Urethral Resistance Factor (URA) Versus Schäfer's Obstruction Grade and Abrams-Griffiths (AG) Number in the Diagnosis of Obstructive Benign Prostatic Hyperplasia

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Abstract

Objectives: Different methods of analysing pressure-flow plots to quantify bladder outlet resistance in men with lower urinary tract symptoms (LUTS) suggestive of benign prostatic hyperplasia (BPH) were developed in the past. The aims of this study were to quantify the degree of agreement between the diagnosis of obstruction by the different methods, and to compare the applicability of the different methods in the evaluation of bladder outflow conditions, in a large group of these men.

Methods: In consecutive men with LUTS basic initial evaluations, recommended diagnostic tests and urodynamic investigations were performed. From pressure-flow studies, the group-specific resistance factor (URA), Schäfer’s obstruction grade and Abrams-Griffiths (AG) number were estimated. Men with $21 \text{ cm H}_2\text{O} \leq \text{URA} \leq 29 \text{ cm H}_2\text{O}$ and men with Schäfer’s grade equal 2 were classified as equivocal. In conformity with the provisional ICS definition, men with $20 \leq \text{AG number} \leq 40$ were classified as equivocal.

Results: In 78% of the 565 included men Schäfer’s classification agreed with URA classification. In 82% ICS classification agreed with URA classification. Most agreement (94%) existed between Schäfer’s classification and ICS classification. Men with relatively low detrusor pressure at maximum flow and relatively low maximum flow had a high prevalence among those in whom URA and Schäfer’s classifications and among those in whom URA and ICS classifications differed.

Conclusions: Differences between URA, Schäfer’s and ICS classification were near the points of intersection of the different boundaries, and a decision whether or not to perform surgery is not likely to be influenced by this disagreement.
Introduction

The only reliable method for directly diagnosing bladder outlet obstruction (BOO) is simultaneous measurement of the driving pressure and the resulting flow rate. If outflow resistance is increased, detrusor pressure will increase and flow rate will decrease. Urodynamics offers an objective tool for the assessment of BOO in benign prostatic hyperplasia (BPH). Whether or not to perform surgery on patients with lower urinary tract symptoms (LUTS) suggestive of BPH is partially based on the extent of obstruction derived from pressure-flow relations.

Different methods of analysing pressure-flow plots and to quantify bladder outlet resistance in patients with BPH have been developed in the past. These different approaches are based on similar theoretical principles, but are different in detail and objectives.

Urethral resistance factor (URA)

The concept of the passive urethral resistance relation (PURR) to quantify bladder outflow conditions from the complex pressure-flow relation in a few parameters is generally accepted. Urethral resistance can be quantified using a group-specific resistance factor (URA) that is based empirically on the pressure-flow plots obtained in a large number of voidings of adult patients. Every combination of pressure and corresponding flow occurring during a micturition, can be represented in the figure by a point. The value of the intercept on the pressure axis (at zero flow) for the curve on which the point lies, represents the urethral resistance factor URA. URA can be calculated for any pair of pressure-flow values by solving the following equation for URA ($p_{det}$ is detrusor pressure (in cm H$_2$O) and Q is the corresponding flow rate (in ml/s)):

\[
URA = \frac{[(1 + 1.52.10^{-3} \cdot Q^2 \cdot p_{det})^{1/2} -1]}{(7.6.10^{-4} \cdot Q^2)}
\]

The units of URA are the same as those of pressure, i.e., cm H$_2$O. In practice, URA is calculated from the maximum flow rate and corresponding detrusor pressure.

Schäfer’s obstruction grade

A simplification of the PURR is the linear PURR (linPURR), which allows clear identification of individual outflow conditions with distinction of different obstruction types. Reduction to single-value grading is reached when the linear PURR is plotted in a specific pressure-flow diagram, which is divided in seven areas corresponding to different outflow conditions: Schäfer’s obstruction grade (0, no obstruction to 6, severe obstruction).
tion). Classification of what is more or less obstructed is to a minor degree influenced by subjective judgement.

**AG number**

Based upon the Abrams-Griffiths nomogram, Lim and Abrams introduced the Abrams-Griffiths (AG) number for quantifying the urethral resistance. Each pressure-flow plot can be represented by an AG number that can be easily calculated by the following equation (where \(p_{\text{det.Qmax}}\) is detrusor pressure in cm H\(_2\)O at maximum flow rate and \(Q_{\text{max}}\) is maximum flow rate in ml/s):

\[
\text{AG number} = p_{\text{det.Qmax}} - 2 * Q_{\text{max}}
\]

**Obstructed, unobstructed, equivocal**

URA and AG number are continuous variables and Schäfer’s grade is a discrete variable, all allowing quantification of urethral resistance. Special values of URA, Schäfer’s grade, and AG number offer the possibility to classify men in obstructed, unobstructed, and equivocal categories. Patients with URA>29 cm H\(_2\)O were classified as obstructed and those with URA<21 cm H\(_2\)O as unobstructed (see results and discussion). The remaining patients were classified as equivocal.

Patients with Schäfer grade 0 or 1 are defined as unobstructed and those with grade 3 or higher as obstructed. We defined men with Schäfer grade 2 as equivocal.

In 1997, the International Continence Society published a provisional nomogram, which is a modification of the Abrams-Griffiths nomogram. Classification is based upon where a plot of \((Q_{\text{max}}, p_{\text{det.Qmax}})\) is positioned in the nomogram. Because the AG number also originates from the Abrams-Griffiths nomogram, the ICS cut-off values are particular values of the AG number:

- If: \((p_{\text{det.Qmax}} - 2 * Q_{\text{max}}) < 20\) : ICS unobstructed
- If: \(20 \leq (p_{\text{det.Qmax}} - 2 * Q_{\text{max}}) \leq 40\) : ICS equivocal
- If: \((p_{\text{det.Qmax}} - 2 * Q_{\text{max}}) > 40\) : ICS obstructed

**Aim of study**

Our aim is to quantify the extent of (dis)agreement among the different methods of analysing pressure-flow plots to define bladder outlet obstruction in a large group of men with LUTS suggestive of BPH.
Materials and Methods

From October 1993 on, in consecutive men with LUTS basic initial evaluations (history, quantification of symptoms, physical examination and digital rectal examination, urinalysis and renal function assessment) and recommended diagnostic tests (uroflowmetry and residual urine estimation) were performed, conforming to the recommendations of the International Consensus Committee on Benign Prostatic Hyperplasia (BPH) 11. Men were included if they were over the age of 50 years, without any of the other specified exclusion criteria of the International Consensus Committee on BPH12, they voided a sufficient volume (>150 ml) during one or more free uroflowmetry studies, residual urine was estimated reliably and prostate size was determined by transrectal ultrasound. International Prostate Symptom Index (S) for BPH and quality of life assessment (L) as developed and validated by the American Urological Association Measurement Committee13, were used to quantify symptoms. In case the results of these evaluations were suggestive of bladder outflow obstruction, these patients were also evaluated urodynamically by filling cystometry and pressure-flow studies. Filling cystometric studies were performed with the patient supine and erect. Pressure-flow studies were done twice with the patient erect. Bladder pressure was recorded with a 5F catheter and rectal pressure was measured with a 14F catheter connected to external pressure transducers. The bladder was filled with saline at 37°C, through a second 5F catheter, at a constant rate of 50 ml/min. In some men an 8F double lumen catheter was used for bladder pressure measurement and bladder filling. Filling was stopped when the patient had a strong desire to void. The first pressure-flow study was done with measuring and filling catheters in the bladder, and the second study was done after removal of the filling catheter. The pressure-flow study with the lowest urethral resistance (usually during voiding with only the measuring catheter in the bladder) was used for further analysis.

In all patients residual urine was estimated during one of the visits at the outpatient department by transabdominal ultrasound or catheterisation. If residual urine was significant, this test was repeated. The urodynamic investigation always started with uroflowmetry and determination of the residual volume by catheterisation. Some patients were not able to arrive with a full bladder and sometimes were not able to produce a flow curve. At the end of the urodynamic investigation the bladder of these patients was refilled and after removal of the catheters uroflowmetry was performed. If these patients were known to have significant residual volume, catheterisation was performed once more.

From pressure-flow studies, the group-specific resistance factor URA and Schäfer’s obstruction grade were estimated and the provisional ICS method for definition of obstruction was applied, using the values of the maximum flow rate and corresponding detrusor pressure. Patients with URA>29 cm H₂O were classified as obstructed10. We defined patients with 21 cm H₂O ≤ URA < 29 cm H₂O as equivocal and patients with URA < 21 cm H₂O as unobstructed.
(see results and discussion). Patients with Schäfer grade 0 or 1 were classified as unobstructed, with grade 2 as equivocal and with grade ≥ 3 as obstructed.

Patients with AG number > 40 were classified as obstructed, with AG number < 20 as unobstructed, and with 20 ≤ AG number ≤ 40 as equivocal.

Descriptive statistics were used, including Spearman’s distribution-free correlation coefficient. The Kolmogorov-Smirnov goodness of fit test was used to examine whether or not the distribution of a variable was normal.

Results

Results were obtained from 565 included men. Table 6.1 describes baseline characteristics of the evaluated patients.

A capacity of 1100 ml was found in one patient. The maximum capacity in the other men was 900 ml. In 218 patients (39%) no residual volume was found. In men with a residual volume, this volume was lower than or equal to 50 ml in 131 men (23%), between 50 and 100 ml in 107 men (19%) and higher than 100 ml in 109 men (19%).

From 511 (90%) of our 565 men the pressure-flow point lies in the area enclosed by maximum flow between 0 and 25 ml/s and detrusor pressure between 0 and 100 cm H$_2$O.

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<tr>
<th>Table 6.1 Mean, standard deviation (SD) and range of different baseline characteristics of the evaluated population (N=565).</th>
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<tbody>
<tr>
<td>Characteristic</td>
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<td>----------------------</td>
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<tr>
<td>Age (yrs)</td>
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<tr>
<td>Prostate volume (ml)</td>
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<tr>
<td>$Q_{\text{max.free}}$ (ml/s)</td>
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<td>$Q_{\text{max}}$ (ml/s)</td>
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<tr>
<td>$P_{\text{det}_{\text{Qmax}}}$ (cm H$_2$O)</td>
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<td>Capacity (ml)</td>
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<td>Residual volume (ml)</td>
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<td>Symptom Index (S)</td>
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<td>Quality of Life (L)</td>
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</table>
Figure 6.1 shows the distribution of these 511 men with respect to detrusor pressure (cm H$_2$O) at maximum flow and with respect to maximum flow (ml/s). The upper boundary values of 25 ml/s and 100 cm H$_2$O were chosen in order to exclude extreme pressure-flow points.

Figure 6.2 shows frequencies of URA, Schäfer’s grade and AG number for all 565 men. Normal curves are displayed. Distributions of all three variables are not normal (Kolmogorov-Smirnov test).

In our group, highest agreement between URA classification and Schäfer’s classification of unobstructed and equivocal was reached by choosing URA=21.3 cm H$_2$O. Highest agreement between URA and ICS classification was obtained by setting URA=21.1 cm H$_2$O. Therefore, as boundary value between unobstructed and equivocal men URA=21 cm H$_2$O was chosen.
Figure 6.2 Frequencies of URA, Schäfer’s grade and AG number. Normal curves are displayed.
Although in our study we defined URA=29 cm H₂O as the limit between equivocal and obstructed, in our well-defined group most agreement with Schäfer’s classification and with ICS classification was reached when we defined URA>30 cm H₂O as obstructed. In that case, agreement of 7 more patients was reached between URA and Schäfer’s classification and between URA and ICS classification.

Table 6.2 shows the distribution of the patients in unobstructed, equivocal and obstructed, following URA, Schäfer’s grade and the definition of the ICS.

<table>
<thead>
<tr>
<th>Unobstructed</th>
<th>Equivocal</th>
<th>Obstructed</th>
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<tbody>
<tr>
<td>URA</td>
<td>21%</td>
<td>26%</td>
</tr>
<tr>
<td>Schäfer’s grade</td>
<td>20%</td>
<td>27%</td>
</tr>
<tr>
<td>ICS</td>
<td>19%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Although in our study we defined URA=29 cm H₂O as the limit between equivocal and obstructed, in our well-defined group most agreement with Schäfer’s classification and with ICS classification was reached when we defined URA>30 cm H₂O as obstructed. In that case, agreement of 7 more patients was reached between URA and Schäfer’s classification and between URA and ICS classification.

Table 6.2 shows the distribution of the patients in unobstructed, equivocal, and obstructed, following URA, Schäfer’s grade, and the definition of the ICS. According to all three possible classifications, about 50% of our patient group is defined as obstructed and about 20% as unobstructed.

Figure 6.3A Scatterplot of patients where ICS classification differs from URA classification. Borderlines in URA and ICS nomograms are indicated. Note: Due to overlapping data, the number of points in the figure may be lower than the actual number of men.
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Figure 6.3B Scatterplot of patients where Schäfer’s classification differs from URA classification. Borderlines in URA and Schäfer’s nomograms are indicated. See note figure 6.3A. Due to the properties of the printer program, minimal differences may be observed between the positions of common men in the figures 6.3A and 6.3B.

Figure 6.3C Scatterplot of patients where Schäfer’s classification differs from ICS classification. Borderlines in Schäfer’s and ICS nomograms are indicated. See note figure 6.3A.
In figure 6.3A-C patients are shown where the three classification methods differ from each other. Borderlines in URA, ICS, and Schäfer’s nomograms are indicated. The area enclosed by maximum flow from 0 to 25 ml/s and detrusor pressure from 0 to 100 cm H₂O is displayed.

Discussion

Extensive scientific and clinical considerations led to the recommendations of the International Consensus Committee on BPH. Our inclusion criteria were based on these recommendations and we considered it not reasonable to change any of these recommendations. However, we realise that the condition that men were included only if they could void a volume of at least 150 ml during free uroflowmetry may have excluded men with severe and prolonged obstruction. In a reasonable number of these excluded men, however, bladder properties may have changed resulting in (partly) decompensated bladders. We assume that our group included men who were able to compensate more or less for the impaired outflow condition. In our group most men (81%) did not have a residual volume, or had a residual volume lower than 100 ml.

In our urodynamic department measures are taken to guarantee the privacy of the patients. Telephone calls are not allowed, personnel are not allowed to enter the examination room during the investigation, buzzers are forbidden. The number of investigators is restricted to a minimum. During voiding the investigators withdraw in a room with a second display showing the actual pressure and flow curves. It is always verified whether the patient has voided like at home. If not, the study is not suited for analysis and a new attempt is made to obtain a reliable measurement. On an average an examination lasted one hour. Patients who met the inclusion criteria of the consensus committee but were not able to produce a reliable pressure-flow study were exceptional. We have computerised systems to abstract data from the curves. Nevertheless, it is always checked by visual inspection of the curves whether these data are correct and if necessary data are adjusted.

Schäfer defines the line between grade 1 and grade 2 as the upper limit of non-obstruction and the line between grade 2 and 3 as the lower limit of real obstruction. The authors of the provisional ICS definition recommend among others the use of an equivocal zone. Schäfer has objections against the use of the term equivocal. In men who are urodynamically clearly unobstructed or who are urodynamically clearly obstructed this finding will play a prominent role, but not the only one, in the decision
whether or not to perform surgery. In patients falling in the equivocal zone other clinical findings will dominate that decision. Based on the knowledge we have now, this is our interpretation of the term equivocal. Strictly speaking, urodynamic findings can not be equivocal but a classification can. Whether Schäfer’s grade 2 or the ICS zone should be taken as equivocal zone is a question we can not (yet) answer; nevertheless the equivocal zone of the provisional method of the ICS is similar, but not identical, to the region defining Schäfer’s grade 2.

According to Rollema et al.\textsuperscript{10} patients with URA $> 29 \text{ cm H}_2\text{O}$ were classified as obstructed. No URA value was defined to discriminate between unobstructed and equivocal. We calculated the values of URA with the best agreement between classification by Schäfer’s grade and by URA of equivocal and unobstructed men (URA $= 21.3 \text{ cm H}_2\text{O}$) and between classification by ICS and by URA of these men (URA $= 21.1 \text{ cm H}_2\text{O}$). For reasons of simplicity we finally took URA $= 21 \text{ cm H}_2\text{O}$ as the cut-off point. In order to be able to compare the consequences of the use of the ICS classification with those of the URA classification, we recommend definition of the zone $21 \text{ cm H}_2\text{O} \leq \text{URA} \leq 29 \text{ cm H}_2\text{O}$ as equivocal. Despite the fact that the URA equivocal zone is based on ICS equivocal zone, still 20 men are classified as unobstructed by URA and equivocal by ICS and nine more are classified as equivocal by URA and unobstructed by ICS (see figure 6.3A).

In our group of 565 men with LUTS suggestive of BPH, in 127 men (22\%) classification according to Schäfer differs from that by URA. In 100 men (18\%) classification by ICS differs from that by URA.

Using URA $= 30 \text{ cm H}_2\text{O}$ as boundary between equivocal and obstructed increased the agreement between classification by URA on the one side and classification by Schäfer’s grade and ICS on the other side. However, this increase related to 7 men of 127 and 7 men of 100, respectively. In 33 men (6\%), Schäfer’s grade differs from ICS. No patient was classified more than one class different.

Fifty-four men had a point in the pressure-flow plot outside the area enclosed by maximum flow between 0 and 25 ml/s and detrusor pressure between 0 and 100 cm H$_2$O. No disagreement among the different methods existed in these patients. Thus all differences between the classifications by URA, Schäfer, and ICS are concentrated near the points of intersection of the different boundaries. The decision whether or not to perform surgery is not likely to change when in these cases another classification is applied. Not only degree of obstruction, but also many more, objective and subjective, variables will lead to this decision.

Lim et al.\textsuperscript{15} reviewed urodynamic tracings of 85 patients who had pressure-flow studies before and after prostatectomy. They classified equivocal patients as unobstructed. Like in our study, AG number $> 40$, URA $> 29 \text{ cm H}_2\text{O}$, and Schäfer’s grade $\geq 3$ were
considered as obstructed. About 73% of these 85 patients were classified as obstructed. In our study only about 50% of the patients were obstructed. This difference could be expected, because Lim et al.\textsuperscript{15}, in contrast to our inclusion, studied men who were already selected for surgery.

The classification agreement between URA and Schäfer’s grade was 95% (in our study it was 86%, defining only two categories of patients: unobstructed and obstructed). Agreement between URA and ICS was 94% (in our study it was 87%) and between Schäfer’s grade and ICS 98% (in our study it was 97%). The higher agreement in the study of Lim et al.\textsuperscript{15} may be due to the higher prevalence of men who are obstructed. Defining just two classes of obstruction, unobstructed and obstructed, will increase the agreement between URA, Schäfer’s grade and AG number.

In figure 6.1 men are concentrated in the area around a detrusor pressure at maximum flow of about 60 cm H\textsubscript{2}O and a maximum flow of about 10 ml/s. In 127 men of our well-defined group of 565 men, classification according to Schäfer’s grade differs from that by URA. Of these 127 men, 41 (32%) lie in the area in which URA classified them as obstructed and Schäfer’s grade as equivocal. In 100 men of the 565 men ICS-classification differs from that by URA. Of these 100 men 44 (44%) lie in the area in which URA classified them as obstructed and ICS as equivocal. Thus men with relatively low detrusor pressure at maximum flow and relatively low maximum flow have the highest prevalence among those in which URA and Schäfer’s grade classifications and among those in which URA and ICS classifications differ.

We want to emphasise that these conclusions are formulated for our well-defined group of men with LUTS suggestive of BPH. However, we assume that the men included in our study form a reasonable representative sample of the population of men who attend a urology clinic, and for whom there is some suspicion of prostatic obstruction.
Conclusions

In our group of 565 included men with LUTS due to BPH, in 438 men (78%) classification according to Schäfer’s grade agrees with classification according to URA. In 465 men (82%) agreement exists between classification by URA and ICS. Disagreement between the methods of classification exists only near the points of intersection of the different boundaries, and a decision whether or not to perform surgery is not likely to be influenced by this disagreement.

Men with relatively low detrusor pressure at maximum flow and relatively low maximum flow have a high prevalence among those in which URA and Schäfer’s grade classifications and among those in which URA and ICS classifications differ.

References


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