating, as can be judged from the rising cuff pressure. Beneath are the four graphs of flow versus cuff pressure, corresponding to the four shaded areas of cuff inflation. From these graphs can be estimated the bladder pressure at the point of flow interruption.

![Graph of flow versus cuff pressure](image)

NOTE: There is a fifth inflation shown at the top of this page, but not shaded in grey. The corresponding graph of flow versus cuff pressure will be shown on the next page printed by the cuff machine.
**Estimation of cuff interruption pressure**

For interpretation of the measurements, we recommend that you extrapolate the downward slope of the flow versus Cuff pressure graph, and estimate where it would reach zero flow.

This example shows four cuff measurements where it is relatively easy to estimate the interruption pressure. In each case, the red line shows our 'best fit' to the downward slope.

We would make estimates of 160, 160, 120 and 115 cm H₂O respectively for interruption pressure in the four graphs.
Exclusion rules

In the example, all the cuff inflation cycles are easy to interpret. However, in some cases, there is a good theoretical basis for excluding some inflation cycles. In other cases, it is simply not possible to make a good estimate of the pressure at which flow is interrupted.

We have developed a set of rules by which individual inflations can be excluded (Drinnan et al, 2003b). At this point, we will state the rules. Later, we will give examples of how the rules can be applied.

An inflation cycle should be excluded immediately if:

(1) There was no recovery of flow after cuff deflation
When the cuff is released after an inflation cycle, one normally expects a brief surge of urine stored in the proximal urethra, followed by the resumption of flow. This is seen clearly in the printout on the previous page. If there is no flow recovery, this indicates that the void finished sometime during the current inflation cycle, and that the cuff may not be responsible for stopping the flow.

(2) There was an erratic flow trace, leading to ambiguity about the cuff pressure at flow interruption
In some cases the flow trace is erratic, making it difficult to estimate accurately the exact moment of flow interruption. As with uroflowmetry, we have some evidence that this may be due to straining, and we also suspect contractions in the pelvic floor or membranous urethra.

(3) Flow was not interrupted at the instrument's maximum pressure of 200 cm H$_2$O
This situation is normally associated with a highly contractile bladder capable of developing an unusually high isovolumetric pressure; for safety reasons, 200 cm H$_2$O represents the upper limit of our instrument's pressure source. While the exact bladder pressure cannot be estimated reliably, hypocontractility can in most cases be ruled out, so this measurement is nevertheless clinically useful.

Making the measurement
If an inflation has not been excluded by these three rules, it should be possible to estimate the cuff interruption pressure, as shown in the previous page. It is common to get more than two inflation cycles from an individual void, and we have had ten or more in isolated cases.

Review of the entire void
As with many clinical tests, there are times when an apparently genuine measurement is inconsistent with other measurements in the same subject, and it is appropriate to treat the erratic measurement with suspicion. In the cuff test this might be due to the cuff slipping (leading to an artificially high value of pressure) or a mid-void contraction of the pelvic floor muscles (leading to an artificially low value of pressure).

According to current urodynamic theory, one would expect a relatively constant value of bladder pressure, which may however diminish towards the end of the void, and indeed this is our experience. The repeat measurements through the void give the observer an opportunity to assess the repeatability of the test, and to discard measurements that are clearly out of keeping with the rest of the void.
How often are the exclusion rules applied?

In a study on inter-observer agreement (Drinnan et al, 2003b), 486 inflation cycles were rated by 3 independent observers, a total of 1458 ratings. The graph below summarises the outcomes of those 1458 ratings:

The important points are as follows:

- Most exclusions are due to rule (1) - no recovery of flow. This is normally the case on the final inflation cycle of the void.

- Very few (about 4%) of measurements are discarded because they are not consistent with others in the same subject. In the clinic we would prefer to repeat the test under these circumstances.

- Overall, over half of all inflation cycles give a usable measurement. In fact, 90% of all patients will provide useable data on at least one of two occasions (McIntosh et al, 2003).
Validation studies

Agreement of cuff interruption pressure with true bladder pressure

As we have said, the cuff interruption pressure should give an estimate of the simultaneous value of isovolumetric bladder pressure. In 153 patients we performed the cuff measurement with simultaneous invasive cystometry (McIntosh et al, 2003). For each cuff inflation cycle we estimated the cuff pressure $p_{\text{cuff,int}}$ at which flow was reduced to zero, and from the cystometry data measured the simultaneous bladder pressure $p_{\text{ves,iv}}$.

The results are shown in the figure; on average, $p_{\text{cuff,int}}$ over-estimated $p_{\text{ves,iv}}$ by $16.4 \pm 27.5$ cm H$_2$O, and possible reasons for the discrepancy are discussed later.

Test-retest repeatability

In the same study (McIntosh et al, 2003), a proportion of patients agreed to return for repeat cuff tests without invasive cystometry lines. The graph shows the relationship of the two measurements in the same individual.

In common with flow rate measurements, note that within-patient reproducibility is better for voided volumes of 150 ml or more.

**We therefore recommend that where the voided volume is < 150 ml, the test be repeated.**

Acceptability of the test

In the clinical study 85% of patients expressed a preference for the non-invasive cuff test (Robson et al, 2002), as shown in the figure below. Younger men and men with very powerful bladder contraction may experience brief discomfort at the time of interruption.
Inter-rater agreement

As with many clinical measurements, there is a degree of interpretation required with the cuff measurement, and so good inter-observer agreement in the interpretation would be desirable. The quantification of inter-observer agreement was the subject of a study mentioned earlier, where 486 inflation cycles were rated by 3 independent observers (Drinnan et al, 2003b). For the cuff test, there are two aspects to agreement:

Agreement on whether to interpret an inflation cycle
For 385 of the 486 inflation cycles, the three observers agreed completely that the cycle should be analysed (n = 203) or should not be analysed (n = 182). For just 22% of all inflation cycles was there any disagreement, as shown in the figure.

Agreement in estimation of cuff interruption pressure
For those cycles where two or more observers did decide to analyse the cycle, we studied the agreement. The graph shows the two or three individual measurements (Y axis) plotted against the mean of them (our best estimate of the true value).

On the basis of the data presented, we believe inter-observer agreement is excellent.
Abdominal pressure and straining

One of the key features of cystometry is the provision of a rectal line, for measurement of abdominal pressure. Since the cuff test is non-invasive, it does not provide any measurement of abdominal pressure, and we have considered the potential implications.

The origin of abdominal pressure

The resting pressure in the abdomen is caused by the weight of body tissues sitting within the abdomen. Since the lungs and diaphragm must be at (approximately) atmospheric (zero) pressure, and the body is largely water, you might estimate a resting pressure (in an upright patient) as the distance from the diaphragm to the pubic symphysis (below).

Detrusor versus vesical pressure

In conventional cystometry, subtracted or detrusor pressure is the most commonly quoted measure of bladder contraction. Detrusor pressure is determined by subtracting the abdominal pressure from the vesical pressure; the vesical pressure \( p_{\text{ves}} \) is that actually measured in the bladder. As it turns out, abdominal pressure (from a rectal line) is reasonably consistent between individuals; the mean (±SD) abdominal pressure during voiding for 76 patients was 35 (±9) cm water, and this agrees with other similar studies. There is a detectable effect due to the patient's weight, but this is too small to be of clinical importance (McIntosh et al., 2003b).

In the cuff test, there is a further small offset because the cuff is positioned typically 8 cm below the pubic symphysis, the datum for invasive measurements. Beneath the cuff, the fluid pressure measured will be correspondingly 8 cm H\(_2\)O higher due to the hydrostatic gradient.

In principle, it would be possible for the cuff machine to apply an automatic correction for these factors. In practice, we prefer to present the data as recorded.

The cuff pressures will therefore be higher than the detrusor pressures in the same individual, which means the measurements must be interpreted differently.

Abdominal straining

Straining is a way for the patient to generate an artificially high bladder pressure by contracting the abdominal muscles.

In conventional cystometry, the strain has little or no effect on the subtracted detrusor pressure.

In addition, the abdominal pressure line gives a clue about straining. In the example (left) recorded during a voiding phase, there is a clear rise in \( p_{\text{abd}} \) due to the strain.

For the cuff test, straining will affect the measured pressure, but at present cannot reliably be detected.

During trials with invasive lines, patients were asked not to strain. When the request was made in terms they understood, 83% were able to comply, as judged from their abdominal pressure measurements.
Bladder contractility and isovolumetric pressure

As we have already said, the cuff test estimates isovolumetric pressure. The isovolumetric pressure is the pressure in the bladder when flow is completely stopped, and is therefore an indicator of bladder contractility under known conditions.

The figure shows invasive data recorded during a cuff test. As the cuff is inflated (green trace), the flow is reduced and finally stops (orange trace). At this point, the isovolumetric detrusor pressure can be read from \( p_{\text{det}} \) (purple trace).

As the flow was stopped, the detrusor pressure \( p_{\text{det}} \approx 90 \) cm H\(_2\)O has clearly risen from its original value \( \approx 50 \) cm H\(_2\)O.

This can be thought of as the bladder's response to the increasing obstruction, but in fact can be explained by the Hill equation and the bladder physiology.

There is an extremely sound theoretical basis for measuring isovolumetric pressure, and some authorities (Griffiths & van Mastrigt, 1985; Comiter et al., 1996) would claim it is a more appropriate measurement of bladder contractility than the more common \( p_{\text{det},Q_{\text{max}}} \), which is measured at maximum flow.

However once again, this isovolumetric pressure rise means that pressures measured using the cuff test will be higher than those from a conventional cystometry.

Magnitude of the isovolumetric pressure rise

To assess the effect of the isovolumetric pressure rise on the cuff measurement, we have assessed the relationship between isovolumetric pressure and pressure at maximum flow in three separate studies.

One set of results is shown in the figure (left), with the best fit shown in blue; the effect amounts to a pressure rise of 2 cm H\(_2\)O for each 1 ml/s reduction in flow, and this value was extraordinarily consistent (within 5%) between the three studies.

Using this statistic, an allowance can be made in the construction of a specific nomogram for the non-invasive data (Griffiths et al., 2003). This is considered next.
Using the data - the case for a modified ICS nomogram

The ICS nomogram

The ICS nomogram (right) is similar to earlier nomograms produced by Paul Abrams & Derek Griffiths, and by Werner Schäfer. The stages in using the ICS nomogram are as follows:

- Determine \( Q_{\text{max}} \) from cystometry;
- Determine \( p_{\text{det}Q_{\text{max}}} \) from cystometry;
- Plot a point on the nomogram using those values.

The point will lie in one of the regions unobstructed, equivocal or obstructed.

A comparable cuff test nomogram

Using the ICS nomogram as a starting point, a comparable nomogram can be constructed for the cuff test. Since the ICS, Schäfer, Abrams and Griffiths all agree on the position of the uppermost (obstructed versus equivocal) line, we use this as the starting point. {A similar argument could be applied to the lower line, when the authorities finally agree on its rightful position.}

To recall, the pressures recorded by the cuff test will be higher than those from cystometry. To allow for these differences, the ICS nomogram can be modified in 2 steps:

**STEP 1** In the cuff measurement, the abdominal pressure component has not been subtracted. This means that 'cuff' pressures will be higher than 'cystometry' pressures by about 40 cm H\(_2\)O

**STEP 2** In the cuff measurement, pressures are measured at zero flow, and due to the isovolumetric pressure rise will be higher than those in cystometry at full flow. We estimate this effect is about 2 cm H\(_2\)O for every 1 ml/s flow, and this affects the slope of the line.

To show the effect of these two steps pictorially in the diagram... →

...and the result is a new nomogram that looks like this.

This is the modified ICS nomogram.
Using the modified nomogram

In the earlier example (reproduced left), we made estimates of 165, 160, 120 and 120 cm H₂O interruption pressure in the four graphs.

We take the largest as the peak interruption pressure, representing the patient's best bladder contraction:

\[ P_{\text{cuff, int}} = 165 \text{ cm H}_2\text{O} \]

We have also added our estimate of peak flow to the flow trace:

\[ Q_{\text{max}} = 8 \text{ ml/s} \]

Note that we ignore the surge of urine occurring every time the cuff is released.

It now remains to plot the point, exactly as for the ICS nomogram...

...so we think this patient is obstructed.

And that's it.
The Newcastle – Bristol validation study

To validate this new nomogram, we present data from 143 subjects who had free cuff tests (ie. without simultaneous cystometry) in either Newcastle or Bristol. Each was also classified according to the ICS standard using invasive cystometry, giving rise to the red, yellow and green colours of the points plotted.

Since it was derived from the equivalent line on the ICS nomogram, the line on the modified nomogram ought to separate obstructed subjects (above the line) from equivocal and unobstructed patients (below the line).

For a long time, standard flow rate criteria (Q_{\text{max}}<10 \text{ ml/s}, indicated by the blue line on the graph) have been used to diagnose obstruction. The table below summarises the classification for the cuff test, and for the flow criterion.

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<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
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<tr>
<td>Modified ICS Nomogram</td>
<td>69%</td>
<td>82%</td>
<td>68%</td>
<td>81%</td>
</tr>
<tr>
<td>Q_{\text{max}} &lt; 10 \text{ ml/s}</td>
<td>63%</td>
<td>84%</td>
<td>69%</td>
<td>80%</td>
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For the 68% of patients where flow classification and cuff classification agree:

<table>
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<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined cuff &amp; flow</td>
<td>76%</td>
<td>94%</td>
<td>85%</td>
<td>90%</td>
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At present, we believe this indicates the most useful algorithm for using the cuff test:

- If flow and cuff measurements agree the patient is obstructed, there is an 85% probability they are obstructed.
- If flow and cuff measurements agree the patient is not obstructed, there is an 90% probability they are not obstructed.
- In the 32% of patients where flow and cuff measurements disagree, the patient may be referred for cystometry.

On this basis we repeat our earlier statement: The new cuff test is an adjunct to a conventional flow study. It is not a replacement for cystometry (the best gold standard), the cuff test gives some information on bladder contraction pressure. We believe it can be used in some cases to confirm the likely diagnosis of obstruction, while avoiding the need for full cystometry.
Example recordings and interpretation

Some typical good recordings

This is typical for a good cuff test. The key points are:
- Flow stops on every inflation;
- Flow recovers after the cuff is deflated, as seen in the top panel;
- There is no ambiguity about the cuff interruption pressure.

We would make estimates of 70, 85, 80 and 60 cm H₂O for the cuff interruption pressures.

These are broadly consistent with each other, and so we would accept this as a good cuff test.

In conjunction with a peak flow of around 6 ml/s, we would classify this patient unobstructed, but only just. In fact, this patient was unobstructed on cystometry, but had DI.

For completeness, here is the final inflation from the same patient:

In this case, there is little or no flow recovery after the inflation. The void is complete, and we would have excluded this inflation according to the rules.
More good recordings

This is another one in the same vein:

- We would estimate the peak flow $Q_{\text{max}}$ to be around 13 ml/s.
- Once again, we would make measurements of 70, 70 and 65 cm H$_2$O for the first three cuff interruption pressures.
- Flow does not recover after the fourth inflation, and so we would exclude it according to rule 1.
- According to the nomogram, this patient is more clearly unobstructed. On cystometry, his AG number was 8.

And another. For this one, we'd make an estimate of 175 cm H$_2$O from the first inflation, with a peak flow of 6 ml/s. This makes the chap obstructed, as was demonstrated on cystometry by an AG number of 85.

The second inflation would be acceptable, but the pressure is by this time diminishing towards the end of the void.

We would exclude the third inflation because there was no recovery of flow afterwards.
Applying the exclusion criteria - rule 2 (ambiguous interruption pressure)

In this one, the interruption pressures are anybody’s guess.

On cystometry his AG number was 33 (equivocal), so this might be straining secondary to outlet obstruction.

Or maybe he was leaning on the flow meter.

In any case, you would ask the good man to try again without straining and without touching the flow stand:

- This is the result - usable values of 90 and 85 cm H₂O from inflations 1 and 2.
- Inflation 3 is excluded because there was no recovery of flow.
- With a peak flow of 11ml/s, he would be classified unobstructed by the nomogram, but lies in the area close to the dividing line.
Applying the exclusion criteria - rule 2 (ambiguous interruption pressure)

- Here, inflation 2 gives a good example for the application of rule 2.
- In this case, measurements of 50 and 115 cm H$_2$O are both possible candidates.
- We would therefore exclude inflation 2 in favour of a measurement of 155 cm H$_2$O from inflation 1.
- With this high bladder pressure giving a peak flow of 10 ml/s, this chap was classified *obstructed*. On cystometry, his AG number was almost 60.

Here's another example of the same thing.

- We would exclude inflation 2 in favour of a measurement from inflation 1.
- Inflations 3 and 4 are both excluded for lack of flow recovery.
- A peak flow of (about) 15 ml/s for a pressure of (about) 65 cm H$_2$O makes this chap *unobstructed*. This agrees with cystometry.
Applying the exclusion criteria - rule 3 (flow is not interrupted)

- This is an example (inflation 1) where flow is not stopped at the instrument's maximum pressure of 200 cm H₂O.
- This might mean a very high bladder pressure, but you might also suspect the cuff had slipped.
- You can see the artifact caused by jug removal around 67 seconds into the study.

In this case, we repeated the study. The result shows that the patient did indeed have an unusually high bladder pressure.

He was *equivocal* on cystometry (AG = 30), but we would have classified him as *obstructed*. 
Some more difficult recordings (1)

We suspect this patient was straining from the erratic flow trace.

- For inflation 1, it would initially seem the cuff interruption pressure should be around 110 cm H\textsubscript{2}O, but the final kick causes some ambiguity.

- For inflation 2, there is again an erratic flow, though a pressure of 145 cm H\textsubscript{2}O seems reasonable.

- Inflation 3 follows the expected pattern; the final kick is half-hearted, and we'd probably ignore it.

- Flow does not recover after inflation 4, and so it is excluded.

On review, inflations 1, 2 and 3 seem consistent with each other, and so we would be happy to use these results. A pressure of 145 for a peak flow of 10

Here's another difficult example:

- We could reject inflations 2 and 3 on the grounds that they are ambiguous.

- We should also reject inflations 1 and 4 because there is no flow recovery.

- However - for inflations 3 and 4 we can say the interruption pressure is not less than 140 cm H\textsubscript{2}O.

- For a peak flow of 14 ml/s, this would put the patient just into the obstructed category. On cystometry, he was equivocal.
Some more difficult recordings (2)

- This is one where we think the patient was straining (inflation 3). Even if they weren't flow didn't recover so we would exclude the inflation.

- We would also look on inflation 2 with some suspicion.

- We would, however, be happy to make a measurement of 135 cm H$_2$O from inflation 1.

- In conjunction with a peak flow of perhaps 15 ml/s, this patient would be close to the dividing line on the nomogram.

- On this one (from the same patient on a later date), you might be tempted to exclude the first inflation on the grounds that flow doesn't stop.

- But you would also exclude the second inflation because flow doesn't recover.

- In practice, it is clear that inflation 1 was following the normal pattern.

- You could even make an estimate of the interruption pressure, at least 200 cm H$_2$O. We would be happy to use this pressure.
Some more difficult recordings (3)

• In this example, the peak flow is difficult but around 9-10 ml/s seems reasonable.

• We would not attempt to analyse inflation 1. It would be excluded either on the grounds of high variability (rule 2), or because the flow didn't stop (rule 3).

• Inflation 2 is usable, and we would estimate $p_{\text{cuff,int}} = 120 \text{ cm H}_2\text{O}$.

• Inflation 3 would probably be excluded because flow does not recover afterwards (rule 1).

• For a maximum flow rate of 10 ml/s, this chap would lie right on the line. On cystometry, he had an AG number of 75, which means extremely obstructed.

Who knows what to do with these two? We would probably cut our losses and try to repeat the tests.
Further developments

Newcastle outcome study

While the modified ICS nomogram looks promising, it has so far been compared only with a 'silver standard' from invasive cystometry. Yet it is known that in around 10% of cases, patients who are cystometrically obstructed receive no benefit from surgery to relieve obstruction.

It therefore seems more appropriate to test the new nomogram against a gold standard of surgical outcome. However, since the measurement of outcome is notoriously difficult, this will require large-scale collection of data. This began 6 months ago and over the next year, we plan to collect outcome data on 200 subjects. We also aim to involve other centres with a final target in the region of 1000 subjects.

Knee pressure

In many subjects the inflating cuff has little or no effect on flow rate until some so-called knee pressure, after which the flow falls steadily. We have established the theoretical basis for the knee pressure in an experimental model (left); in the model the knee pressure is analogous to prostatic opening pressure in humans (Drinnan et al, 2003a). We are currently investigating the potential use of this measurement.

The penile compression-release manoeuvre

Sullivan and Yalla first described this manoeuvre, whereby the surge of flow $Q_{\text{surge}}$ on release of the penis after flow interruption (Sullivan & Yalla, 2000), relative to the steady state flow $Q_{\text{ss}}$, carries diagnostic information.

The cuff test can reproduce the manoeuvre, and we now have data supporting Sullivan & Yalla's original work.
References


McIntosh et al. The relationship of abdominal pressure and body mass index in men with LUTS. Neurourol Urodynamics 2003b; In press.


Bibliography
