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·Original Article·

Effects of retrospective quality control on pressure-flow data with computer-based urodynamic systems from men with benign prostatic hyperplasia

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Abstract

Aim: To evaluate the effects of retrospective quality control on pressure-flow data with computer-based urodynamic systems from men with benign prostatic hyperplasia (BPH). **Methods:** A total of 582 traces of pressure-flow study from 181 men with BPH was included in the study. For each trace, maximum urinary flow rate (Q_{max}) and detrusor pressure at Q_{max} ($p_{det.Qmax}$) were, respectively, read from manually smoothed and corrected uroflow and detrusor pressure curves from the computer print-outs. Obstruction coefficient, International Continence Society (ICS) and Schaefer nomograms were used to detect urethral resistance and to diagnose obstruction. The results obtained by manual reading were compared with those from computer-based systems. **Results:** After manual correction, Q_{max} underwent a consistently significant decrease by 1.2 mL/s on average ($P < 0.001$), and had a change range of 0.5–10.4 mL/s. However, $p_{det.Qmax}$ underwent inconsistently intra-individual changes after correction. The obstruction coefficient increased significantly, by an average of 0.07 ($P < 0.05$). Using the ICS nomogram, the percentage of obstruction increased from 69.8% to 73.9%, and of the non-obstruction decreased from 8.8% to 5.3% ($P < 0.05$). There were 11% of traces that changed the classifications using the ICS nomogram, and 28.9% that changed the grades for the Schaefer nomogram. **Conclusion:** Systematically significant differences in parameters from pressure-flow study between manual readings and computer recordings were demonstrated. Manual correction resulted in a consistently lower Q_{max}, a higher urethral resistance, and an aggravating obstruction. Manual readings can correct considerable false diagnoses for obstruction. Retrospective quality control of pressure-flow data with computer-based systems is necessary. *(Asian J Androl 2007 Nov; 9: 771–780)*

Keywords: benign prostatic hyperplasia; pressure-flow study; quality control

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1 Introduction

The pressure-flow study of micturition is the best method of quantitatively analyzing voiding function [1]. The objective diagnosis of bladder outlet obstruction (BOO) depends on the analysis of pressure-flow data.

Computers have been used clinical urodynamic practice and research for about 15 years. Computer-based urodynamic systems have gradually replaced traditional systems and now play a significant role in many aspects of urodynamics. These aspects include urodynamic investigation, storage and retrieval of measurements and parameters, and analysis of signals and results [2]. The investigators have developed complex and sophisticated computer-based methods for pressure-flow analysis. However, the application of computers has introduced some problems into urodynamics. A true urodynamic expert system has not yet been developed. When compared with traditional paper-chart records, considerable artifacts and errors are found in the computer print-outs [3]. Computers are not able to pick up technical artifacts and human errors. Some investigators accept the automated results of computers without question; this often results in a false diagnosis [4]. Therefore, manual interpretation and correction of urodynamic traces and data are necessary. A similar situation is found in the application of computers in other fields [5]. Quality control can be carried out not only during urodynamic testing, but also in retrospective analysis of data. Manual recognition and correction of the computer print-outs is referred to as retrospective quality control. Some authors have investigated manual correction in uroflowmetry. Rowan *et al.* [6] found that up to 20% of uroflow traces show artifacts. Grino *et al.* [7] compared manual and automated values, and find consistently lower values of maximum urinary flow rate (Q_{max}) in manual readings. Few studies report on this aspect in pressure-flow analysis. Schaefer *et al.* [8] provided quality control and initial analysis of pressure-flow studies. Madsen *et al.* [9] compared manual values of Q_{max} and detrusor pressure at Q_{max} ($p_{det.Qmax}$), with values from computer-based systems in a small group of patients. In our study, a total of 606 pressure-flow measurements were manually analyzed, and the results were compared with those from computer-based systems. Several parameters for BOO and methods of analyzing pressure-flow studies were used to evaluate the impact of manual correction on the outcome, and the effectiveness of quality control was assessed. The necessity of quality control in retrospective analysis of pressure-flow data with computer-based urodynamic systems was discussed.

2 Materials and methods

The present study was retrospective and non-random. The urodynamic data of 181 and 100 follow-up men suspected with benign prostatic hyperplasia (BPH) were sent to our laboratory for quality control from other centers. The mean age of the men was 65.3 years (range 43–86 years). In both the initial and the follow-up investigation, a given patient underwent two or three pressure-flow studies. A total of 606 traces were reviewed. The exclusive criteria for the pressure-flow traces to undergo comparative analysis were: (i) a trace was uninterpretable and uncorrectional because of various artifacts and technical errors during voiding; and (ii) there were multi strong strains during voiding. A total of 582 pressure-flow traces (382 baseline traces and 200 follow-up traces) were included for further analysis. All traces were printed out, and were manually read and corrected using a quality control monitor. The reader was blinded to the computer results. The complex and special traces were discussed with other experienced urodynamicists. The methods included the corrections of Q_{max} and $p_{det.Qmax}$. The correction of Q_{max} contained its location and value on the uroflow curve. First, Q_{max} must be located at the highest plateau on a main uroflow curve. The spike artifacts of the uroflow curve and the additional modifications in flow rate were manually smoothed and corrected to obtain a Q_{max} value, according to the method described in the report regarding the standardization of the International Continence Society (ICS) [10]. The following two specifications were used to manually read Q_{max}: (i) Q_{max} had to be measured at the highest plateau or peak of the flow curve that lasted for 2 s or more; and (ii) the Q_{max} value had to be read to the nearest 0.5–1.0 mL/s. Then, the $p_{det.Qmax}$ value responding to Q_{max} was able to be confirmed. Various artifacts and errors could occur in vesical pressure (p_{ves}) and abdominal pressure (p_{abd}) curves, and then influence detrusor pressure (p_{det}) curves. The traces that were not able to be corrected had been excluded. In included traces, the main artifacts of p_{det} were the up or down spikes and negative p_{abd}. Any rapid rising and dropping changes in the p_{det} curve were recognized as spike artifacts, and were smoothed and corrected. A negative value of p_{abd} was corrected using a typical range for initial resting pressure value of p_{abd}: 15–40 cm of water for a sitting position [10].

In analysis of pressure-flow data, various parameters and different methods were used. As a continuous quantitative parameter, the obstruction coefficient (OCO) developed by Schaefer *et al.* [11] was used to detect the difference in urethral resistance between manual results and those from computer-based systems. OCO was calculated according to the following formula: OCO = $p_{det.Qmax}/(40 + 2Q_{max})$. A Schaefer nomogram was used to grade the degree of obstruction and to evaluate the changes of obstructed grade after correction [12]. ICS [1] and Abrams-Griffiths (A/G) nomograms [13] were used to classify and diagnose obstruction and to determine the shifts in classifications as a result of correction.

The different statistical analyses were performed using computers. Correlation analyses between manual and computer-based system results were done for the following variables: Q_{max}, $p_{det.Qmax}$ and OCO. For the above-mentioned variables, the variations between manual values and ones from computer-based system were evaluated using the matched-pairs *Z*-test for a large sample. The percentages in various grades of Schaefer nomogram and classifications of ICS and A/G nomograms were calculated. The variations in classifications of ICS and A/G nomograms and in grades of Schaefer nomogram between manual readings and computer-based system readings were examined using the χ^2-test and relative to an identified distribution (Ridit) analysis, respectively. In the abovementioned statistical analyses, $P < 0.05$ was considered significant.

3 Results

Of 606 pressure-flow traces, 582 (96.0%) were included and analyzed; 24 (4.0%) traces had to be discarded because the artifacts that were not be interpreted and corrected. Comparing the manual values of pressure-flow data with those of computer-based systems, we determined changes in parameters values, including Q_{max}, $p_{det.Qmax}$, urethral resistance, and the changes in grading, classifying and diagnosing for obstruction. Q_{max} had a consistently significant decrease ($P < 0.001$), 1.2 mL/s on average, and had a changed range of –0.5–10.4 mL/s. $p_{det.Qmax}$ had inconsistent changes with a slight systematic increase, 0.8 cm water on average, but no significant variation was demonstrated ($P > 0.05$). Concerning the changes in $p_{det.Qmax}$ after manual correction, 321 (55.2%) of 582 traces had a significant increase ($P < 0.01$), 4.9 cm water on average; 184 (31.6%) had a no significant decrease ($P > 0.05$), 6.2 cm water on average; 77 (13.2%) did not change; and 505 (86.8%) underwent intra-individual changes with a range of –70–56 cm water. OCO underwent a systematically significant increase by 0.07 on average ($P < 0.05$); intra-individual changes were inconsistent, with a range of –1.38–1.00 (Tables 1 and 2, Figures 1–3).

Correlation coefficients (*r*) of Q_{max}, $p_{det.Qmax}$ and OCO between manual and computer-based system readings were 0.91, 0.97 and 0.97, respectively (Table 1).

With respect to the decreased degree of Q_{max} after correction, the percentages of decrease of ≤ 0, 0.1–0.9, 1–1.9, 2–2.9, 3–3.9 and ≥ 4 mL/s were 2.1%, 54.1%, 29.0%, 8.4%, 3.4% and 3.0%, respectively (Figure 1). The percentages of $p_{det.Qmax}$ increase of 1–9, 10–19 and ≥ 20 cm water were 49.3%, 3.4% and 2.4%, respectively; the percentages of $p_{det.Qmax}$ decrease of 1–9, 10–19 and ≥ 20 cm water were 25.8%, 3.6% and 2.2%, respectively (Figure 2). The percentages of OCO increase of 0.001–0.04, 0.05–0.14, 0.15–0.24, 0.25–0.49 and 0.5 were 22.5%, 44.0%, 7.7%, 5.0% and 2.2%, respectively; the percentages of OCO decrease of 0.001–0.24 and ≥ 0.25 were 5.5% and 13.1%, respectively (Figure 3).

The percentages in classifications using ICS and A/G nomograms and in grades using the Schaefer nomogram are shown in Table 3 and Figure 4. Comparing these percentages of manual results with those from computer-based systems, a significant systematic difference was found. Using ICS and A/G nomograms, the obstructed percentage increased from 69.8% to 73.9% ($P < 0.05$), and the unobstructed percentage decreased from 8.8% to 5.3% ($P < 0.05$) and from 1.5% to 0 ($P < 0.01$), respectively. Using the Schaefer nomogram, the obstructed percentage (III–VI) increased from 72.5% to 77.3% ($P < 0.01$), and the unobstructed one (0–I) decreased from 9.1% to 5.5% ($P < 0.01$). Systematically, the distribution and degree of obstruction had a significant increase after correction. However, the intra-individual changes of classification and grade were different. After manual correction, 64 (11.0%) of 582 traces changed the classification in ICS nomogram, and 48 (8.3%) did in A/G nomogram. Of 64 traces, 53 (82.8%) increased obstructed degree, and 11 (17.2%) decreased obstructed degree using the ICS nomogram. Of 48 traces, 39 (81.3%) increased obstructed degree, and 9 (18.7%) decreased obstructed degree using the A/G nomogram (Table 4 and Figure 5). Using the Schaefer nomogram,

Table 1. Changes of parameters of pressure-flow studies after manual correction (mean ± SD). OCO, obstruction coefficient.

	Computer-based system values	Manual values	Change	*P* value	*r*
Q_{max} (mL/s)	8.5 ± 2.9	7.3 ± 2.6	1.2 ± 1.2	< 0.001	0.91
$p_{det.Qmax}$ (cm water)	75.8 ± 33.3	76.5 ± 31.7	–0.8 ± 8.3	0.346	0.97
Increased $p_{det.Qmax}$	68.9 ± 25.4	73.8 ± 25.4	–4.9 ± 6.7	0.007	0.97
Unchanged $p_{det.Qmax}$	74.2 ± 35.3	74.2 ± 35.3	0		1
Decreased $p_{det.Qmax}$	88.3 ± 40.5	82.1 ± 38.7	6.2 ± 7.9	0.068	0.98
OCO	1.36 ± 0.66	1.43 ± 0.65	–0.07 ± 0.16	0.040	0.97

Table 2. Changes of parameters of pressure-flow studies after manual correction. OCO, obstruction coefficient.

	Computer-based system values		Manual values		Changes	
	Median	Range	Median	Range	Median	Range
Q_{max} (mL/s)	8.2	1.6–18.6	7	1.2–16.7	0.9	–0.5–10.4
$p_{det.Qmax}$ (cm water)	69	2–264	70	20–246	–1	–70–56
Increased $p_{det.Qmax}$	67	2–159	70	28–161	–3	–70–1
Unchanged $p_{det.Qmax}$	62	29–246	62	29–46		
Decreased $p_{det.Qmax}$	75	33–264	70	20–240	3	1–56
OCO	1.22	0.03–4.87	1.30	0.35–4.92	–0.06	–1.38–1.00

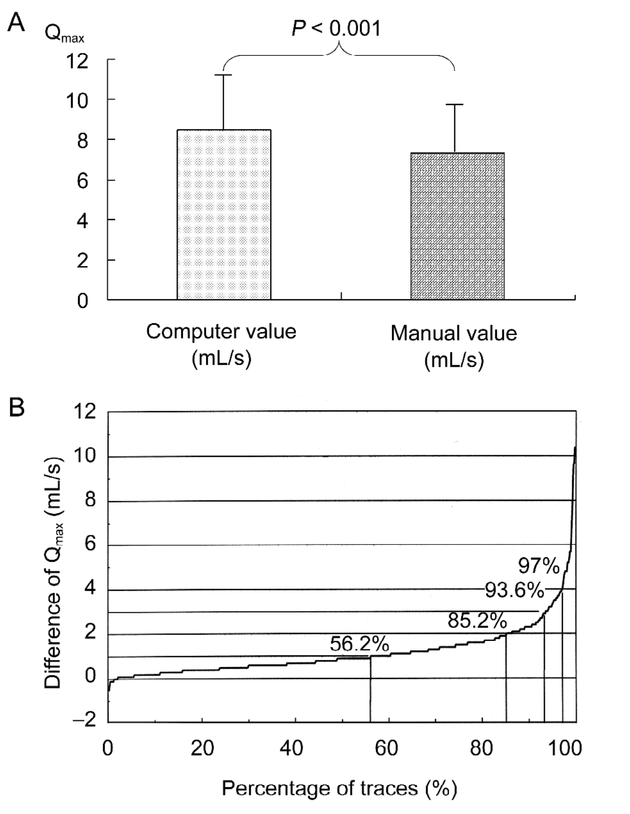

Figure 1. (A): Q_{max} of manual and computer-based system values. (B): The difference of Q_{max} between manual and computer-based system readings, and the percentages of change in 582 pressure-flow traces.

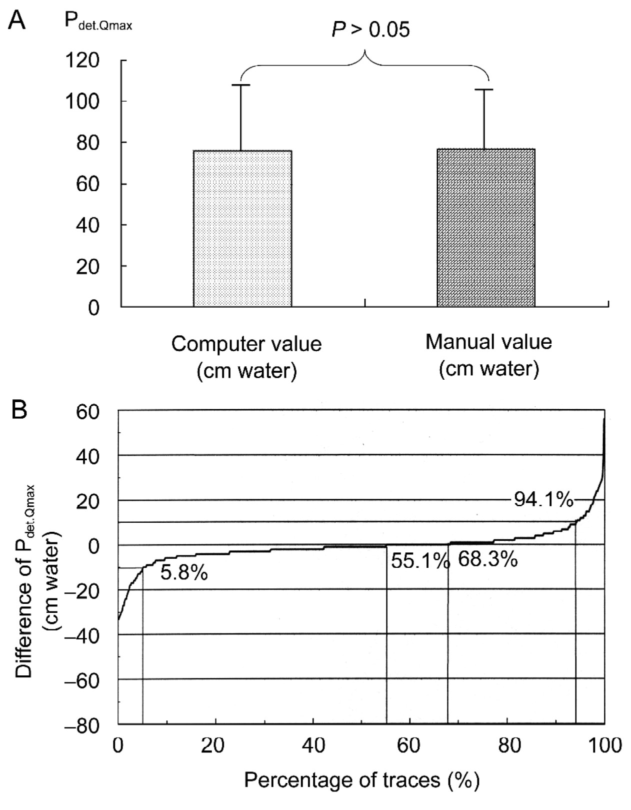

Figure 2. (A): $p_{det.Qmax}$ of manual and computer-based system values. (B): The difference of $p_{det.Qmax}$ between manual and computer-based system readings, and the percentages of change in 582 pressure-flow traces.

Table 3. Difference of percentages between manual reading and computer-based system recording in classifications of International Continence Society (ICS) and Abrams-Griffiths (A/G) nomogram and in grades of Schaefer nomogram.

	Computer-based system recording		Manual reading		*P* value
	Number	Percentage (%)	Number	Percentage (%)	
ICS nomogram					< 0.05
Obstructed	406	69.8	430	73.9	
Equivocal	125	21.5	121	20.8	
Unobstructed	51	8.8	31	5.3	
A/G nomogram					< 0.01
Obstructed	406	69.8	430	73.9	
Equivocal	167	28.7	152	26.1	
Unobstructed	9	1.5	0	0	
Schaefer nomogram					< 0.01
0	6	1.0	1	0.2	
I	47	8.1	31	5.3	
II	107	18.4	100	17.2	
III	179	30.8	164	28.2	
IV	166	28.5	182	31.3	
V	40	6.9	64	11.0	
VI	37	6.4	40	6.9	

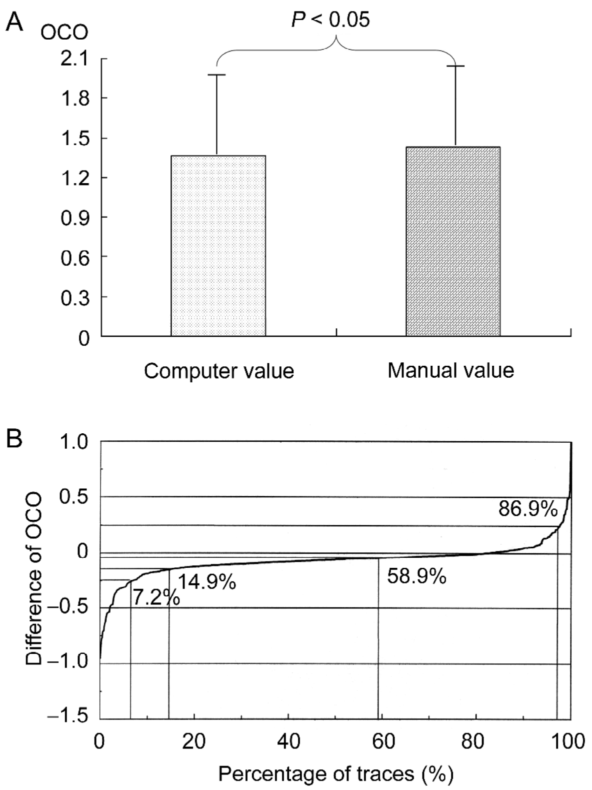

Figure 3. (A): The obstruction coefficient (OCO) calculated according to manual readings and computer-based system values. (B): The difference of OCO between manual and computer-based system readings, and the percentages of change in 582 pressure-flow traces.

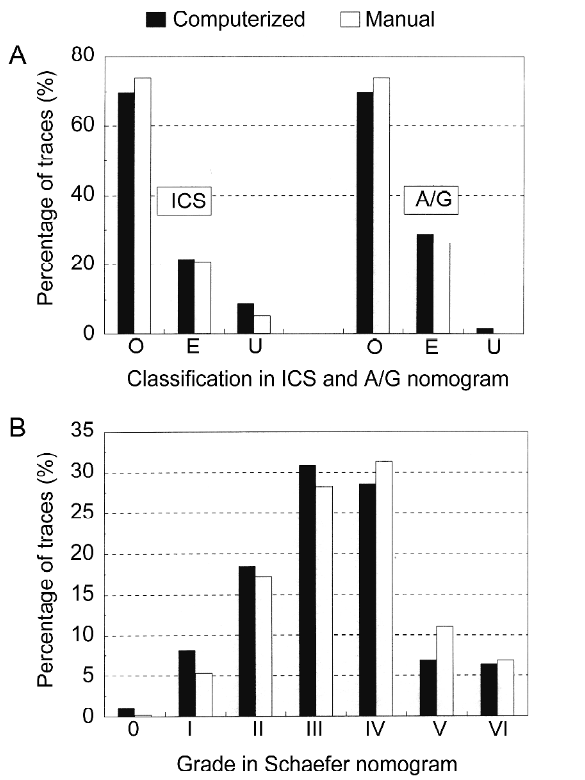

Figure 4. (A): The distribution of measurements in classifications of International Continence Society (ICS) and Abrams-Griffiths (A/G) nomograms according to manual and computer-based system readings. (B): The distribution of 582 pressure-flow measurements in grade of Schaefer nomogram.

Table 4. Shifts of measurements in classification of International Continence Society (ICS) and Abrams-Griffiths (A/G) nomogram after manual correction.

	ICS nomogram		A/G nomogram	
	Number	Percentage (%)	Number	Percentage (%)
Unobstructed → Equivocal	21	32.8	7	14.6
Equivocal → Obstructed	30	46.9	31	64.5
Unobstructed → Obstructed	2	3.1	1	2.1
Equivocal → Unobstructed	3	4.7	1	2.1
Obstructed → Equivocal	8	12.5	8	16.7
Total	64	100	48	100
Shifting into obstructed zone	32	80	32	80
Shifting out of obstructed zone	8	20	8	20
Total	40	100	40	100

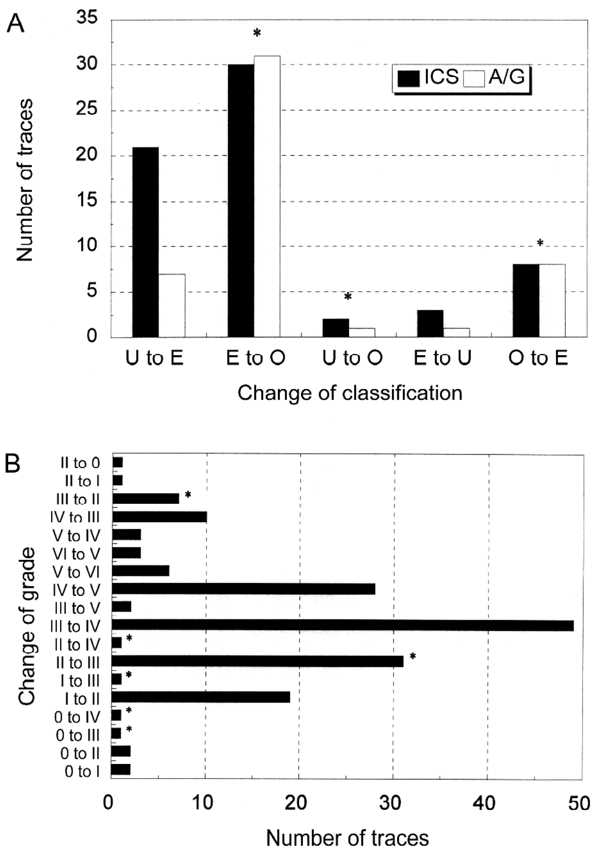

Figure 5. (A): The changes in classifications of International Continence Society (ICS) and Abrams-Griffiths (A/G) nomograms after manual correction. (B): The changes in grade of Schaefer nomogram after manual correction. * indicates the measurements that changed the diagnosis for obstruction.

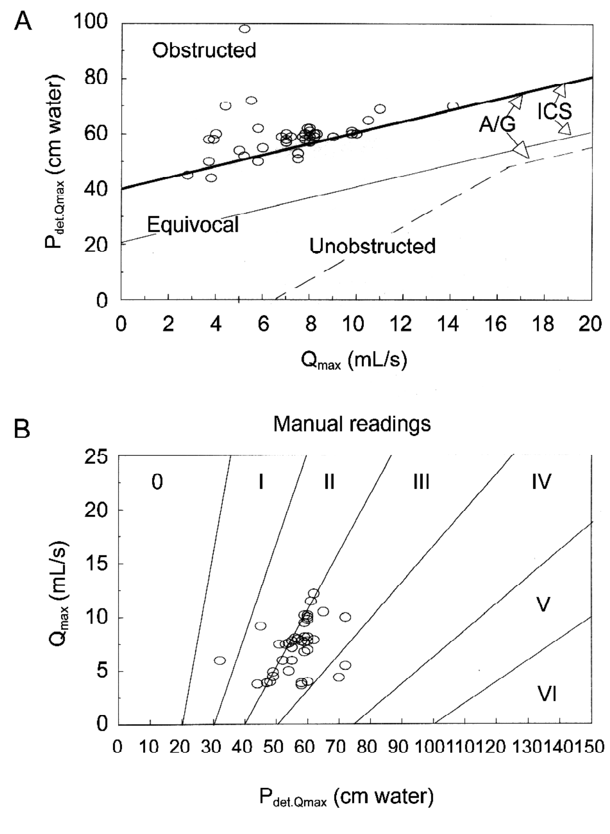

Figure 6. (A): The changes of diagnosis for obstruction using International Continence Society (ICS) and Abrams-Griffiths (A/G) nomograms after manual correction; 32 traces shifted into obstructed zone, and 8 shifted out of one. (B): The changes of diagnosis for obstruction using Schaefer nomogram; 35 traces moved to ≥ III grades, and 7 moved to < III ones.

Table 5. Changes of measurements in grading of Schaefer nomogram after manual correction.

	Number	Percentage (%)
Increased 1 grade	135	80.3
Increased 2 grades	6	3.6
Increased 3 grades	1	0.6
Increased 4 grades	1	0.6
Decreased 1 grade	24	14.3
Decreased 2 grades	1	0.6
Total	168	100
< III → ≥ III grade	35	83.3
≥ III → < III grade	7	16.7
Total	42	100

168 (28.9%) of 582 traces changed grade after correction. Of 168 traces, 143 (85.1%) increased obstructed degree, and 25 (14.9%) decreased obstructed degree. A trace with a great change moved from 0 to IV grade, and most of traces (94.6%) changed one grade after correction (Table 5 and Figure 5).

After manual correction, 40 (6.9%) of 582 traces changed the diagnosis of obstruction using ICS and A/G nomograms; 32 (80%) of 40 traces shifted into obstructed zone from unobstructed and equivocal zones, and 8 (20%) shifted out of obstructed zone (Table 4 and Figure 5). Using the Schaefer nomogram, 42 (7.2%) of 582 traces changed the diagnosis of obstruction. Of 42 traces, 35 (83.3%) moved from < III to ≥ III grade, and 7 (16.7%) moved from ≥ III to < III grade (Table 5, Figure 5).

4 Discussion

Pressure-flow studies can provide us with a diagnostic standard for bladder outlet obstruction, and measure urethral resistance and changes. There are several methods for analysis of pressure-flow data. For these methods, the basic, important and key variables are Q_{max} and $p_{det.Qmax}$. In most methods, ICS nomogram, A/G nomogram, Schaefer nomogram, OCO and A/G number [14], the obstructed degree and urethral resistance only depend on these two variables. The problem that we face is how to obtain the reliable values of Q_{max} and $p_{det.Qmax}$ without various artifacts, to ensure the correct clinical diagnosis. In addition, the abovementioned methods are established on the models without strains. A typical pattern of pressure-flow trace is with smooth and steady rise and drop of p_{ves} and p_{det} curves. Therefore, quality control of pressure-flow data becomes increasingly important; it can be performed during collection of data and in retrospective analysis of data. Quality control during collection of data is the best way to avoid, reduce and eliminate artifacts. However, the artifacts in data can be corrected by quality control in retrospective analysis. This is not an ideal solution, but is necessary for computer results. Modern computer-based urodynamic systems have presented new problems in analysis of data. Almost all machines are unable to pick up and correct artifacts. Many clinicians do not examine the traces for artifacts and accept computer values of parameters; this must significantly influence clinical diagnosis and research results. The main tasks of retrospective quality control of pressure-flow data are the pattern recognition of traces and the manual correction of Q_{max} and $p_{det.Qmax}$ coming from computer printouts.

In our study, 4% traces were discarded because the artifacts and errors from these traces were unable to be interpreted and corrected. In the interpretable pressure-flow traces, Q_{max}, urethral resistance (OCO), grading and classification of obstruction underwent significant systematic changes; $p_{det.Qmax}$ had no systematically significant changes, but considerable intra-individual changes after manual correction. Q_{max} reduced consistently by 1.2 mL/s on average, which was similar to the result (by 1.5 mL/s on average) reported by Grino *et al*. [6] in 1 645 uroflow measurements and the result (by 0.8 mL/s on average) reported by Madsen *et al.* [9] in pressure-flow studies of 25 patients. The decreased value of Q_{max} resulted from the correction of spike artifacts, extracorporeal modifications in flowrate and other artifacts. Some artifacts also changed the location of Q_{max}. The decreased degree of Q_{max} was variable, but 83.1% of readings were accompanied by a 0.1–1.9 mL/s decrease of Q_{max}. The values of Q_{max} increased after correction in 7 (1.2%) traces: the possible reason was that the investigators changed computer-generated Q_{max} values before the data were sent us for analysis. Smoothed and corrected values of Q_{max} underwent a significant decrease; still, there was strong correlation between manual values of Q_{max} and computer-based system ones. This means that manual correction has not changed the nature of Q_{max} data and that the smoothed and corrected Q_{max} can reflect the condition of urethral resistance much more really. How are artifacts of Q_{max} identified? A normal uroflow curve is smooth without any rapid changes or spikes. Rapid changes in flowrate might have physiological and physical causes. The physiological spikes can result from changes in outflow resistance (e.g. sphincter and pelvic floor contraction or relaxation), or from changes in driving energy (e.g. abdominal straining). These intracorporeal physiological artifacts should be minimized during the investigation. Extracorporeal additional modifications in the flow rate signal, which is usually small spikes, can be introduced by any funnel or collecting device of uroflowmeter. This type of non-physiological artifact should be eliminated. As a simple rule of thumb, any rapid change in uroflow rate lasting less than 2 s should be smoothed and corrected as artifacts in retrospective analysis. In a standardization report, ICS recommended that an internal electronic smoothing with a sliding average over 2 s be used to make an electronically reading value of Q_{max} more reliable, comparable and clinically useful [10]. In manual graphical readings of Q_{max}, a graphical line smoothing to a continuous curvature for at least a period of 2 s was drawn to obtain a smoothed Q_{max} value. Generally, only a smoothed Q_{max} that is lower than an electronically read Q_{max} is clinically meaningful. A standardization report of ICS indicated that only smoothed Q_{max} values are reported [10].

$p_{det.Qmax}$ showed a slight systematic increase by 0.8 cm water on average after manual correction, but no significant variation was demonstrated. Similarly, Madsen *et al.* [9] report an insignificant slight decrease of $p_{det.Qmax}$ by 2.8 cm water on average after correction. This is because the location of $p_{det.Qmax}$ responds to Q_{max}; therefore, intra-individual changes of $p_{det.Qmax}$ were inconsistent. 55.2% traces had a significant increase of 4.9 cm water on average, and 31.6% traces had insignificant decreases of 6.15 cm water, on average. Although there were no systematically significant changes, $p_{det.Qmax}$ underwent intra-individually considerable changes ranging from –70 cm to 56 cm water after manual correction. The artifacts of $p_{det.Qmax}$ are various and complex, and are sometimes difficult to interpret. As a smooth muscle, detrusor contracts smoothly and steadily, and then any pressure change caused by detrusor contraction must show a smooth and steady pattern without rapid changes. A typical pattern of trace of detrusor pressure during voiding is that the pressure curve rises and drops smoothly and steadily. Therefore, any rapid changes on the curve over short periods should be considered as artifacts, and must be interpreted and corrected. There are several types of artifacts of detrusor pressure during voiding, which can be produced in a variety of ways. The most common types are spikes and negative p_{abd}. Spike artifacts result from, for example, strains, rectal activity, move of patient or transducer, or a difference in pressure transmission to the p_{ves} and p_{abd}. Generally, insufficient p_{abd} response at straining due to a difference in pressure transmission can produce up-spikes, rectal activity can produce small down-spikes, and cough tests can produce biphasic spikes. A negative p_{abd} can result from a common mistake in zero and reference level, and a meaningless p_{det} value that is higher than p_{ves} will be calculated according to it [8, 10]. In retrospective quality control, the mentioned artifacts are acceptable, and can manually be corrected by smoothing and calculating using typical ranges of p_{abd}. However, often other artifacts cannot be corrected in retrospective analysis. They is often a sudden drop in p_{det} during voiding as a result, for example, of loss of the catheter, multi strong strains, periodic or complete loss of pressure signal, non-responding dead signal, stepwise changes and wrong resting pressures. The traces with these artifacts must be discarded, and were excluded from our comparative study.

As a continuous quantitative parameter, OCO can precisely measure urethral resistance and change. This was demonstrated by our research. In the present study, a systematically significant increase of OCO by 0.07 on average was shown after manual correction. Intra-individually, OCO changes were inconsistent, with a range from –1.38 to 1.00. The reason would be that the inconsistent changes of p_{det} could influence OCO. The change of OCO indicated that manually reading lead to higher urethral resistance, and artifacts reduced urethral resistance. Therefore, we could say that OCO calculated by manually reading values could precisely indicate the condition of urethral resistance.

More serious was that various artifacts influenced the diagnosis of obstruction and the assessment of obstructed degree. Generally, it seems that artifacts lead to a less-obstructed degree. In our study, ICS, A/G and Schaefer nomograms were used to evaluate this impact. After manual correction, more traces were located in obstructed zone or grades. In nomograms, 8.3%–28.9% of traces changed the classification and the grade, and 6.9%–7.2% of traces changed the diagnosis of obstruction. 5.5%–6.0% of traces shifted into obstructed zone or grades. Results with computer-based systems produced 5.5%–6.0% false negative diagnoses of obstruction because of various artifacts in these 582 measurements. However, 1.2%–1.4% traces shifted out of obstructed zone or grades. Readings with computer-based systems produced 1.2%–1.4% false positive diagnoses of obstruction. Therefore, retrospective quality control corrected considerable false diagnoses of obstruction.

We determined that Q_{max} was the most important parameter, and was determined first in retrospective analysis of pressure-flow data. After the determination of Q_{max}, a corresponding location of p_{det} could be found, and then the urethral resistance parameters, such as OCO, could be calculated. It seemed that systematically significant differences in Q_{max} resulted in the differences in OCO, classifying and grading of obstruction after manual correction.

In summary, quality control is involved in both online and offline urodynamic investigations. Getting the most out of urodynamics depends on a good urodynamic practice, but also on the training and experience of the clinician charged with interpreting the results. In the interpretation of pressure-flow data, the clinician must meticulously examine the trace for artifacts before accepting the computer results. At present, retrospective quality control of pressure-flow data with computer-based urodynamic systems is necessary; it can remove the impact of artifacts on Q_{max}, p_{det}, urethral resistance, classifying and grading of obstruction, and diagnosis of obstruction. The data from computer-based urodynamic systems through quality control become more objective, reliable and acceptable, and can be used for further analysis. These effects of retrospective quality control were demonstrated in our study. A reliable diagnosis for BOO and reasonable treatment plans for patients with BPH are based on the pressure-flow data that come originally from computer-based urodynamic systems, and successively undergo the quality control by manual analyses.

In conclusion, we found systematically significant differences in Q_{max}, urethral resistance, and classifying and grading of obstruction between manual and computer-based system readings. The manually corrected Q_{max} had a consistently lower value; a higher value of OCO was calculated, and a more obstructed degree was assessed according to the manual readings. There was no systematically significant change for $p_{det.Qmax}$ after manual correction, but considerable changes in $p_{det.Qmax}$ were found among individuals. Manual reading corrected considerable false diagnoses of obstruction. The effects of manual correction have been shown here. Therefore, retrospective quality control of pressure-flow data with computer-based urodynamic systems is necessary, and only the data in which quality control has been carried out could be used and reported.

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