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The Abrams-Griffiths nomogram

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Summary. The treatment of benign prostatic hyperplasia and the definition of bladder-outlet obstruction has preoccupied urologists and researchers in recent years. Bladder-outlet obstruction can be defined only by pressure-flow measurement. Various methods of analysis of pressure-flow data have been proposed. The Abrams-Griffiths nomogram is an easy method of classifying these data to distinguish between the presence or absence of obstruction. Using the values for the maximal flow and the corresponding voiding detrusor pressure a point can be plotted on the nomogram that determines whether the bladder outlet is obstructed, unobstructed, or equivocally obstructed. For those that fall in the equivocal zone, further criteria for the mean slope of the pressure-flow plot and the minimal voiding detrusor pressure are used to determine whether there is obstruction or not. The nomogram's prognostic value in predicting the outcome of prostatectomy has been studied and found to be excellent. The Abrams-Griffiths nomogram can be modified by assigning an Abrams-Griffiths number to each set of pressure-flow data. This number is easy to calculate and use and gives a continuous variable that can be used to evaluate the effects of therapy. Although the Abrams-Griffiths nomogram and number are somewhat simplistic, none of the more complex methods of pressure-flow analysis have been shown to be better predictors of treatment outcome to date.

The treatment of benign prostatic hyperplasia (BPH) has been the subject of much debate and controversy for many years. Populations all over the world are getting older and older, thereby increasing the number of patients with BPH. Patients are no longer being treated just for complications of the disease but more and more for their symptoms as well. The most common form of treatment is prostatectomy, which has become one of the most common surgical procedures in the developed world and increasingly so in developing countries. All this has put an economic strain on medical budgets and also brought on an explosion of alternative treatments over recent years.

There are several areas of debate, one of which is the subject of bladder-outlet obstruction (BOO). It is well known that BPH, although a pathological and, hence, anatomical diagnosis, does not necessarily cause BOO [12]. The rationale behind the treatment of BPH is to reduce or remove the BOO that is caused by prostatic disease. As the lower-urinary-tract symptoms (LUTS) are not specific to BPH or, indeed, to BOO, a more objective means of determining BOO should be used for better selection of patients for treatment. Furthermore, more objective parameters should be used in evaluating the efficacy of newer forms of treatment.

Urodynamics, being a functional test of the lower urinary tract, would naturally be capable of providing the objective determination of BOO. Uroflowmetry is simple to perform and can predict BOO accurately in a large number of patients. The use of maximal flow rate (Qmax) [17] and various flow-rate nomograms [15, 16, 27, 28] were popularised and became part of the routine practice of many urologists. However, studies have shown a high rate of false-negative diagnosis of 7%–25% [7, 13] and an estimated high false-positive rate of 25% [25]. Pressure-flow (pQ) studies have been used for better definition and grading of the degree of BOO [29]. Various methods of interpretation of pressure-flow data have been proposed and debated upon [3, 11, 24]. The Abrams-Griffiths (AG) nomogram [3] was developed as a simple and practical way to classify pressure-flow data specifically to distinguish the presence or absence of obstruction.

Development and interpretation

The development of the AG nomogram had been well described in the original paper published by Abrams and Griffiths in 1979 [3]. Pressure-flow studies were performed on 117 men over the age of 55 years who had possible prostatic obstruction. The pQ plots were classified (by D. J. G.) as to whether they represented obstructed or unobstructed plots based on criteria learnt from previous studies [5, 10]. Prior to these pQ studies, BOO was also assessed clinically by the other author (P. A.) independently, using the criteria described previously [1, 2, 4].

These two methods of assessment were compared and a nomogram relating Qmax to the corresponding detrusor pressure (pdetQmax) from the pQ data was constructed (Fig. 1). This diagram is divided into three regions, namely, unobstructed, equivocal and obstructed cate-

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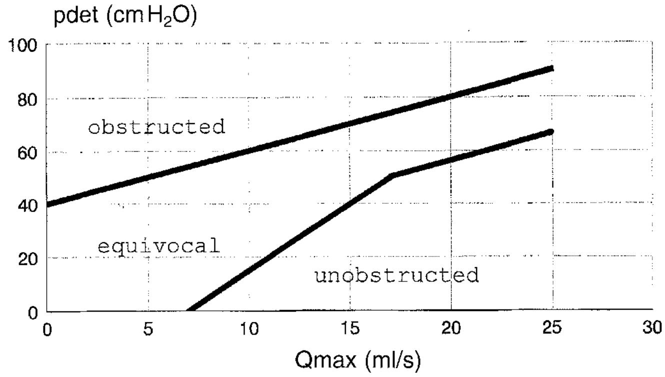

Fig. 1. Abrams-Griffiths nomogram

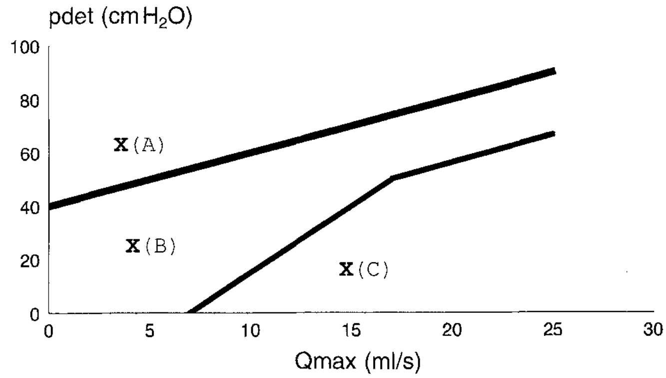

Fig. 2. Position of pdetQmax/Qmax plot: *A*, obstructed; *B*, equivocal (draw pressure-flow plot); *C*, unobstructed

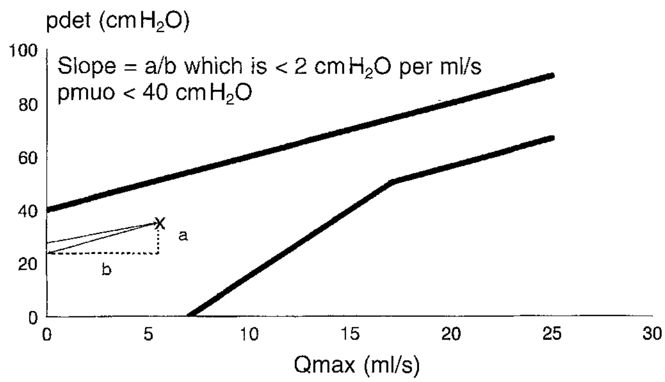

Fig. 3. Slope of ≤ 2 cm H_2O per ml/s and minimal voiding detrusor pressore of ≤ 40 cm H_2O: unobstructed

gories. When plotted on this nomogram, a point representing Qmax and pdetQmax determines whether there was obstruction, no obstruction or equivocal BOO (Fig. 2). For those in the equivocal range, a pQ plot, which is a plot of corresponding values for flow rate and detrusor pressure during the whole of micturition may be used to refine the diagnosis of obstruction. If the mean slope of the pQ plot is less than 2 cmH_2O per milliliter per second and the minimal voiding detrusor pressure (pmuo) is less than 40 cmH_2O, then the blatter outlet is unobstructed (Fig. 3). On the contrary, either a slope of greater than 2

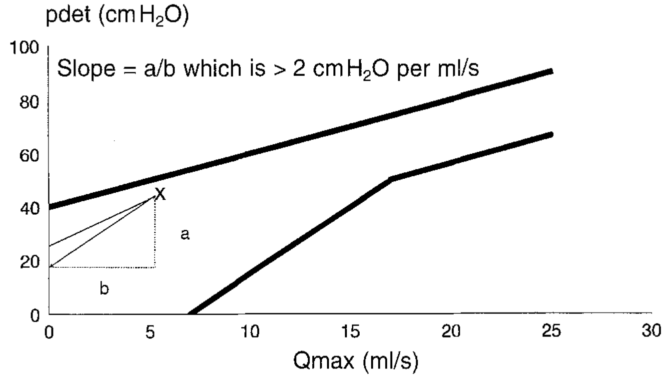

Fig. 4. Slope of > 2 cm H_2O per ml/s: obstructed

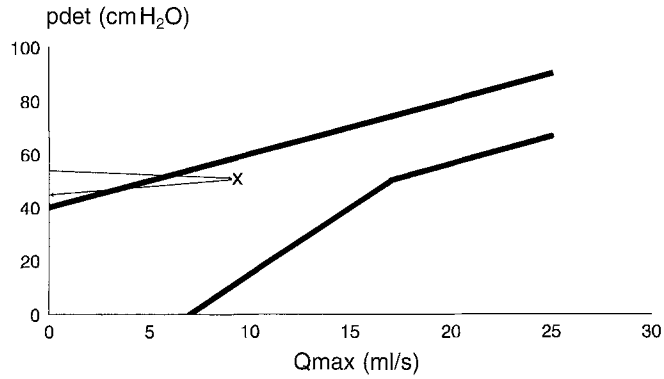

Fig. 5. Slope of ≤ 2 cm H_2O per ml/s and minimal voiding detrusor pressure of > 40 cm H_2O: obstructed

cmH_2O per milliliter per second or a pmuo of > 40 cmH_2O indicates there is BOO (Figs. 4, 5). All patients can therefore be classified as having an obstructed or an unobstructed bladder outflow.

Predictive value of the AG nomogram

The AG nomogram has been used in studying the outcome of prostatectomy. Jensen et al. [14] reported a prospective study whereby patients with LUTS suggestive of BOO were selected for prostatectomy based on a clinical score system and the pQ results were blinded pre-operatively. After surgery, pQ studies were repeated and the pre- and post-operative results were analysed. The presence or absence of obstruction was determined according to the AG nomogram.

There was a statistically significant difference in all pQ parameters between the obstructed group and the unobstructed group as determined pre-operatively. However, after surgery there was no difference between these two groups. In the group of patients who were unobstructed pre-operatively, it was most noteworthy that there was no difference between the pre- and post-operative pQ parameters. Prostatectomy in unobstructed patients, therefore, does not change the urodynamic parameters significantly. In those patients who were obstructed pre-operatively there was a statistical difference in the pQ parameters af-

Table 1. Mean urodynamic values obtained before and after prostatectomy in 78 patients pre-operatively classified as obstructed and 7 classified as unobstructed

Parameter	Pre-operative	Post-operative	*P* value (Wilcoxon test)
Obstructed:			
Qmax (ml/s)	6.8 ± 3.6	20.2 ± 7.3	< 0.0001
PdetQmax (cmH_2O)	108 ± 40.5	44 ± 18.5	< 0.0001
AG number	94.5 ± 42.6	3.6 ± 24.4	< 0.0001
URA (cmH_2O)	61.0 ± 29.9	15.0 ± 7.0	< 0.0001
Unobstructed:			
Qmax (ml/s)	8.6 ± 0.9	18.6 ± 5.3	0.018
PdetQmax (cmH_2O)	37.6 ± 12.8	34.4 ± 8.2	0.31
AG number	20.3 ± 11.7	−2.5 ± 16	0.018
URA (cmH_2O)	22.1 ± 5.9	13.5 ± 4.4	0.018

ter prostatectomy. All of these patients became unobstructed after surgery. In Jensen et al.'s study the AG nomogram correctly predicted the outcome of prostatectomy as judged by pQ studies.

In a prospective study evaluating the computer program CLIM, Rollema and Mastrigt [20] classified their patients into obstructed and unobstructed using the AG nomogram. They too showed findings similar to those of Jensen's group.

We reviewed 85 of our own patients who had pQ studies with good-quality urodynamic tracings both before and after prostatectomy. The Qmax, pdetQmax and pmuo values were noted for each pQ recording, taking into account a 0.5-s time lag between Qmax and pdetQmax. Of these patients, 78 were obstructed and 7 were unobstructed on the AG nomogram. As can be seen in Table 1, the Qmax and pdet values were significantly changed after surgery in the obstructed group. However, in the unobstructed group these parameters were not changed significantly at the 1% level.

In Jensen et al.'s study [14] the prognostic value of the AG nomogram was also related to the patients' subjective outcome of surgery. The success rate in the obstructed group was 93.1% versus 77.8% in the unobstructed group. Similarly, in Rollema and Mastrigt's study [20] the symptomatic relief was much more significant in the obstructed group as compared with the unobstructed group. It does appear, therefore, that patients who are not obstructed do not do as well either symptomatically or urodynamically after surgery.

The AG nomogram is therefore a good prognostic tool for the selection of patients for surgery. It predicts not only the urodynamic but also the subjective outcome of prostatectomy.

AG number

The use of the AG nomogram can be expanded further. The Qmax and pdetQmax values for each set of pQ data can be represented by an AG number that can be easily calculated by the equation:

AG number = pdetQmax − 2 Qmax.

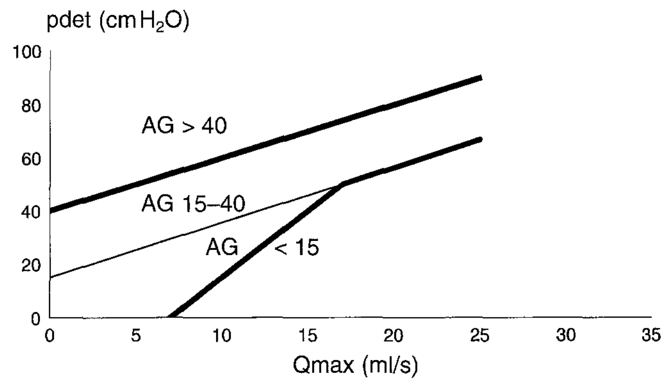

Fig. 6. AG of > 40, obstructed; AG of 15–40, equivocally obstructed; AG of < 15, majority unobstructed (see AG number)

The upper line of the AG nomogram that divides the obstructed from the equivocal zone has a gradient of 2 cmH_2O per milliliter per second and meets the pressure axis at 40 cmH_2O. It follows, therefore, that a pdetQmax/Qmax point that falls in the obstructed zone will have an AG number of greater than 40. Those that fall in the equivocal and unobstructed zones will have AG numbers of less than 40. Using this simple method, an AG number can be assigned to each set of pQ data. A continuous variable can therefore be obtained and any changes that occur between different pQ studies in a patient can be detected by a change in the AG number.

We are not proposing this AG number as a new urethral resistance factor to add to the numerous formulae proposed in the past [7]. However, we feel this is a simple equation that can be used as a parameter of pQ results when applied to the AG nomogram. As can be seen from Fig. 6, an AG number of > 40 is in the obstructed zone and that of 15–40 is in the equivocal obstruction zone. Most patients with an AG number of < 15 are in the unobstructed zone. The majority of those who have an AG number of < 15 and fall in the equivocal zone have pQ plots that are unobstructed. In the group of patients studied by Abrams and Griffiths [3], for example, 34 sets of results (21 pre-operative and 13 post-operative) had AG numbers of < 15. Of these, 23 sets were in the unobstructed zone and 11, in the equivocal zone. Of these 11

Table 2. Pre- and post-operative diagnosis of BOO using AG number and URA in 85 patients

	AG number		URA	
	Unobst.	Obst.	Unobst.	Obst.
Pre-operative	12	73	11	74
Post-operative	72	8	82	3
Total	89	81	93	77

Obst., Obstruction; *Unobst*; equivocally obstructed/unobstructed

Table 3. Correlation between AG number and URA in 85 patients[a]

		URA	
		Unobst.	Obst.
AG number	Unobst.	86	3
	Obst.	7	74

Obst., Obstruction; *Unobst.*, equivocally obstructed/unobstructed
[a]Pre- and post-operative results combined

sets of pQ results in the equivocal zone, only 4 were obstructed. In the study published by Jensen et al. in 1988 [14], obstructed patients in the equivocal zone were confined to the upper part of the zone with AG numbers ranging between 15 and 40.

The AG number is therefore a rapid way to decide whether a pQ study is obstructed, equivocal or unobstructed. For equivocal cases the mean slope can be easily calculated by subtracting the pmuo, which is usually at the end of micturition, from the pdetQmax value divided by Qmax:

$$\text{pQ slope} = \frac{\text{pdetQmax} - \text{pmuo}}{\text{Qmax}}.$$

If the slope is > 2 cmH_2O per milliliter per second or the pmuo is > 40 cmH_2O, then the pQ study is obstructed. On the other hand, if the slope is < 2 cmH_2O per milliliter per second and the pmuo is < 40 cmH_2O, then the study is unobstructed.

Use of the AG number as a quantitative measure of obstruction

The AG nomogram has sometimes been criticised as not being capable of giving a quantitative measure of obstruction. The AG number is very simple to calculate and gives a continuous variable for comparison of results, especially before and after therapy. Analysis by statistical methods can also be applied. We applied this in our aforementioned analysis of the 85 patients who had pQ studies before and after prostatectomy. As can be seen in Table 1, the patients in the obstructed group had a very significant decrease in their AG numbers ($P < 0.0001$). On the other hand, those in the unobstructed group had a decrease in their AG numbers, but not to a significant extent.

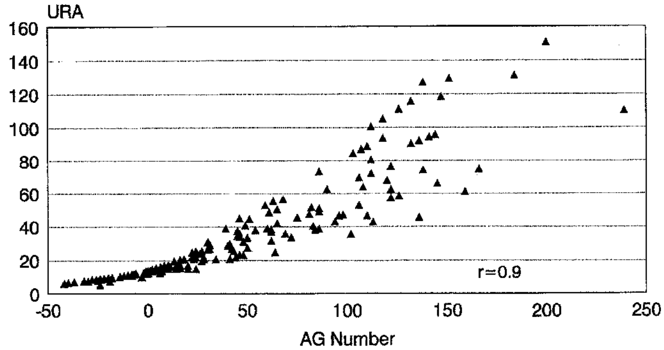

Fig. 7. Scattergram of AG number versus URA

Comparison between the AG number and the group-specific urethral resistance factor

To see how the AG number would compare with the group-specific urethral resistance factor (URA) [11], we used the pQ data of the same 85 patients mentioned above who had pQ studies before and after prostatectomy. The AG number was calculated as described above and the URA was calculated using the formula described elsewhere [11]. An AG number of greater than 40 and a URA factor of greater than 29 was considered as "obstructed", whereas lower values were considered as "equivocal or unobstructed". Table 2 shows the pre- and post-operative diagnoses expressed according to the AG number and URA. Table 3 shows the agreement of the diagnoses made by these two methods. The agreement in diagnosis between these two factors was 94% {(86 + 74)/170}.

Figure 7 represents a scattergram of the AG numbers against the URA factors of the pre- and post-operative pQ data of the 85 patients. There was an excellent correlation with the Pearson's correlation coefficient between these two factors at 0.9. The correlation was much better at lower grades of obstruction and in the unobstructed zone.

The AG number is very easy to calculate, gives a quantitative measure of obstruction and correlates very well with URA. As such, it may prove useful not just in the diagnosis of BOO but also in giving a quantitative value that can be used for evaluating the efficacy of therapy.

Similarities with other methods

There is a great deal of agreement between the AG nomogram and other methods that make use of pdetQmax and Qmax values from pQ data to determine BOO. Some comparison has been made in our earlier discussion. Figure 8 illustrates a comparison between the AG nomogram and URA. The curve represents a URA factor of 29, above which the bladder outflow is considered obstructed (see R. van Mastrigt and M. Kranse, pp 40–46, this issue). To see how these methods would compare with each other we reviewed the pQ data of 279 consecutive men over the age of 50 years who had LUTS but no previous treatment and no neurological disease and were referred to our urodynamic unit. It was found that 142 (51%) were classified

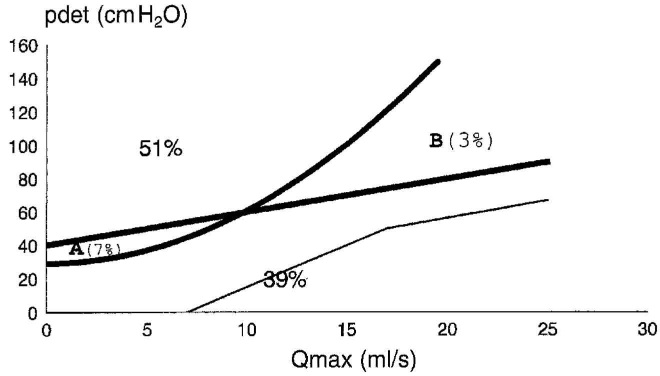

Fig. 8. Comparison between AG nomogram and URA

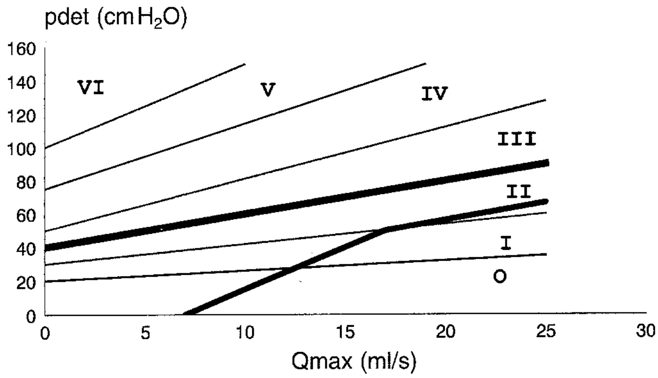

Fig. 9. Comparison between the AG nomogram and Schäfer's nomogram

as definitely obstructed (by both AG nomogram and URA) and 109 (39%) were classified as unobstructed (AG nomogram and URA) or equivocal (AG nomogram only). In the areas of disagreement, only 19 (7%) were in region A and 9 (3%), in region B.

If we superimpose the AG nomogram with Schäfer's [24, 26] nomogram of the linear passive urethral resistance relation (LPURR) technique, the line separating definite obstruction from equivocal obstruction on the AG nomogram is the same as that separating grade II and III on Schäfer's nomogram (Fig. 9). The AG nomogram's equivocal range is largely represented by the milder grades of obstruction on the LPURR nomogram.

It is not surprising that these methods compare so well with each other as they share the same theoretical background. From a research point of view there are differences between the AG nomogram and other methods of pQ analysis. However, from a practical aspect there is virtual agreement in the vast majority of cases.

In a recent article by Nielsen et al. [19], various methods of diagnosis of prostatic obstruction were reviewed. These methods included computerised models as described by Schäfer [21–23], Spangberg et al. [30], Terio et al. [31] and Mastrigt and Rollema [18]. Nielsen and coauthors find that these models are too complicated and cumbersome for daily urological practice. Furthermore, they think these methods have not proven their superiority to the simple AG nomogram except in one aspect. The model developed by Mastrigt and Rollema gives a quantitative measure of obstruction (URA), whereas the AG nomogram merely categorises the presence or absence of it. However, as described above, it is possible to expand the AG nomogram to obtain a measure on a continuous variable (AG number), and this compares very well with URA.

Conclusions

From a clinical viewpoint, a reliable but simple and robust method of analysing pQ studies for the diagnosis and grading of BOO and its changes after treatment is required. We believe the AG nomogram and its derivative, the AG number, can meet this requirement. The nomogram is easy to use and its number is easy to calculate. Small changes can be detected and be assessed by statistical methods. Hopefully, this will encourage the greater use of pressure-flow studies in the management of BOO.

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