0022-5347/97/1586-2034$03.00/0
THE JOURNAL OF UROLOGY

Vol. 158, 2034–2044, December 1997
Printed in U.S.A.

Review Article

URODYNAMIC EFFECTS OF VARIOUS TREATMENT MODALITIES FOR BENIGN PROSTATIC HYPERPLASIA

J. L. H. RUUD BOSCH

From the Department of Urology, Academic Hospital Rotterdam-Dijkzigt, Rotterdam, The Netherlands

ABSTRACT

Purpose: I studied the effects of various treatments for benign prostatic hyperplasia on urethral resistance.

Materials and Methods: I reviewed the literature on urodynamic effects of treatments for benign prostatic hyperplasia. Articles that reported pretreatment and posttreatment values of relevant urodynamic parameters were analyzed. Average before and after treatment values of maximum flow rate and detrusor pressure at maximal flow rate for every study were plotted on an Abrams-Griffiths nomogram and classified as obstructed, equivocal or nonobstructed. Average values of maximum flow rate and detrusor pressure at maximal flow rate were calculated for the total number of patients treated by a certain modality.

Results: Based on this analysis, the rank order of urodynamic efficacy was that open prostatectomy is more effective in reducing urethral resistance than is transurethral prostatectomy. These treatments diminish obstruction better than laser treatment or transurethral incision of the prostate, which again are more effective than balloon dilation, α-blockers or transurethral microwave thermotherapy. Finally, androgen deprivation performs better than placebo treatment.

Conclusions: The rank order of urodynamic efficacy as determined in this analysis shows a high level of agreement with reported rank order of symptomatic efficacy of various modalities. After placebo treatment there is no significant change in urethral resistance. This finding indicates that pressure-flow studies are a sensitive way to compare active to placebo treatment and that pressure-flow studies have excellent long-term reproducibility.

KEY WORDS: bladder, prostatic hypertrophy, urodynamics, treatment outcome

The role of pressure-flow studies in the evaluation of treatments for benign prostatic hyperplasia (BPH) is controversial. The third international consultation on BPH[1] and the Agency for Health Care Policy and Research (AHCPR) clinical practice guidelines[2] have included pressure-flow studies as an optional diagnostic test in their algorithms for the evaluation of patients with symptoms suggestive of prostatism. These algorithms refer to clinical diagnostic situations. However, the American Urological Association (AUA) new technology assessment committee,[3] which looks at the evaluation of new treatments has made the following statement: "Detrusor pressure flow studies should be done on as many patients as possible, and at minimum, in a subgroup of at least 30 patients."[3] In the assessment of the value of pressure-flow studies in the evaluation of BPH treatment, several questions arise. Are pressure-flow studies reproducible? What is known about urodynamic results of various treatment modalities? Should the effect on parameters measured during pressure-flow studies be considered a treatment outcome? Is it possible to rank treatments according to urodynamic efficacy? Is urodynamic improvement correlated with symptomatic improvement? This review tries to answer these questions.

DEFINITION OF URETHRAL RESISTANCE AND URODYNAMIC OBSTRUCTION

During a pressure-flow study, detrusor pressure and urinary flow rate are measured simultaneously. The main challenge in interpreting these data is to separate contributions of the bladder and outflow tract to these 2 measures in order to generate independent parameters for detrusor contraction strength and urethral resistance. A pressure-flow study can be represented graphically by an X-Y plot in which detrusor pressure is plotted against flow rate throughout voiding (fig. 1). A high detrusor pressure at maximum flow rate in combination with relatively low maximum flow rate characterizes the typically obstructed patient (fig. 1, plot A). A flat plot such as C in figure 1 indicates that the patient is unobstructed. Many plots, however, are intermediate and more difficult to classify (fig. 1, plot B).

Several methods to analyze and interpret the pressure flow data have been developed. Three of these methods have been used in larger outcome studies of BPH treatment by authors other than the developer of the method.[4–7] These methods try to reduce the data content of a pressure-flow plot to 1 number or 1 parameter, or 1 straight line characterized by 2 parameters. A fourth method, the so-called "3 parameter model"[8] has not been used in larger outcome studies by authors other than the developer of the method.[9]

The Abrams-Griffiths nomogram. Pressure-flow plots can be drawn on an Abrams-Griffiths nomogram.[4] The developers of this nomogram have drawn 2 lines that separate an obstructive from an equivocal area and the equivocal from the unobstructed zone, respectively (fig. 1). These lines were drawn on the basis of clinical judgment of which patients were truly obstructed and which patients were not. The data

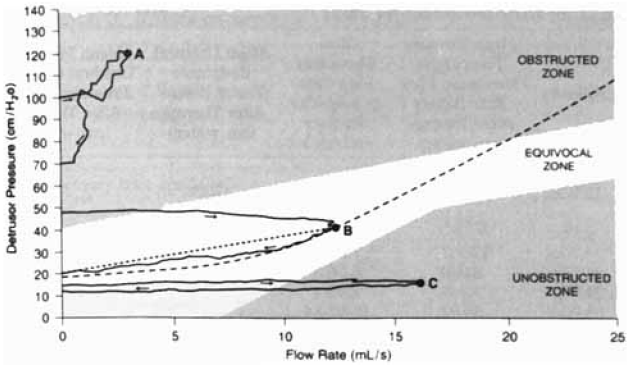

FIG. 1. Abrams-Griffiths nomogram with examples of obstructed (*A*), equivocal (*B*) and unobstructed (*C*) pressure-flow plots. Example of linear passive urethral resistance relation line is drawn, in this case for plot B. Point where this straight dotted line intersects with Y-axis is value of minimal urethral opening pressure. Example of quadratic urethral resistance factor function is also fitted to plot B. Point where this curved dashed line intersects with Y-axis is value of urethral resistance factor.

point that represents the value of detrusor pressure at maximum flow rate can be used to classify patients as obstructed, equivocal or unobstructed (fig. 1, points A to C).

The group-specific urethral resistance factor. Griffiths et al have stated that "although it is impossible to give a universally valid definition of urethral resistance, the existence of a valid group-specific resistance factor means that, within a particular group, the value of the resistance factor is the urethral resistance, thus defining it quantitatively."[5] Based on statistical evaluation of a large number of voidings, a quadratic curve can be computed and fitted through detrusor pressure at maximum flow rate (for example the curved dashed line through point B on fig. 1). The intersection of this curve with the vertical axis indicates the value of Griffiths' urethral resistance factor.[5] Rollema and Van Mastrigt have classified patients as obstructed or nonobstructed on clinical grounds and subsequently determined the discrimination value of urethral resistance factor. This value was set at such a level that sensitivity and specificity of the parameter in separating obstructed from nonobstructed patients were equal. The discrimination limit of urethral resistance factor was found to be 29 cm. water.[10] Patients with a preoperative value below this showed only small decreases of urethral resistance factor after transurethral resection of the prostate.

The Schäfer nomogram and linear passive urethral resistance relation. Schäfer et al have introduced the linear passive urethral resistance relation.[6] This is a straight line that can be drawn through detrusor pressure at maximum flow rate and the lowest pressure at which flow can be detected. The latter point is also called the passive urethral resistance relation footpoint or minimal urethral opening pressure (see straight dotted line through point B on fig. 1). The linear passive urethral resistance relation is characterized by the value of minimal urethral opening pressure and its slope. Schäfer has devised a nomogram that divides the whole spectrum of possible urethral resistance values into 7 classes called 0 to VI.[7] He contended that values of minimal urethral opening pressure below 20 cm. water were not further reduced by therapy and that therefore these patients were not obstructed before the initiation of therapy. The value of minimal urethral opening pressure is reported in several studies, whereas linear passive urethral resistance relation classes have been reported less frequently.

Since the cutoff values that are being used to indicate whether a patient is obstructed are somewhat arbitrarily chosen (except maybe for the borderline between classes 0 and I in the Schäfer nomogram), it seems more appropriate to analyze outcome data on the basis of changes in urethral resistance that occur after intervention. There is a high degree of agreement between the aforementioned 3 methods and for clinical purposes there are no important differences between them.[11]

MATERIAL AND METHODS

English language articles on the urodynamic effects of treatments for BPH that were published before July 1996 were identified by an extensive MEDLINE search starting from 1966, a search of reference lists of review articles published in that period and a hand search starting January 1990 of lists of contents from *The Journal of Urology, Urology, The British Journal of Urology, Neurourology and Urodynamics, The Scandinavian Journal of Urology and Nephrology*. Articles were read if the abstract indicated that urodynamic or pressure-flow studies had been performed. Only articles that included quantitative data from pressure-flow studies before and after treatment were subsequently included in this analysis. If the pretreatment and posttreatment values of maximum flow rate and the corresponding detrusor pressure at maximum flow rate are reported, it is possible to depict results of treatment graphically by plotting average pretreatment and posttreatment detrusor pressure at maximum flow rate values on an Abrams-Griffiths nomogram.

In some articles the authors report maximum voiding pressure, maximum detrusor pressure or maximum intravesical pressure in combination with maximum flow rate. According to the International Continence Society standardization of terminology[12] these are usually not equivalent to detrusor pressure at maximum flow rate.

The data were considered to be nonevaluable if detrusor pressure at maximal flow rate was only reported in combination with a maximum free flow rate that was not measured at the time of the pressure-flow study, if only the average flow rate was reported in combination with detrusor pressure at maximum flow rate, or if pretreatment and posttreatment values were reported in grossly different numbers of patients. Several other articles have only or additionally reported the pretreatment and posttreatment values of urethral resistance parameters like urethral resistance factor and minimal urethral opening pressure (see tables 1 to 4).

In articles that were included in this analysis, an average pretreatment and posttreatment value for detrusor pressure at maximum flow rate and maximum flow rate and/or minimal urethral opening pressure and/or urethral resistance factor was either reported or could be calculated for respective patient groups. Finally, data from all articles dealing with 1 particular treatment modality could be combined and average values for the pressure-flow parameters could be determined. Urodynamic effects of various treatments could thus be compared in large numbers of patients.

RESULTS

Effects of various treatment modalities on urethral resistance. Androgen deprivation in the treatment of BPH can achieve reduction of prostatic volume of about 20 to 30%.[13,14] Theoretically this results in a decrease of outflow tract obstruction and may lead secondarily to symptom reduction.[13] Effects of the luteinizing hormone releasing hormone analogues buserelin[14] and leuprolide,[15] the anti-androgens cyproterone acetate[14] and casodex[16] and of the 5-α-reductase inhibitor finasteride[17,18] have been explored urodynamically.

In table 1 the data of 124 men treated with various types of androgen deprivation are summarized. Effects of these treatments can be shown graphically on an Abrams-Griffiths nomogram (fig. 2). The study of finasteride by Tammela and Kontturi (line 2 on fig. 2)[17] shows a clear effect on urethral

TABLE 1. *Effects on urethral resistance of medical treatment for BPH*

References	Treatment (dose/day)		No. Men	Followup	Mean Detrusor Pressure at Maximum Flow Rate Before/After Therapy (cm. water)	Mean Maximum Flow Rate Before/After Therapy (ml./sec.)	Mean Urethral Resistance Factor Before/After Therapy (cm. water)	Mean Minimal Urethral Opening Pressure Before/After Therapy (cm. water)
Androgen deprivation:								
Bosch et al[14]	Buserelin	(1.2 mg./cyproterone acetate (200 mg.)	8	12 Wks.	78/81	6.2/7.9	47/49	
Rollema et al[18]	Finasteride	(5 mg.)	7	2 Yrs.			45/32	
Tammela and Kontturi[17,*]	Finasteride	(5 mg.)	19	24 Wks.	126/87	7.7/10.3		125/86
Eri and Tveter[16,*]	Casodex	(50 mg.)	14	24 Wks.	84/80	9.0/8.5		77/72
Eri and Tveter[15,*]	Leuprolide	(3.75 mg./28)	26	24 Wks.	79/66	5.9/7.4		78/66
Risi et al[19,*]	Finasteride	(5 mg.)	50	36 Wks.	89/82	10.3/10.4		84/79
α-Adrenoceptor blockers:								
Hedlund et al[24,*]	Prazosin	(4 mg.)	20	4 Wks.	67/65†	4.9/6.9		47/40
Hedlund and Andersson[25,*]	Prazosin	(4 mg.)	8	4 Wks.	75/69†	7.2/9.2		55/42
Chapple et al[26,*]	Prazosin	(4 mg.)	15	12 Wks.	71/56	9.4/12.6		
Stott and Abrams[27,*]	Indoramin	(40 mg.)	18	4 Wks.	98/82	6.7/9.4		
Rollema et al[34,*]	Doxazosin	(4 mg.)	16	4 Wks.			47/41	
Chapple et al[28,*,‡]	Prazosin	(4 mg.)	12	12 Wks.	98/84†	7.2/9.5		
Chapple et al[28,*,‡]	Prazosin	(4 mg.)	20	12 Wks.	86/69†	10.9/17		
Chapple et al[31,*]	Doxazosin	(4 mg.)	53	12 Wks.	78/74†	9.1/11.7		
Rosier et al[33]	Terazosin	(10 mg.)	24	26 Wks.			44/35	40/30
Martorana et al[30,*]	Alfuzosin	(7.5 mg.)	15	12 Wks.	90/39	6.7/12.3		97/29
Martorana et al[32,*]	Alfuzosin	(7.5 mg.)	25	12 Wks.	78/40	7.8/13.1		
Risi et al[19,*]	Terazosin	(5 mg.)	50	36 Wks.	82/75	9.2/10.9		79/72
Witjes et al[29]	Terazosin	(10 mg.)	33	26 Wks.	73/59	7.1/8.9		
Gerber et al[35]	Doxazosin	(4 mg.)	44	3 Mos.	94/83	11.7/13.2		39/30
Miscellaneous drugs:								
Kadow and Abrams[39]	β-Sitosterol	(0.3 mg.)	25	24 Wks.	92/103	9.9/10.8		
Abrams[38]	Candicidin	(300 mg.)	23	6 Mos.	120/125	7.8/9.2		

Numbers before author names correspond to numbers on figures 2 and 3.
* Results were derived from randomized (and in most cases placebo) controlled studies.
† These authors have reported maximum voiding (detrusor) pressure instead of detrusor pressure at maximum flow rate.
‡ These results are from 2 different study locations reported in 1 paper.

TABLE 2. *Effects on urethral resistance of placebo treatment for BPH*

References	No. Men	Followup	Mean Detrusor Pressure at Maximum Flow Rate Before/After Therapy (cm. water)	Mean Maximum Flow Rate Before/After Therapy (ml./sec.)	Mean Urethral Resistance Factor Before/After Therapy (cm. water)	Mean Minimal Urethral Opening Pressure Before/After Therapy (cm. water)
Abrams[38]	29	6 Mos.	141/138	8.4/8.4		
Hedlund et al[24]	20	4 Wks.	67/63*	4.9/4.7		47/43
Kadow and Abrams[39]	28	24 Wks.	98/107	7.6/10.4		
Hedlund and Andersson[25]	8	4 Wks.	75/74*	7.2/7.6		55/54
Chapple et al[26]	16	12 Wks.	76/82	10.2/11.0		
Stott and Abrams[27]	16	4 Wks.	107/103	7.0/6.6		
Rollema et al[34]	17	4 Wks.			42/45	
Chapple et al[28,†]	16	12 Wks.	83/84*	5.9/6.2		
Chapple et al[28,†]	23	12 Wks.	92/90*	10.8/14.9		
Tammela and Kontturi[17]	17	24 Wks.	115/118	8.8/9.9		113/116
Eri and Tveter[16]	13	24 Wks.	86/82	8.0/7.2		71/70
Eri and Tveter[15]	24	24 Wks.	71/76	6.4/6.4		67/71
Chapple et al[31]	50	12 Wks.	74/82*	9.1/10.2		
Martorana et al[30]	15	4 Wks.				100/88
Nielsen et al[41]	6	4 Mos.	72/85	10.8/10.7		
Martorana et al[32]	26	4 Wks.	82/77	8.5/12.5		
de Wildt et al[42,‡]	98	6 Mos.			28/26	24/22

Numbers before author names correspond to numbers on figure 4.
* These authors have reported maximum voiding (detrusor) pressure instead of detrusor pressure at maximum flow rate.
† These results are from 2 different study locations reported in 1 paper.
‡ This study involved watchful waiting.

resistance as evidenced by an increase of maximum flow rate in combination with a decrease of detrusor pressure at maximum flow rate. However, on average these men have not reached the unobstructed zone after treatment. Of individual patients 10 of 19 were still obstructed after 6 months of finasteride therapy.[17] A larger study of finasteride by Risi et al (line 5 on fig. 2)[19] who treated 50 men with the same average initial prostate volume (50 cm.^{3}) as in the Tammela and Kontturi patients, showed only small and statistically insignificant change in urethral resistance after 9 months of treatment (line 5 on fig. 2).[19] There are some unexplained differences between these 2 studies. Initial detrusor pressure at maximum flow rate in the patients of Tammela and Kontturi is higher than corresponding values in Risi's cases and most of the other urodynamic studies of effects of BPH treatment. Also prostate volume in studies of Tammela and Kontturi and Risi decreases from 50 to 35 gm. (30%) and from 50 to 44 gm. (12%), respectively. Percentage decrease of prostate volume in both of these studies is at variance with the reported decrease of 19% in a large randomized study of finasteride.[13] Differences between these 2 studies are also evident when comparing effects on minimal urethral opening pressure (table 1). Glazier et al found that after a mean 6 months of treatment with finasteride at a dose of 5 mg. per day, voiding pressures had not decreased but even increased in 74% of 39 men.[20]

Prostate volume decrease after treatment with casodex (27%),[16] leuprolide (34%)[15] and buserelin or cyproterone ac-

TABLE 3. *Effects on urethral resistance of (open) prostatectomy, transurethral resection, transurethral incision and transurethral electrovaporization for BPH*

References	No. Men	Followup	Mean Detrusor Pressure at Maximum Flow Rate Before/After Therapy (cm. water)	Mean Maximum Flow Rate Before/After Therapy (ml./sec.)	Mean Minimal Urethral Opening Pressure Before/After Therapy (cm. water)
Prostatectomy (not specified):					
Abrams[44]	100	4 Mos.	131/75	7.1/20.1	
Abrams et al[45]	152	Greater than 4 Mos.	132/77	6.9/19.9	
Open prostatectomy:					
Castro[46]	7§	4 Wks.	92/39†	6.9/23.5	
Meyhoff et al[47,*]	25‖	6 Mos.	75/30	8.0/23.0	
Transurethral resection:					
1. Edwards and Powell[48,*]	22	6–18 Wks.	57/35	5.6/19.2	
Meyhoff et al[47,*]	34	6 Mos.	75/40	8.3/16	
Hellström et al[49,*]	13	6 Mos.	58/26	7.5/16.5	
Jensen et al[50]	134	6 Mos.	60/27	9.5/16.3	
Neal et al[51]	179	Greater than 3 Mos.	100/61	9.0/18	
Meyhoff et al[54]	11	6 Mos.	126/79‡	10.8/19.3	
Spångberg et al[9]	23	3–6 Mos.	95/34	8.3/16.5	
Rollema and Van Mastrigt[10]	29	3 Mos.			41/16
Gill and Kabalin[52,*]	12	12 Mos.	92/59	8.9/19.2	
Jung et al[53,*]	43	9 Mos.	60/35	9.2/21	
Transurethral incision:					
Edwards and Powell[48,*]	22	6–18 Wks.	50/39	5.6/14.4	
Hellström et al[49,*]	11	6 Mos.	35/35	8.6/12.9	
Sirls et al[58]	28	12–96 Mos.	84/44	7.7/10.7	
Transurethral electrovaporization:					
Porru et al[60]	16	2 Mos.	80/37	7.2/17	

Numbers or letters before author names correspond to numbers and letters on figures 5 and 6.
* Results were derived from randomized controlled studies.
† This author reported "maximal intravesical pressure during micturition."
‡ These authors reported intravesical pressure at maximum flow rate.
§ Two patients underwent transvesical and 5 retropubic prostatectomy.
‖ All patients underwent transvesical prostatectomy.

TABLE 4. *Effects on urethral resistance of nonelectrical forms of energy delivery and miscellaneous treatments for BPH*

References	Treatment	No. Men	Followup	Mean Detrusor Pressure at Maximum Flow Rate Before/After Therapy (cm. water)	Mean Maximum Flow Rate Before/After Therapy (ml./sec.)	Mean Urethral Resistance Factor Before/After Therapy (cm. water)	Mean Minimal Urethral Opening Pressure Before/After Therapy (cm. water)
Laser prostatectomy:							
Bosch et al[62]	Transurethral ultrasound laser induced prostatectomy	30	3 Mos.	63/39	6.6/11.2	38/21	
Kabalin et al[55,*]	Urolase	10	12 Mos.	91/55	8.2/21.6		
Jung et al[53,*]	Urolase (less than 50 cm.^{3})	32	9 Mos.	52/42	6.8/17.0		
Jung et al[53,*]	Urolase (greater than 50 cm.^{3})	58	9 Mos.	65/54	5.1/9.9		
de Wildt et al[66]	Transurethral ultrasound laser induced prostatectomy + visual laser ablation of prostate (various)	40	6 Mos.			49/19	41/17
Cannon et al[64]	Visual laser ablation of prostate (various)	75	26 Wks.	80/40	6.0/13.7	49/19	42/18
Cummings et al[63]	Ultraline	25	3 Mos.	85/55	6.1/14.5		
James et al[65]	Visual laser ablation of prostate (various)	Less than 61	3 Mos.	74/54†	6.5/10.6		
Other forms of high energy delivery:							
Porru et al[69]	Transurethral microwave thermotherapy low energy	38	12 Mos.	70/60	8.3/12.9		
de la Rosette et al[70]	Transurethral microwave thermotherapy low energy	77	6 Mos.	74/75	6.8/9.0	45/40	45/41
Venn et al[72,*]	Transurethral microwave thermotherapy low energy	47	3 Mos.	91/91‡	11.5/11.2		
Manieri et al[71]	Transurethral microwave thermotherapy high energy	31	6 Mos.	67/60	7.1/9.7	41/31	42/31
Madersbacher and Marberger[75]	High intensity focused ultrasound	28	3–6 Mos.	66/55	8.5/11.5		
Potts et al[78]	Transurethral needle ablation	39	12 Mos.	97/79			
Miscellaneous:							
Weiss et al[82]	Balloon dilation	11	12 Wks.	84/82§	6.5/9.7		
Cherry et al[80]	Balloon dilation	28	12 Wks.	87/67‖	7.7/10.3		
Ganabathi et al[81]	Balloon dilation	15	24 Wks.	88/65	6.2/8.5		
Nielsen et al[41,*]	Prostate spiral	9	4 Mos.	74/60	8.1/9.0		
Venn et al[72,*]	1 Hr. dilation to 22F	46	3 Mos.	84/86‡	10.2/10.0		

Letters before author names correspond to letters on figure 6.
* Results derived from randomized controlled studies.
† Authors reported "voiding pressure" instead of detrusor pressure at maximum flow rate and average instead of maximum flow rate.
‡ Authors reported median instead of mean values of detrusor pressure at maximum flow rate for total patient group.
§ Authors reported "average voiding pressure" instead of detrusor pressure at maximum flow rate.
‖ Authors reported "detrusor pressure" instead of detrusor pressure at maximum flow rate.

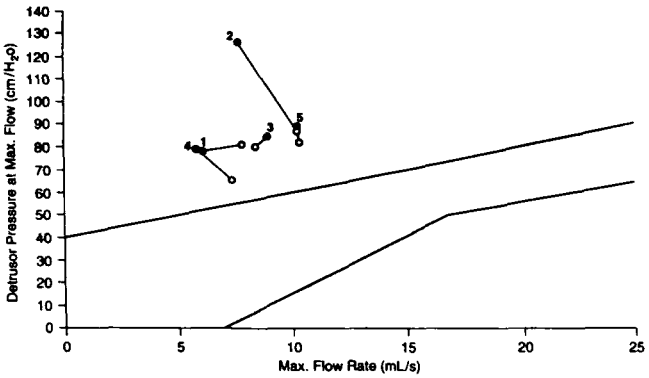

FIG. 2. Effects of androgen deprivation on urethral resistance. Average pretreatment data points (closed circles) are connected with average posttreatment data points (open circles) for studies of buserelin/cyproterone acetate (line 1), finasteride (lines 2 and 5), casodex (line 3) and leuprolide (line 4). Numbering of lines corresponds to numbering of androgen deprivation studies in table 1.

etate (29%)[14] seems to be somewhat greater than that achieved with finasteride but urodynamic effects were equally small (table 1 and fig. 2). On an individual basis, 7 of 8 patients treated with buserelin or cyproterone acetate were still obstructed after 3 months of therapy.[14] Urethral resistance parameter was measured in 2 studies.[14,18] Finasteride has resulted in a decrease from 45 to 32 cm. water in 7 patients followed for 2 years.[18] In a group of 8 patients treated with either buserelin or cyproterone acetate, urethral resistance factor increased from 47 to 49 cm. water after 3 months of therapy.[14] In both studies patients were, on average, still classified as obstructed based on the cutoff value of 29 cm. water.[10] In 4 studies small[16,19] to moderate[15,17] decreases of minimal urethral opening pressure were found (table 1). On average patients treated with androgen deprivation or 5-α-reductase inhibition did not become unobstructed.

α-Adrenoceptor blockers. The use of α-adrenoceptor blockade to treat men with BPH is based on the hypothesis that bladder outflow obstruction is partly determined by dynamic factors. These dynamic factors are determined by prostatic smooth muscle cell tension, which is mediated by α-1-adrenoceptors.[21-23]

Studies on urodynamic effects of α-adrenoceptor blockers all show average increase of maximum flow rate in combination with average decrease of detrusor pressure at maximum flow rate or maximum detrusor pressure (table 1 and fig. 3).[19,24-31] Comparison of data from 2 studies reported by Chapple et al[28] shows some interesting features, 2 subgroups, 5 and 6 on fig. 3 and table 1, from different sites that followed the same protocol, were included in 1 article. Surprisingly, patients in study 6 showed a much larger increase in flow rate, which is unexplained, and patients in study 5 were more obstructed initially.[28] Excellent urodynamic results achieved with alfuzosin in a study by Martorana et al (line 8 on fig. 3) are also at variance with other studies of effects of α-blockers.[32] However, only about half of the men initially included in this study were finally evaluated urodynamically. With alfuzosin treatment a large average decrease in minimal urethral opening pressure from 97 to 29 cm. water has been reported by the same group.[30] In a study of the terazosin effects the average urethral resistance factor values decreased from 44 to 35 cm. water, leaving patients in improved but still obstructed state after 6 months of treatment.[33] Doxazosin treatment for 1 month resulted in an average decrease of urethral resistance factor from 47 to 41 cm. water.[34] Mean minimal urethral opening pressure decreased moderately in studies of prazosin,[24,25] terazosin[19,29] and doxazosin[35] but an unobstructed value was not achieved (table 1).

In summary, α-blocker treatment on average results in decrease of urethral resistance. After treatment patient groups in 3 of 11 studies reached the equivocal zone of the Abrams-Griffiths nomogram. Patients remained in the obstructed zone in the other studies. One additional study[36] of prazosin could not be evaluated because of grossly different numbers of patients in which maximum flow rate and maximum voiding pressure were reported. A 9-month randomized comparative study of 5 mg. finasteride and 5 mg. terazosin showed greater decrease in urethral resistance in the terazosin group[19] (line 5 on fig. 2 versus line 9 on fig. 3).

Miscellaneous drugs. Serum cholesterol lowering agents with the proposed secondary effect of reabsorption of cholesterol from hyperplastic glands have been used for BPH treatment because of the higher cholesterol content of hyperplastic glands compared to normal glands.[37] Double-blind placebo controlled studies of candicidin in a dose of 300 mg. per day and of β-sitosteryl β-D-glucoside in a dose of 0.3 mg. per day showed that 6 months of treatment with these drugs had effects on urethral resistance that were statistically not significantly different from effects of placebo (table 1).[38,39]

Placebo arms of (medical) treatment protocols. In controlled trials of pharmacologic treatment, a large placebo effect of more than 40% has been observed on symptoms suggestive of BPH.[40] Table 2 and figure 4 show results obtained in 14

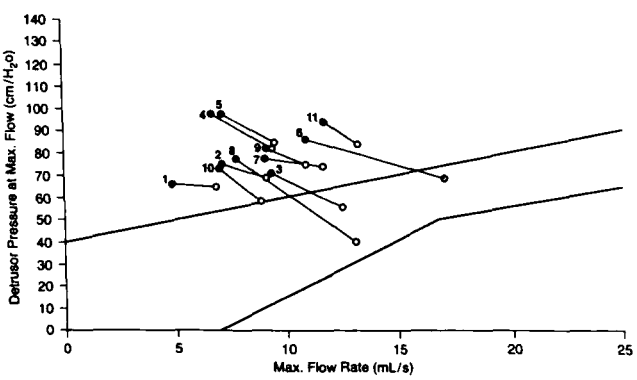

FIG. 3. Effects of α-blocker treatment on urethral resistance. Average pretreatment data points (closed circles) are connected with average posttreatment data points (open circles) for studies of prazosin (lines 1, 2, 3, 5 and 6), indoramine (line 4), doxazosin (lines 7 and 11), alfuzosin (line 8) and terazosin (lines 9 and 10). Numbering of lines corresponds to numbering of α-blocker studies in table 1.

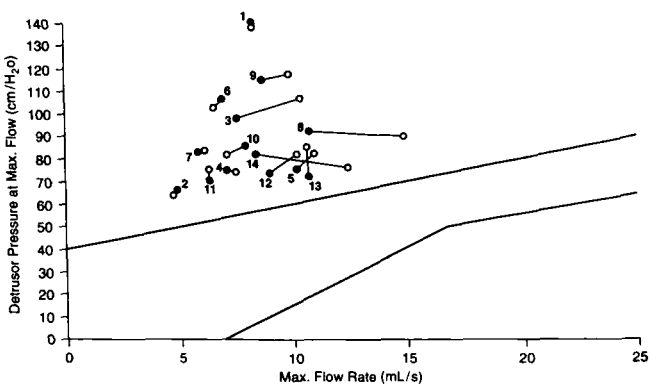

FIG. 4. Effects of placebo treatment on urethral resistance. Average pretreatment data points (closed circles) are connected with average posttreatment data points (open circles) for studies of which numbering of lines corresponds to numbering of placebo studies in table 2.

placebo treatment arms. Flow rate slightly increased in 7 studies[17,25,26,28,30,31,39] and slightly decreased or remained the same in 6 studies.[15,16,24,27,38,41] With the exception of study 8[28] and study 14[32] (table 2), differences in position on the Abrams-Griffiths nomogram before and after treatment are minimal, which indicates that urethral resistance does not change, and that on average pressure-flow studies are reproducible. The relatively large increase in flow rate without change in detrusor pressure in studies 8 and 14 is unexplained.

In the placebo arm of a controlled study of the effects of doxazosin, mean urethral resistance factor value increased slightly from 42 to 45 cm. water after 1 month.[34] Mean minimal urethral opening pressure did not change significantly in 2 placebo arms of α-blocker studies[24,25] and of 3 studies using androgen deprivation (table 2).[15–17] de Wildt et al[42] have studied effects of watchful waiting in 98 patients with symptoms suggestive of BPH. After a 6-month period average values of urethral resistance factor and minimal urethral opening pressure showed only negligible changes (table 2).

OPEN PROSTATECTOMY

In open prostatectomy the prostatic adenoma is removed surgically, either retropubically, that is through an incision of the surgical capsule of the prostate, or transvesically.[43]

In 2 studies by Abrams et al the type of prostatectomy was not clearly specified.[44,45] In these studies, which on average involved patients who were clearly obstructed initially, an average shift from obstructed to equivocal zone was observed after therapy (table 3). Transvesical and retropubic variants of open prostatectomy are effective urodynamically. In 2 studies[46,47] that exclusively involved patients undergoing open prostatectomy, average effect is a shift from obstructed to unobstructed zone (table 3 and fig. 5).

ELECTROSURGERY OF THE PROSTATE

In transurethral resection of the prostate prostatic tissue is electroresected from the level of the bladder neck to the verumontanum including adenomatous tissue that surrounds it.[43] Prostatic tissue is ideally resected until the surgical capsule becomes visible. Patient groups in all urodynamically evaluated transurethral resection studies have moved away from the obstructed zone (fig. 5 and table 3).[9,47–54] In 2 of 9 studies patients ended in the equivocal zone after treatment.[51,52] In only 1 study patients ended just above the borderline of the equivocal zone, although in that article intravesical pressure at maximum flow rate instead of detrusor pressure at maximum flow rate was reported.[54] The parameter urethral resistance factor was measured in 29 patients before and 3 months after transurethral incision by Rollema and van Mastrigt.[10] Average urethral resistance factor value decreased from 41 to 16 cm. water, which is clearly unobstructed.

The fate of individual patients could be determined from 2 studies. Kabalin et al treated 10 patients with average prostatic volume of 34 cm^3.[55] All were obstructed preoperatively. Six patients ended in the equivocal zone and 4 were unobstructed after treatment. Meyhoff et al studied 34 patients with estimated prostatic weights of 25 to 75 gm.[47] Of these 27 were in the obstructed and 7 in the equivocal zone preoperatively. Postoperatively only 3 patients were still obstructed and 27 had become unobstructed. The combined data of these 2 studies show that of 44 patients 84% were obstructed before transurethral resection while after the operation only 6% were still obstructed and 51% were truly unobstructed.

Transurethral incision of the bladder neck and transurethral incision of the prostate are procedures that are essentially the same. Transurethral incision was popularized by Orandi[56] and Turner-Warwick.[57] The latter introduced the term "trapped prostate," indicating the relatively small obstructing prostate that was trapped between bladder neck and external sphincter, and that could be released by an incision from the ureteral orifices, passing through the bladder neck and the prostatic tissue to the verumontanum.

Size of the prostate was an important selection criterion in these studies, that is a prostate volume of 30 $cm.^3$ or less.[48,49,58] In 2 of 3 studies of transurethral incision the patients, on average, were initially in the equivocal zone (fig. 6).[48,49] This probably indicates that these studies involved considerable numbers of urodynamically unobstructed patients. In 2 studies[48,49] patients on average remained in the equivocal zone and in 1 other study[58] they shifted from the clearly obstructed area to the equivocal zone. In the latter study 93% and 7% of patients were in the obstructed or in the equivocal zone, respectively, before the operation, whereas after the procedure 39% and 32% of the patients were in the equivocal or the unobstructed zone, respectively.[58] Kelly et al[59] found a decrease in urethral resistance after transurethral incision but did not report actual pretreatment and posttreatment values of maximum flow rate and intravesical pressure at maximum flow rate.

Transurethral electrovaporization of the prostate. Porru et al used a grooved roller bar electrode with an average current setting of 200 to 300 W to evaporate prostatic tissue in 16

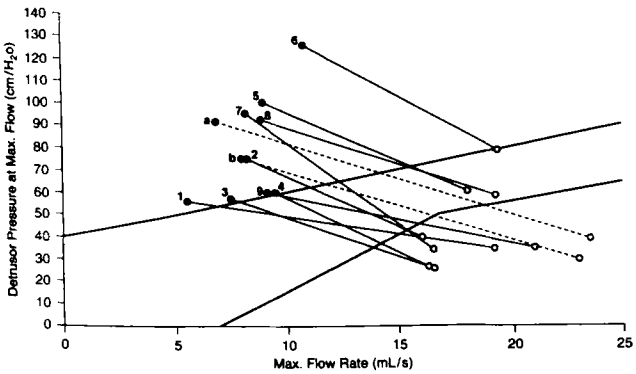

FIG. 5. Effects of open prostatectomy and transurethral resection on urethral resistance. Average pretreatment data points (closed circles) are connected with average posttreatment data points (open circles) for studies of open prostatectomy (lines a and b) and transurethral resection (lines 1–9). Numbers and letters of lines correspond to numbers and letters used for studies of open prostatectomy and transurethral resection in table 3.

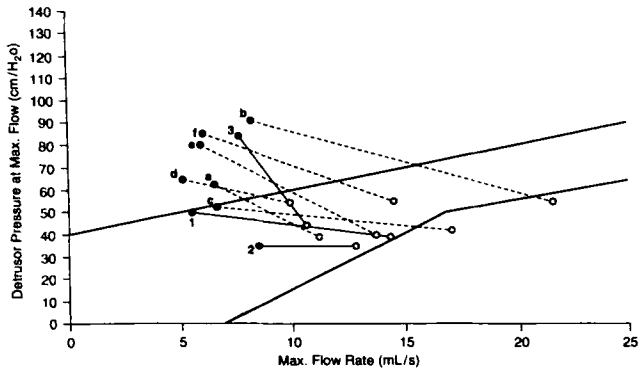

FIG. 6. Effects of laser prostatectomy and transurethral incision on urethral resistance. Average pretreatment data points (closed circles) are connected with average posttreatment data points (open circles) for studies of laser prostatectomy (lines a–f) and transurethral incision (lines 1–3). Numbering of lines corresponds to numbering of transurethral incision studies in table 3. Letters of lines corresponds to letters used for studies of laser prostatectomy in table 4.

patients with BPH.[60] On average the patient group moved from obstructed to unobstructed zone on the Abrams-Griffiths nomogram. The minimal urethral opening pressure decreased from 73 to 30 cm. water (table 3).

NONELECTRICAL FORMS OF HIGH ENERGY DELIVERY TO THE PROSTATE

Laser prostatectomy. Laser treatment involves energy delivery to prostatic tissue that leads either to tissue coagulation in the case of side-firing fibers or to vaporization when contact laser tips are used. Immediate tissue ablation is achieved with the latter technique whereas delayed tissue sloughing is the rule in the former.[61] Most studies have been done with side-firing fibers. After laser treatment all patient groups have moved away from the obstructed zone (fig. 6 and table 4). Average prostatic volumes were reported to be 56, 39 and 40 cm.^{3} in studies by Bosch et al,[62] Kabalin et al[55] and Cummings et al,[63] respectively. In the study of Cannon et al the volume was stated to be more than 30 cm.^{3}.[64] Particularly interesting is an article that looked differentially at prostates bigger or smaller than 50 cm.^{3}.[53] (studies of Jung et al (c) and deWildt et al (d), respectively, in fig. 6 and table 4). Men with larger prostates were more obstructed at baseline and showed relatively moderate urodynamic response to treatment. One article mentioned pressure-flow study results of treatment with a vaporizing contact laser tip.[65] These authors compared 4 different side-firing fibers with the SLT* contact tip. Unfortunately it is not entirely clear how many patients were followed after treatment but the effects of the 2 approaches on pressure-flow parameters were statistically not significantly different.

Three studies have reported pre and postoperative values of urethral resistance factor and/or minimal urethral opening pressure after transurethral ultrasound guided laser induced prostatectomy and/or visual laser ablation of the prostate.[62,64,66] After 3 to 6 months the average values of urethral resistance factor and minimal urethral opening pressure changed from clearly obstructed to clearly unobstructed values (table 4).

Results on individual patients were reported in 4 studies involving a total of 159 patients.[55,62,66,67] Combined results indicate that of these men 128 (81%) were in the obstructed zone and 31 (19%) were in the equivocal zone preoperatively. Postoperatively only 14 (9%) were still clearly obstructed, while 65 (41%) of the patients were truly unobstructed.

In transurethral microwave thermotherapy tissue destruction results from coagulative necrosis that is caused by heating the tissue above 44C using a transurethrally placed antenna mounted in a water cooled probe.[68] Most of the studies[69-71] were done with the Prostatron† device, which operates at 1,296 MHz. Venn et al used a different device that operated at 434 MHz with a maximum power output of 50 W.[72] They were the only group to report average prostate volume of patients, that is 40 cm.^{3}. Effects of transurethral microwave thermotherapy on pressure-flow parameters are summarized in table 4. Manieri et al used the high energy version of the software program (Prostasoft version 2.5) with maximum power output of 70 W.[71] In that study and also in 1 of the low energy studies[69] moderate decrease of urethral resistance was noted. In the 2 other low energy studies[70,72] urethral resistance did not decrease.

In addition to the aforementioned studies, Dahlstrand et al treated 37 patients with the Prostatron device, using Prostasoft version 2.0 and reported the 6-month results.[73] These investigators found no statistically significant change of detrusor pressure at maximum flow rate with baseline value of 70 and value of 67 cm. water after treatment. They did not report maximum flow rates that were measured during pressure-flow studies. Average values of urethral resistance factor and minimal urethral opening pressure decreased from 45 to 40 cm. water and from 45 to 41 cm. water, respectively, in a study of 77 patients treated with the low energy program.[70] In 31 patients treated with the high energy program, average values of urethral resistance factor and minimal urethral opening pressure decreased from 41 to 31 cm. water and from 42 to 31 cm. water, respectively, which on average brings the patients close to unobstructed values.[71] Some investigators have pointed out that although values of urethral resistance parameters have not changed significantly after low energy transurethral microwave thermotherapy, there was a decrease in the slope of the linear passive urethral resistance relation line.[74] Whether this indicates a relevant effect of the treatment is unclear.

High intensity focused ultrasound thermoablates prostatic tissue by a beam of ultrasound waves that can be focused at a selected depth, thus producing a region of high energy density.[75] Madersbacher et al have used the transrectal approach and reported their results in 28 patients followed for 3 to 6 months.[76] On average the patient group moved from just above to just below the borderline between obstructed and equivocal zone (table 4). Average prostatic volume was not reported.

Transurethral needle ablation of the prostate uses low level radiofrequency energy that is delivered directly into selected prostatic areas, producing necrotic lesions inside the parenchyma and sparing urethral mucosa.[77] Preliminary urodynamic results were reported by Potts et al, who performed repeat pressure-flow studies in 39 of 71 treated patients after followup of 12 months.[78] Of these patients 79% had remained obstructed (table 4).

MISCELLANEOUS MINIMALLY INVASIVE TREATMENT MODALITIES

Prostate stent. Nielsen et al have studied urodynamic effects of the Prostakath prostate spiral (table 4).[41] This is a gold-plated stainless steel stent that is endoscopically inserted into the prostatic urethra to keep the prostatic urethra sufficiently wide during voiding. Urethral resistance decreased in 8 of 9 patients after insertion of the spiral. Initially 8 patients were in the obstructed and 1 in the equivocal zone. After treatment 3 patients were still in the obstructed zone, while only 1 was truly unobstructed.[41]

Balloon dilation. Transurethral balloon dilation of the prostate may achieve a decrease in urethral resistance by several possible mechanisms, that is disruption of anterior and/or posterior commissures of the prostate, loss of elastic recoil of the prostatic capsule due to overstretching or ischemic atrophy if blood flow to the prostate is interrupted for a sufficiently long time during high pressure inflation of the balloon.[79] Of 3 studies[80-82] that reported urodynamic effects of balloon dilation, 2[80,81] have shown a decrease in urethral resistance (table 4). On average the patients remained in the obstructed zone of the Abrams-Griffiths nomogram.

One-hour dilation to 22F. One-hour dilation of the urethra with a 22F Foley catheter as a sham arm in a comparative study of microwave thermotherapy and sham treatment did not change urethral resistance (table 4).[73]

DISCUSSION

The compilation of studies presented in this review makes it possible to calculate average values of pressure-flow study parameters detrusor pressure at maximum flow rates and maximum flow rate before and after treatment for different treatment modalities. Results of these calculations can be plotted on an Abrams-Griffiths nomogram for comparison (fig. 7).

Validity of comparisons of urodynamic effects of different BPH treatment modalities is somewhat limited by the fact that prostatic volumes of patient groups in these studies are

* Surgical Laser Technologies, Oak, Pennsylvania.
† Technomed, Lyon, France.

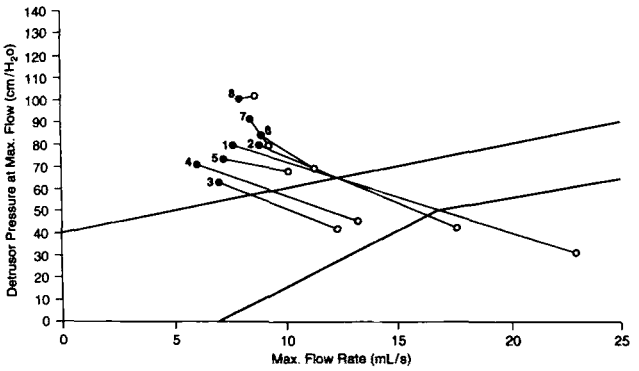

FIG. 7. Effects of various treatment modalities for BPH on urethral resistance. Lines based on average results of studies represented in tables 1 to 4. Treatments represented are open prostatectomy (line 1), transurethral resection (line 2), transurethral incision (line 3), laser prostatectomy (line 4), transurethral microwave thermotherapy (line 5), α blocker treatment (line 6), androgen deprivation (line 7) and placebo (line 8).

generally not known. Theoretically a certain treatment modality might be more effective than another above a certain prostate volume cutoff but differences in effect on urethral resistance might be small or nonexistent when treating groups of men with smaller prostates. These issues can be resolved only in randomized studies of effects of treatment in patient groups with comparable prostatic volumes.

Interestingly, initial average urethral resistance differs between groups of patients treated with various treatment modalities (fig. 7). These differences may be due to prostate volume driven selection of treatment modality. Patients selected for transurethral resection are clearly more obstructed than those treated with transurethral incision and slightly more obstructed than those treated with transurethral microwave thermotherapy or laser prostatectomy. Patients selected for open prostatectomy are on average about as obstructed as patients selected for transurethral resection or α-blocker treatment.

The α-blockers are moderately effective in decreasing urethral resistance and are more effective than androgen deprivation. Androgen deprivation is somewhat more effective than placebo. On average, however, medical treatment does not bring patients out of the obstructed zone (fig. 7 and table 1). The recent finding that androgen deprivation with finasteride might be more effective in patients with larger prostates[83] cannot be confirmed urodynamically, since a study of men with average prostate volume of 50 cm.^{3} did not show statistically significant changes in urethral resistance.[19]

Pretreatment and posttreatment values of placebo can be connected with a short line that runs perfectly parallel to the borderline between obstructed and equivocal zone (fig. 7). This indicates that there is no change in urethral resistance. This is an important finding because it indicates that on average pressure-flow studies are reproducible and a sensitive way of comparing placebo with active treatment. The fact that balloon dilation clearly is not more effective than medical treatment may be 1 explanation for its rapid decline in popularity. Transurethral microwave thermotherapy has also led to urodynamic results comparable to results achieved with α-blocker treatment. However, this treatment modality is still being developed in the sense that progressively higher energies may result in better effect, although the first urodynamic results with high energy software have not been impressive.[71]

Lines that connect average pretreatment and posttreatment values for open prostatectomy, transurethral resection, transurethral incision, Laser prostatectomy, transurethral microwave thermotherapy and α-blocker treatment run almost perfectly parallel to each other and away from the obstructed area (fig. 7). Relative lengths of these lines indicate efficacy of the various methods. Based on this analysis and taking the a for ementioned limitations into consideration, treatment modalities can be ranked according to urodynamic efficacy. Open prostatectomy seems to be more effective than transurethral resection, which again is more effective than the almost equally effective duo of laser treatment and transurethral incision. Then follows a group of almost equally effective treatments, that is balloon dilation, α-blockers and transurethral microwave thermotherapy. Finally, the less effective androgen deprivation outperforms placebo treatment. These results are confirmed by studies that have used the parameters urethral resistance factor and/or minimal urethral opening pressure as a way to express urethral resistance (tables 1 to 4). Again, on average, medical treatment generally did not make patients truly unobstructed, but α-blockers are slightly more effective than androgen deprivation in decreasing urethral resistance. The urodynamic effect of transurethral microwave thermotherapy seems to be comparable to that of α-blocker treatment and the results of placebo and watchful waiting studies confirm the reproducibility of pressure-flow studies.

Clinicians are interested primarily in results obtained in individual patients. More than 80% of all patients in urodynamic studies of transurethral resection (data available in 2 studies[47,55]), transurethral incision (data available in 1 study[58]) and laser prostatectomy (data available in 4 studies[55,62,66,67]) were obstructed before treatment. The percentages of truly unobstructed patients after treatment were recorded in the following percentages, transurethral resection 51%; laser prostatectomy 41% and transurethral incision 29%. Available data on androgen deprivation are less detailed than data in articles on other modalities. Few patients seem to be truly unobstructed after treatment.[14,17] One study of doxazosin (4 mg. per day) indicates results that can be achieved in this respect with an α-blocker.[35] Before the start of therapy 74% of the patients were obstructed and none was in the unobstructed zone. After 3 months 66% were still obstructed and only 5% were in the unobstructed area.

A dissociation between symptomatic versus urodynamic improvement is believed to occur with some newer forms of medical or instrumental treatment. As pointed out by Wein, there may be several possible explanations for such a phenomenon.[84] It may not be necessary to reduce obstruction to an amount similar to prostatectomy to achieve significant symptomatic improvement. Alternatively this may indicate that symptomatic results will be of short duration or that symptoms of prostatism have much less to do with urodynamically defined obstruction than we think.

However, there is a high level of agreement between ranking of treatment modalities based on the magnitude of urodynamic improvement as determined in this study and ranking based on probability and magnitude of symptomatic improvement as reported by Roehrborn.[85] The rank order for probability of symptom improvement was open prostatectomy, transurethral resection, transurethral incision, α-blocker, balloon dilation, placebo, watchful waiting. For the magnitude of symptomatic improvement the rank order was transurethral resection, open prostatectomy, transurethral incision, balloon dilation, α-blocker, placebo, finasteride.[85] This suggests that there may be a correlation between symptomatic and urodynamic improvement. Since only a minority of the urodynamic studies reviewed included detailed symptom score data, it was not possible to investigate independently this question based on data from the literature.

The durability of treatment effect has been determined for several modalities by Roehrborn.[85] Probability for retreatment need for open prostatectomy, transurethral resection and transurethral incision was 2.3%, 9.8% and 12.9% respectively, at 5 years after initial treatment. This rank

order also shows clear similarities with that based on urodynamic improvement.

Compared to symptoms and quality of life, which are direct outcome measures of treatment, pressure-flow studies are indirect measures. The idea that magnitude of short-term urodynamic improvement correlates with durability of the treatment response should be examined prospectively. Confirmation of this preliminary thought would make the short-term urodynamic effect a powerful predictor of durability. In that case the urodynamic effect would deserve to be accepted as a true treatment outcome. Presently these effects should be considered a treatment outcome in relation to treatments that claimed to decrease obstruction.

CONCLUSIONS

Despite some limitations, treatment modalities can be listed in descending order of urodynamic efficacy and open prostatectomy is more effective than transurethral resection. These 2 treatments decrease urethral resistance more than laser treatment or transurethral incision, which again are more effective than balloon dilation, α-blockers or transurethral microwave thermotherapy. Finally, androgen deprivation performs better than placebo treatment.

The results of pressure-flow studies in placebo treatment arms show that they exhibit good long-term reproducibility. Pressure-flow studies are a sensitive way to compare active treatment to placebo. There seems to be a relation between urodynamic effect and probability as well as magnitude of a symptomatic effect of a certain treatment. There also seems to be a relation between magnitude of short-term urodynamic effect and durability of a treatment modality.

REFERENCES

1. Cockett, A. T. K., Aso, Y., Denis, L., Murphy, G., Khoury, S., Abrams, P. H., Barry, M. J., Carlton, G. E., Fitzpatrick, J., Frohmüller, H., Gibbons, R., Griffiths, K., Hald, T., Holtgrewe, L., Jardin, A., McConnell, J. D., Mebust, W., Roehrborn, C. G. and Smiths, P.: Recommendations of the International Consensus Committee concerning: 2. Diagnostic work-up of men with lower urinary tract symptoms (LUTS) suggestive of bladder outlet obstruction. In: Proceedings of the 3rd International Consultation on Benign Prostatic Hyperplasia. Edited by A. T. Cockett, S. Khoury, Y. Aso, C. Chatelain, L. Denis, K. Griffiths, and G. Murphy. Channel Islands: S.C.I. Ltd., pp. 628–635, 1996.
2. McConnell, J. D., Barry, M. J., Bruskewitz, R. C., Bueschen, A. J., Denton, S. E., Holtgrewe, H. L., Lange, J. L., McClennan, B. L., Mebust, W., Reilly, N. J., Roberts, R. G., Sacks, S. A. and Wasson, J. H.: Optional diagnostic tests. In: Benign prostatic hyperplasia: Diagnosis and treatment. Clinical practice guideline number 8. Rockville, Maryland: U.S. Department of Health and Human Services. Agency for Health Care Policy and Research, pp. 35–51, 1994.
3. Holtgrewe, H. L.: Guidance for clinical investigation of devices used for the treatment of benign prostatic hyperplasia. J. Urol., **150:** 1588, 1993.
4. Abrams, P. H. and Griffiths, D. J.: The assessment of prostatic obstruction from urodynamic measurement and from residual urine. Brit. J. Urol., **51:** 129, 1979.
5. Griffiths, D., Van Mastrigt, R. and Bosch, R.: Quantification of urethral resistance and bladder function during voiding, with special reference to the effects of prostate size reduction on urethral obstruction due to benign prostatic hyperplasia. Neurourol. Urodyn., **8:** 17, 1989.
6. Schäfer, W., Waterbär, F., Langen, P.-H. and Deutz, F.-J.: A simplified graphic procedure for detailed analysis of detrusor and outlet function during voiding. Neurourol. Urodynam., **8:** 405, 1989.
7. Schäfer, W.: Principles and clinical application of advanced urodynamic analysis of voiding function. Urol. Clin. N. Amer., **17:** 553, 1990.
8. Spångberg, A., Teriö, H., Engberg, A. and Ask, P.: Quantification of urethral function based on Griffiths' model of flow through elastic tubes. Neurourol. Urodyn., **8:** 29, 1989.
9. Spångberg, A., Teriö, H., Ask, P. and Engberg, A.: Pressure/flow studies preoperatively and postoperatively in patients with benign prostatic hypertrophy: Estimation of the urethral pressure/flow relation and urethral elasticity. Neurourol. Urodyn., **10:** 139, 1991.
10. Rollema, H. J. and Van Mastrigt, R.: Improved indication and followup in transurethral resection of the prostate using the computer program CLIM: a prospective study. J. Urol., **148:** 111, 1992.
11. Abrams, P., Bruskewitz, R., de la Rosette, J., Griffiths, D., Konayagi, T., Nordling, J., Park, Y. C., Schäfer, W. and Zimmern, P.: The diagnosis of bladder outlet obstruction: Urodynamics. In: Proceedings of the 3rd International Consultation on Benign Prostatic Hyperplasia. Edited by A. T. Cockett, S. Khoury, Y. Aso, C. Chatelain, L. Denis, K. Griffiths and G. Murphy. Channel Islands: S.C.I. Ltd., pp. 299–354, 1996.
12. Abrams, P., Blaivas, J. G., Stanton, S. L. and Andersen, J. T.: Standardisation of terminology of lower urinary tract function. Neurourol. Urodyn., **7:** 403, 1988.
13. Gormley, G. J., Stoner, E., Bruskewitz, R. C., Imperato-McGinley, J., Walsh, P. C., McConnell, J. D., Andriole, G. L., Geller, J., Bracken, B. R., Tenover, J. C., Vaughan, E. D., Pappas, F., Taylor, A., Binkowitz, B. and Ng, J.: The effect of finasteride in men with benign prostatic hyperplasia. The Finasteride Study Group. New Engl. J. Med., **327:** 1185, 1992.
14. Bosch, R. J. L. H., Griffiths, D. J., Blom, J. H. M. and Schroeder, F. H.: Treatment of benign prostatic hyperplasia by androgen deprivation: effects on prostate size and urodynamic parameters. J. Urol., **141:** 68, 1989.
15. Eri, L. M. and Tveter, K. J.: A prospective, placebo-controlled study of the luteinizing hormone-releasing hormone agonist leuprolide as treatment for patients with benign prostatic hyperplasia. J. Urol., **150:** 359, 1993.
16. Eri, L. M. and Tveter, K. J.: A prospective, placebo-controlled study of the antiandrogen Casodex as treatment for patients with benign prostatic hyperplasia. J. Urol., **150:** 90, 1993.
17. Tammela, T. J. and Kontturi, M. J.: Urodynamic effects of finasteride in the treatment of bladder outlet obstruction due to benign prostatic hyperplasia. J. Urol., **149:** 342, 1993.
18. Rollema, H. J., Rosier, P. F. W. M., van Mastrigt, R. and Janknegt, R. A.: Clinical efficacy of Proscar (MK906) in BPH, objectively appraised by pressure-flow measurement analysed with the computer program Dx/CLIM; 2 years results. Neurourol. Urodyn., **11:** 392, 1992.
19. Risi, O., Blefari, F., Ghilardi, M., Milesi, R., Migliori, M. and Pino, P.: Urodynamic and echographic effects of finasteride and terazosin in the treatment of benign prostatic hyperplasia. Urodinamica, **5:** 184, 1995.
20. Glazier, D. B., Lee, M. G., Weiss, R. E., Vates, T. S., Brogle, B. N., Tous, A. M., Weiser, A. C., Hwang, J. and Cummings, K. B.: Urodynamic assessment of the efficacy of finasteride. J. Urol., part 2, **153:** Abstract 361, 319A, 1995.
21. Furuya, S., Kumamoto, Y., Yokoyama, E., Tsukamoto, T., Izumi, T. and Abiko, Y.: Alpha-adrenergic activity and urethral pressure in prostatic zone in benign prostatic hypertrophy. J. Urol., **128:** 836, 1982.
22. Shapiro, E., Hartanto, V. and Lepor, H.: Quantifying the smooth muscle content of the prostate using double-immunoenzymatic staining and color assisted image analysis. J. Urol., **147:** 1167, 1992.
23. Shapiro, E., Hartanto, V. and Lepor, H.: The response to alpha blockade in benign prostatic hyperplasia is related to the percent area density of prostate smooth muscle. Prostate, **21:** 297, 1992.
24. Hedlund, H., Andersson, K. E. and Ek, A.: Effects of prazosin in patients with benign prostatic obstruction. J. Urol., **130:** 275, 1983.
25. Hedlund, H. and Andersson, K. E.: Effects of prazosin and carbachol in patients with benign prostatic obstruction. Scand. J. Urol. Nephrol., **22:** 19, 1988.
26. Chapple, C. R., Christmas, T. J. and Milroy, E. J.: A twelve-week placebo-controlled study of prazosin in the treatment of prostatic obstruction. Urol. Int., Suppl. 1, **45:** 47, 1990.
27. Stott, M. A. and Abrams, P.: Indoramin in the treatment of prostatic bladder outflow obstruction. Brit. J. Urol., **67:** 499, 1991.
28. Chapple, C. R., Stott, M., Abrams, P. H., Christmas, T. J. and

Milroy, E. J.: A 12-week placebo-controlled double-blind study of prazosin in the treatment of prostatic obstruction due to benign prostatic hyperplasia. Brit. J. Urol., **70:** 285, 1992.
29. Witjes, W. P. J., Rosier, P. F., de Wildt, M. J., van Iersel, M. P., Debruyne, F. M. and de la Rosette, J. J.: Urodynamic and clinical effects of terazosin therapy in patients with symptomatic benign prostatic hyperplasia. J. Urol., **155:** 17, 1996.
30. Martorana, G., Giberti, C., Pacella, M., Casadei, G., Pacifico, P. and Giuliani, L.: Effects of alfuzosin on outlet obstruction of BPH patients measured by means of urodynamic pressure/flow study. Urodinamica, **4:** 245, 1994.
31. Chapple, C. R., Carter, P., Christmas, T. J., Kirby, R. S., Bryan, J., Milroy, E. J. and Abrams, P.: A three month double-blind study of doxazosin as treatment for benign prostatic bladder outlet obstruction. Brit. J. Urol., **74:** 50, 1994.
32. Martorana, G., Giberti, C., Di Silverio, F., von Heland, M., Rigatti, P., Colombo, R., Casadei, G. and Pacifico, P.: Short-term evaluation of alfuzosin or placebo treatments of BPH patients by means of symptoms, free flow uroflowmetry, and pressure/flow (P/F) study. Urodinamica, **5:** 180, 1995.
33. Rosier, P. F., Witjes, W. P. J., de Wildt, M. J., de la Rosette, J. J. and Debruyne, F. M. J.: Urodynamic results of terazosin treatment for symptomatic BPH. In: Proceedings of the 23rd congress of the Societé Internationale d' Urologie, Abstract 486, Sydney: 209, 1994.
34. Rollema, H. J., Rosier, P., Janknegt, R. A. and van Mastrigt, R.: Efficacy of alpha-blocker (doxazosin) in BPH appraised by pressure-flow (CLIM) analysis. Neurourol. Urodyn., **10:** 295, 1991.
35. Gerber, G. S., Kim, J. H., Contreras, B. A., Steinberg, G. D. and Rukstalis, D. B.: An observational urodynamic evaluation of men with lower urinary tract symptoms treated with doxazosin. Urology, **47:** 840, 1996.
36. Kirby, R. S., Coppinger, S. W., Corcoran, M. O., Chapple, C. R., Flanigan, M. and Milroy, E. J.: Prazosin in the treatment of prostatic obstruction. A placebo-controlled study. Brit. J. Urol., **60:** 136, 1987.
37. Swyer, G. I. M.: The cholesterol content of normal and enlarged prostates. Cancer Res., **2:** 372, 1942.
38. Abrams, P. H.: A double-blind trial of the effects of candicidin on patients with benign prostatic hypertrophy. Brit. J. Urol., **49:** 67, 1977.
39. Kadow, C. and Abrams, P. H.: A double-blind trial of the effect of beta-sitosteryl glucoside (WA184) in the treatment of benign prostatic hyperplasia. Eur. Urol., **12:** 187, 1986.
40. Isaacs, J. T.: Importance of natural history of benign prostatic hyperplasia in the evaluation of pharmacologic intervention. Prostate, suppl. **3:** 1, 1990.
41. Nielsen, K. K., Kromann-Andersen, B., Poulsen, A. L., Schou, J. and Nordling, J.: Subjective and objective evaluation of patients with prostatism and infravesical obstruction treated with both intraprostatic spiral and transurethral prostatectomy. Neurourol. Urodyn., **13:** 13, 1994.
42. de Wildt, M. J., Witjes, W. P., Rosier, P. F., Debruyne, F. M., Wijkstra, H. and de la Rosette, J. J.: A urodynamic view on watchful waiting in patients with benign prostatic hyperplasia. Neurourol. Urodyn., **14:** 566, 1995.
43. Roehrborn, C. G.: Standard surgical interventions: transurethral incision/transurethral resection/OPSU. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn, and P. Boyle. Oxford: Isis Medical Media Ltd., pp. 341–378, 1996.
44. Abrams, P. H.: The urodynamic changes following prostatectomy. Urol. Int., **33:** 181, 1978.
45. Abrams, P. H., Farrar, D. J., Turner-Warwick, R. T., Whiteside, C. G. and Feneley, R. C. L.: The results of prostatectomy: a symptomatic and urodynamic analysis of 152 patients. J. Urol., **121:** 640, 1979.
46. Castro, J. E.: The effect of prostatectomy on the symptoms and signs of benign prostatic hypertrophy. Brit. J. Urol., **45:** 428, 1973.
47. Meyhoff, H. H., Nordling, J. and Hald, T.: Urodynamic evaluation of transurethral versus transvesical prostatectomy. A randomized study. Scand. J. Urol. Nephrol., **18:** 27, 1984.
48. Edwards, L. and Powell, C.: An objective comparison of transurethral resection and bladder neck incision in the treatment of prostatic hypertrophy. J. Urol., **128:** 325, 1982.
49. Hellström, P., Lukkarinen, O. and Kontturi, M.: Bladder neck incision or transurethral electroresection for the treatment of urinary obstruction caused by a small benign prostate. A randomized urodynamic study. Scand. J. Urol. Nephrol., **20:** 187, 1986.
50. Jensen, K. M.-E., Jorgensen, J. B. and Mogensen, P.: Urodynamics in prostatism. I. Prognostic value of uroflowmetry. Scand. J. Urol. Nephrol., **22:** 109, 1988.
51. Neal, D. E., Ramsden, P. D., Sharples, L., Smith, A., Powell, P. H., Styles, R. A. and Webb, R. J.: Outcome of elective prostatectomy. Brit. Med. J., **299:** 762, 1989.
52. Gill, H. S. and Kabalin, J. N.: Urodynamic evaluation of patients in a randomized study of transurethral resection versus laser prostatectomy: pre-operative and one year follow-up. Neurourol. Urodyn., **12:** 372, 1993.
53. Jung, P., Schäfer, W. and Jakse, G.: Visual laser ablation of the prostate. Efficacy according to prostate size evaluated by urodynamics and compared to TUR. Neurourol. Urodyn., **14:** 570, 1995.
54. Meyhoff, H.-H., Gleason, D. M. and Bottaccini, M. R.: The effects of transurethral resection on the urodynamics of prostatism. J. Urol., **142:** 785, 1989.
55. Kabalin, J. N., Gill, H. S., Bite, G. and Wolfe, V.: Comparative study of laser versus electrocautery prostate resection: 18-month followup with complex urodynamic assessment. J. Urol., **153:** 94, 1995.
56. Orandi, A.: Transurethral incision of the prostate. J. Urol., **110:** 229, 1973.
57. Turner-Warwick, R., Whiteside, C. G., Worth, P. H., Milroy, E. J. and Bates, C. P.: A urodynamic view of the clinical problems associated with bladder neck dysfunction and its treatment by endoscopic incision and trans-trigonal posterior prostatectomy. Brit. J. Urol., **45:** 44, 1973.
58. Sirls, L. T., Ganabathi, K., Zimmern, P. E., Roskamp, D. A., Wolde-Tsadik, G. and Leach, G. E.: Transurethral incision of the prostate: an objective and subjective evaluation of long-term efficacy. J. Urol., **150:** part 2, 1615, 1993.
59. Kelly, M. J., Roskamp, D. and Leach, G. E.: Transurethral incision of the prostate: A preoperative and postoperative analysis of symptoms and urodynamic findings. J. Urol., **142:** 1507, 1989.
60. Porru, D., Scarpa, R. M., Montisci, I., Delisa, A., Campus, G. and Usai, E.: Urodynamic results in benign prostatic hyperplasia patients treated by transurethral electrovaporization of the prostate. Urodinamica, **5:** 186, 1995.
61. Stein, B. S.: Laser prostatectomy. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn and P. Boyle. Oxford: Isis Medical Media Ltd., pp. 379–387, 1996.
62. Bosch, J. L., Groen, J. and Schröder, F. H.: Treatment of benign prostatic hyperplasia by transurethral ultrasound-guided laser-induced prostatectomy (TULIP): effects on urodynamic parameters and symptoms. Urology, **44:** 507, 1994.
63. Cummings, J. M., Parra, R. O. and Boullier, J. A.: Laser prostatectomy: Initial experience and urodynamic follow-up. Urology, **45:** 414, 1995.
64. Cannon, A., de Wildt, M., Abrams, P. H. and de la Rosette, J. J.: Urodynamics and laser prostatectomy. World J. Urol., **13:** 134, 1995.
65. James, M. J., Harriss, D. R., Ceccherini, A., Manhire, A. R. and Bates, C. P.: A urodynamic study of laser ablation of the prostate and a comparison of techniques. Brit. J. Urol., **76:** 179, 1995.
66. de Wildt, M. J., te Slaa, E., Rosier, P. F., Wijkstra, H., Debruyne, F. M. and de la Rosette, J. J.: Urodynamic results of laser treatment in patients with benign prostatic hyperplasia. Can outlet obstruction be relieved? J. Urol., **154:** 174, 1995.
67. Te Slaa, E., de Wildt, M. J., Rosier, P. F., Wijkstra, H., Debruyne, F. M. and de la Rosette, J. J.: Urodynamic assessment in the laser treatment of benign prostatic enlargement. Brit. J. Urol., **76:** 604, 1995.
68. Devonec, M. A.: Transurethral thermotherapy. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn and P. Boyle. Oxford: Isis Medical media Ltd., pp. 413–421, 1996.
69. Porru, D., Scarpa, R. M., Delisa, A. and Usai, E.: Urodynamic changes in benign prostatic hyperplasia patients treated by transurethral microwave thermotherapy. Eur. Urol., **26:** 303, 1994.

70. de la Rosette, J. J., Tubaro, A., Trucchi, A., Carter, S. S. and Höfner, K.: Changes in pressure-flow parameters in patients treated with transurethral microwave thermotherapy. J. Urol., **154:** 1382, 1995.
71. Manieri, C., Tubaro, A., Trucchi, A., Galatioto, G. P. and Miano, L.: Urodynamic evaluation of high energy transurethral microwave thermotherapy (v. 2.5) in the treatment of BPH. Urodinamica, **5:** 127, 1995.
72. Venn, S. N., Montgomery, B. S., Sheppard, S. A., Hughes, S. W., Beard, R. C., Bultitiude, M. I., Lloyd-Davies, R. W. and Tiptaft, R. C.: Microwave hyperthermia in benign prostatic hypertrophy: a controlled clinical trial. Brit. J. Urol., **76:** 73, 1995.
73. Dahlstrand, C., Waldén, M., Geirsson, G. and Pettersson, S.: Transurethral microwave thermotherapy versus transurethral resection for symptomatic benign prostatic obstruction: a prospective randomized study with a 2-year follow-up. Brit. J. Urol., **76:** 614, 1995.
74. Höfner, K., Tan, H.-K., Kramer, A. E. J. L., Kuczyk, M., von Dalwig-Nolda, D. and Jonas, U.: Changes in outflow obstruction in patients with benign prostatic hypertrophy (BPH) after transurethral microwave thermotherapy (transurethral microwave thermotherapy). Neurourol. Urodyn., **12:** 376, 1993.
75. Madersbacher, S. and Marberger, M.: High-intensity focused ultrasound. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn and P. Boyle. Oxford: Isis Medical Media Ltd., pp. 429–435, 1996.
76. Madersbacher, S., Klingler, H. C., Schmidbauer, C. P. and Marberger, M.: The impact of transrectal high intensity focused ultrasound on prostatic obstruction in BPH assessed by pressure-flow studies. J. Urol., **153:** part 2, 435A, abstract 827, 1995.
77. Schulman, C. C. and Zlotta, A. R.: Transurethral needle ablation of the prostate. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn and P. Boyle. Oxford: Isis Medical Media Ltd., pp. 423–427, 1996.
78. Potts, K. L., Rosario, D., Woo, H. H., Byrne, L., Cutinha, P., Hastie, K. J. and Chapple, C. R.: 12 months follow-up of transurethral needle ablation (TUNA). Brit. J. Urol., **77** (suppl. 1): 9, 1996.
79. Vale, J. A. and Christmas, T. J.: Transurethral balloon dilatation of the prostate. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn and P. Boyle. Oxford: Isis Medical Media Ltd., pp. 437–441, 1996.
80. Cherry, R. J., Thomas, R. and Ghoneim, G.: Transurethral balloon dilatation of the prostate (TUDP) for benign prostatic hyperplasia (BPH). J. Urol., **145:** part 2, abstract 208, 264A, 1991.
81. Ganabathi, K., Roskamp, D., Foote, J., Zimmern, P. E. and Leach, G. E.: Prospective urodynamic evaluation of the efficacy of prostatic balloon dilatation. Neurourol. Urodyn., **11:** 483, 1992.
82. Weiss, J. N., Badlani, G. H., Ravalli, R., Manne, J. and Smith, A. D.: Balloon dilatation of the prostate: urodynamic assessment. J. Urol., **143:** part 2, abstract 373, 282A, 1990.
83. Boyle, P., Gould, A. L. and Roehrborn, C. G.: Prostate volume predicts outcome of treatment of benign prostatic hyperplasia with finasteride: Meta-analysis of randomized clinical trials. Urology, **48:** 398, 1996.
84. Wein, A. J.: Criteria for assessing outcome following intervention for benign prostatic hyperplasia. In: Prostate diseases. Edited by H. Lepor and R. K. Lawson. Philadelphia: W. B. Saunders Co., pp. 139–149, 1993.
85. Roehrborn, C. G.: Treatment outcomes and their interpretation in benign prostatic hyperplasia. In: Textbook of benign prostatic hyperplasia. Edited by R. Kirby, J. D. McConnell, J. M. Fitzpatrick, C. G. Roehrborn and P. Boyle. Oxford: Isis Medical Media Ltd, pp. 473–506, 1996.