Improved reliability of uroflowmetry investigations: results of a portable home-based uroflowmetry study

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Objectives To compare the results obtained using a portable home-based uroflowmeter with the results of traditional flowmetry performed in the out-patient department (OPD).

Patients and methods Sixty-seven patients (mean age 61 years, range 38–79) with lower urinary tract symptoms and/or benign prostatic enlargement used a home-based uroflowmeter comprising a datalogger and specially designed fluid sensors incorporated into disposable beakers. The results of these measurements were compared with those from uroflowmetry in the OPD and with other clinical variables.

Results There was a good correlation between the uroflow results obtained when voiding at home and at the OPD. The highest measured maximum flow and voided volume were obtained with the home-based uroflowmeter system. However, the mean of all consecutive home-based maximum flow and voided volume measurements were lower than those obtained by single-void uroflowmetry in the OPD.

Conclusions Home-based uroflowmetry provides reliable voiding results which are comparable with those obtained in the OPD.

Keywords Uroflowmetry, urodynamics, home-based uroflowmetry

Introduction

About one-third of men older than 50 years present with lower urinary tract symptoms (LUTS) [1]; such symptoms eventually develop in most men and the predominant mechanism for this disorder is bladder outlet obstruction (BOO), caused by prostatic adenoma [2]. However, clinical experience suggests that the degree of obstruction is not always related to the volume of the prostate. Small prostates in younger men can cause severe obstruction and voiding disorders, but large adenomas can be present without causing obstruction [3]. In the treatment of patients with LUTS and BPE, the success of (surgical) treatment seems to be closely related to the presence of BOO [4,5]. Therefore, if patients with LUTS and BPE are to be treated appropriately, information about the grade of obstruction should be obtained.

A urodynamic investigation with pressure/flow analysis is considered to be the ‘gold standard’ to determine BOO [6]. However, rather than performing this invasive investigation, uroflowmetry is used most often to document voiding disorders because it is simple, readily available and easy to use [7]. The most recent uroflowmeters measure voided volume, the maximum flow rate ($Q_{max}$), the mean flow rate, time to maximum flow and the duration of flow. Moreover, the pattern of flow can be described and characterized. In general, urologists use measurements of $Q_{max}$ with the patient’s symptoms and other clinical findings, to make decisions about the need for therapeutic intervention to relieve LUTS and/or BOO. These clinical investigations can also be used in the follow-up of patients and to document the outcome of therapy.

The uroflow can be measured using several methods, e.g. a rotating disc, an electronic dipstick or gravimetric measurement. These systems are used mainly in the clinical environment and consequently the results are seldom obtained under conditions equivalent to ‘voiding at home’; indeed, the patient has to void in an environment that can be very embarrassing. He must also void with a bladder full enough to obtain a representative voided volume. Moreover, the results of uroflowmetry may vary during the day [8]. To overcome these problems, a home-based system of uroflowmetry has been introduced. A system was designed and developed that would provide reliable results, was easy to use by the patient, had quality-control of flow-measurement, was hand-held for practical use, used hygienic disposable beakers and from which the results were quickly and easily available. In the present pilot study, the results from a portable home-based uroflowmeter (HBU) were compared with other clinical variables and the results from uroflowmetry performed in the out-patient department (OPD).

Patients and methods

Sixty-seven consecutive patients (mean age 61 years, range 38–79) with voiding complaints were seen in the...
When the battery voltage becomes too low, the small pulsing light can be used to signal low battery levels. The sensor is used to stop the system from attempting to charge the battery. In this mode, the system will not attempt to charge the battery further.

When the sensor is used to stop the system, the battery voltage is monitored continuously. If the voltage drops below a certain level, the system will automatically stop charging. This ensures that the battery is not damaged and that it is not overcharged.

The sensing circuit is robust and reliable, with a high degree of accuracy and consistency. It is able to detect low voltages and provide a warning to the user, allowing them to take appropriate action before the battery runs out of power.

The sensor is designed to be easy to use and is versatile, being able to work with a variety of different battery types and voltages.

To meet the requirements of a full charge, a new method of charging is employed. The sensor is able to accurately detect when the battery is fully charged, allowing it to be disconnected from the mains supply. This ensures that the battery is not overcharged and that it is not damaged in any way.

The sensor is also capable of detecting when the battery is not in use, allowing it to be disengaged from the system. This saves power and ensures that the battery is not wasted.

In summary, the sensor is an essential component of the system, providing accurate and reliable information about the battery's state of charge. It is able to detect low voltages and provide a warning to the user, ensuring that the battery is not damaged or overcharged. The sensor is also capable of detecting when the battery is not in use, allowing it to be disengaged from the system. This saves power and ensures that the battery is not wasted.
flashing green and red light indicate that the user should replace the batteries.

The device includes a micro-processor board, memory, a real-time clock and the measurement electronics. Each measurement is stored in the memory, together with the exact time and date. After completion of the required flow measurements, the system is returned to the physician. At the OPD, the device is connected to a desktop computer and the contents of the memory (the flow records and times) read from the flowmeter. Flow curves can be presented on the computer screen and printed as hardcopy. Flow variables, e.g. peak flow and mean flow rates, are calculated, stored in a database and can be presented on the screen or printer. These variables are also presented as a flow diary with all variables, including date and time, displayed; the mean, minimum and maximum values are also calculated. A program to automatically detect artefacts was also implemented and was able to identify those flows that were probably measured incorrectly.

The variables are stored in a database on the computer (in a standard Dbase format), together with data identifying the patient; the data can thus be exported to other programs like spreadsheets or statistical packages. Almost 7 h of continuous use can be stored and processed by the HBU, equivalent to about 400 flow measurements. The accuracy of the volume measurement was determined by filling the beakers with known quantities of fluid and was also tested with the beakers at two angles (0° and 15°); the error of the measured volume was < 1% of full scale (800 mL) at any angle. The flow error was measured similarly using a constant flow source and was < 5% of full scale (50 mL/s).

**Urodynamic evaluation**

Urodynamic investigations were performed with an 8-F transurethral lumen catheter equipped with an intravesical microtip pressure sensor for recording bladder pressure. Abdominal pressure was recorded intrarectally with an 8-F microtip-sensor catheter (MTC, Dräger, Germany). Before cystometry, the bladder was emptied through the lumen of the transurethral catheter. The bladder was filled with water at 20°C and at a filling speed of 50 mL/min. Equipment developed in our department (UIC/BME Research Centre, Department of Urology, Nijmegen, the Netherlands) was used to record the pressure and flow data. The linear passive urethral resistance (LPURR) concept was used to provide an objective and accurate grading of obstruction [9]; in this system, patients graded 0–2 are minimally obstructed and those graded 3–6 definitely obstructed.

Descriptive statistics were used to assess the results of the HBU and the other clinical findings. Student’s t-test was used to compare the mean Q_max and mean voided volume obtained at home and at the OPD.

**Results**

All the patients confirmed that the system was easy to use. All 67 patients received 12 beakers each and completed several micturitions free of artefacts. During a 3-day period, 6–12 (mean 10) measurements were obtained from each patient. A total of 673 flow measurements were recorded and the quality-control system indicated that there were possible artefacts in 142 flows (21%). After visual evaluation of these records, there were 572 (85%) correctly measured flows in total.

The mean prostate volume was 43 mL (range 16–115) and the mean IPSS score was 15.4 (range 1–33). The mean values of voided volume and Q_max for the consecutive measurements made at home are shown in Table 1, which shows that the means were stable but with a large dispersion, indicated by the 95% CI. Evaluation of the uroflowmetry studies showed that the Q_max at the OPD ranged from 3.0 to 35 mL/s and the comparison between the mean Q_max using the HBU and at the OPD

<table>
<thead>
<tr>
<th>Number of HBU estimates</th>
<th>Number of patients</th>
<th>Mean voided volume (volume, mL [95% CI])</th>
<th>Mean maximum flow (flow, mL/s [95% CI])</th>
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<tbody>
<tr>
<td>2</td>
<td>67</td>
<td>211 [71-427]</td>
<td>13.0 [3.5-22.6]</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>211 [74-556]</td>
<td>12.9 [3.3-25.4]</td>
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<td>4</td>
<td>65</td>
<td>226 [73-545]</td>
<td>12.6 [2.9-25.6]</td>
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<td>5</td>
<td>64</td>
<td>224 [95-551]</td>
<td>13.4 [2.8-25.5]</td>
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<td>7</td>
<td>57</td>
<td>212 [89-434]</td>
<td>12.6 [2.2-21.6]</td>
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<td>8</td>
<td>50</td>
<td>202 [45-488]</td>
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<td>9</td>
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<td>211 [47-440]</td>
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<td>10</td>
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<td>196 [94-430]</td>
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<td>11</td>
<td>15</td>
<td>240 [96-420]</td>
<td>12.6 [1.8-26.0]</td>
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is shown in Fig. 3. The mean $Q_{\text{max}}$ at the OPD (13.7 mL/s) was slightly higher, but not significantly, than the mean $Q_{\text{max}}$ from the HBU (12.9 mL/s; $P=0.11$), possibly because the mean voided volume was significantly higher at the OPD (277 mL) compared to that from the HBU (215 mL; $P<0.01$). There was a difference in the highest $Q_{\text{max}}$ achieved with the HBU and at the OPD (Fig. 4); in most cases, the highest $Q_{\text{max}}$ of the individual HBU sessions was considerably higher than that obtained in the OPD. There was a similar pattern for the measurements of voided volume.

The $Q_{\text{max}}$ at home was larger than that obtained in the OPD on 234 occasions (41%), was similar on seven occasions and smaller on 331 (58%). The differences between the $Q_{\text{max}}$ obtained at home and in the OPD were very variable; Fig. 5 shows that these differences appeared to have a Gaussian distribution, either negative or positive. On 373 occasions (65%) the absolute difference between the $Q_{\text{max}}$ obtained at the OPD and at home was <4 mL/s and on the other 199 occasions the absolute difference was >4 mL/s (Fig. 5). There was a similar distribution of differences between the measurements of voided volume at the OPD and at home; on 396 occasions (69%) the voided volume at home was smaller than the flow at the OPD.

On urodynamic study using pressure/flow analysis, the LPURR ranged from 0–6 (mean 1.8). There were no significant differences in the variability of values from the HBU between groups with minimal ($n=49$) and definite BOO ($n=18$) (Fig. 5).

**Discussion**

For decades, uroflowmetry has played a major role in the evaluation of voiding complaints. Urologists use the results of uroflowmetry with the patient's symptoms and other clinical findings to make decisions about the need for therapeutic intervention to relieve BOO. Although uroflowmetry can provide useful information suggesting whether a patient has BOO, and a particular flow pattern may suggest the possible underlying pathology, the interpretation of results may sometimes be difficult and misleading. For the appropriate use of the results of uroflowmetry, certain aspects should be considered, i.e. reproducibility, artefacts, circadian changes, variation within and between observers, association with volume and outlet obstruction, reference values and the clinical relevance to BPE [10–13].

Reliability is a prerequisite for any measuring technique; because consecutive flow measurements can produce variable results, particularly for $Q_{\text{max}}$, any decision based on a single-flow measurement is questionable. We agree with Blaivas that multiple samples are the most reliable for an accurate assessment [14]. For this reason, many units have developed urine-flow clinics to obtain multiple uroflowmetry results. Although this approach increases the number of reliable measurements, it is not an ideal situation, being time-consuming for both the patient and doctor, while the patient is still not voiding under 'normal conditions'. Therefore, another method was suggested to obtain multiple and reliable measurements, i.e. ambulatory home uroflowmetry. Golomb et al. were among the first to report the results of a home uroflowmetry study [8], in which the Home UroData System (Biodan Medical Systems Ltd, Rehovot, Israel) was used, and they concluded that there was large variability between consecutive maximum flows. This was confirmed by Meiter et al. [15] who presented results from 140 men with micturition disorders using another home flowmeter.

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In view of the importance of obtaining reliable uroflowmetry results, a portable HBU was developed in our department. The present pilot study assessed the practical use of this flowmeter for both the patient and the urologist and whether it is possible to overcome some of the disadvantages of 'traditional' uroflowmetry.

There was a close relationship between the mean Q_{\text{max}} and voided volume from the HBU and those obtained in a single void at the OPD. However, during the voids at the OPD, there was a slightly higher mean Q_{\text{max}} and a significantly higher mean voided volume when compared with the results from the HBU. The slightly higher Q_{\text{max}} at the OPD could be explained by the higher voided volume, probably because the results in the OPD were obtained under 'forced' conditions. When the highest Q_{\text{max}} achieved during voids at home was compared with the Q_{\text{max}} at the OPD, a considerable number of patients showed a significant difference in voiding performance, as expected, because more voids were performed using the HBU. However, almost one-third of the patients produced their highest Q_{\text{max}} at the OPD, which is not surprising because the sole aim at the OPD is to have the bladder as full as possible, while at home the timing of micturition is related to other normal daily activities. The value of the 'supranormal' values obtained in the conditions of the OPD may be questioned when they are used as inclusion criteria in treatment protocols.

How many voiding sessions are needed to obtain reliable uroflowmetry results and should these be obtained by using the HBU? By establishing a 'flow clinic', several recordings of voids can be obtained and the results of such repeated uroflowmetry can then be assessed [16]. It is generally accepted that at least two or three voiding sessions, with an adequate voided volume, are required; indeed the Q_{\text{max}} and voided volumes of the first three consecutive HBU measurements showed 'stable' results (Table 1). Whether this is enough to judge the voiding performance accurately needs to be assessed further. However, few would question that 'voiding under normal conditions' is better achieved when using the HBU than in the OPD.

One of the key questions in the treatment of patients with LUTS and BPE is whether or not they have BOO. However, when using the HBU, the relationship between the grade of obstruction and the results of uroflowmetry were no better than those from the OPD. There was a large variation in Q_{\text{max}} in minimally obstructed patients and in those with definite obstruction (Fig. 5). Although a low Q_{\text{max}} (<10 mL/s, at an appropriate volume) has a higher probability of originating from a patient with BOO, only a full urodynamic study with pressure-flow analysis can determine the exact grade of obstruction.

Another important factor in improving the reliability of uroflowmetry is quality control; all voiding studies are subject to numerous artefacts and many stem from the lack of privacy. Because environmental factors can significantly influence the results of voiding, a considerable number of patients showed 'stable' results (Table 1). Whether this is enough to judge the voiding performance accurately needs to be assessed further. However, few would question that 'voiding under normal conditions' is better achieved when using the HBU than in the OPD.
number of artefacts detected correctly was decreased to 15%. In conjunction with the technical specifications, this guarantees reliable uroflowmetry results if the HBU reports no abnormalities. Many artefacts were detected in the present study because the threshold values were determined by the software; based on the present results, the software has been adapted and the thresholds modified so that fewer flows are inspected unnecessarily.

Irrespective of age and education, patients confirmed that the HBU was easy to use; it is relatively small and the functions are easily available. Thus, the HBU can be installed easily for practical use in the home and during outdoor activities. The device is readily available and hygienic because of the disposable beakers used with the device. Thus, specific voiding difficulties that cannot be assessed by uroflowmetry in a daily clinical practice can be documented. We are aware that there is a significant circadian change in voiding values: a multicentre study has been initiated to examine these changes and to investigate the precise role of the HBU.

In conclusion, home-based uroflowmetry studies are an interesting diagnostic investigation which provide more detailed information than does single-void traditional uroflowmetry. However, the exact role of home-based uroflowmetry still needs to be determined.

References

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