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Differences in urodynamic voiding variables recorded by conventional cystometry and ambulatory monitoring in symptomatic women

Juan Pablo Valdevenito[1], Ann Leonard[2], Clive J. Griffiths[3], Robert Pickard[4], Christopher Harding[2]

[1]Servicio de Urología, Hospital Clínico Universidad de Chile. Santiago, Chile; [2]Urology Department, Newcastle upon Tyne Hospitals NHS Foundation Trust, Freeman Hospital. Newcastle upon Tyne, United Kingdom; [3]Regional Medical Physics Department, Newcastle upon Tyne Hospitals NHS Foundation Trust, Freeman Hospital, Newcastle upon Tyne, United Kingdom; [4]Institute of Cellular Medicine, Newcastle University, Newcastle upon Tyne, United Kingdom

ABSTRACT

Objectives: To determine whether there are differences in pressure and flow measurements between conventional cystometry (CONV) and ambulatory urodynamic monitoring (AMB) in women with overactive bladder syndrome and urinary incontinence.
Materials and Methods: Retrospective study which included female subjects who underwent both CONV (with saline filling medium) and AMB, separated by less than 24 months, not using medication active on the lower urinary tract and without history of prior pelvic surgery. Both tests were carried out in compliance with the International Continence Society standards. The paired Student's t test was used to compare continuous variables. Bland-Altman statistics were used to assess the agreement of each variable between both studies.
Results: Thirty women with a median (range) age of 50 (14 - 73) years met the inclusion criteria. AMB was carried out at a mean (SD) of 11 (6) months after CONV. Measurements of p_{ves} and p_{abd} at the end of filling, and Q_{max} were significantly higher from AMB recordings. There were no differences in p_{det} at the end of filling, $p_{detQmax}$ or p_{detmax} during voiding, nor significant difference in V_{void}.
Conclusions: We provide previously undocumented comparative voiding data between CONV and AMB for patients who most commonly require both investigations. Our findings show higher values of Q_{max} but similar values of $p_{detQmax}$ measured by AMB which may partly reflect an overall lower catheter caliber, physiological filling but perhaps also more 'normal' voiding conditions.

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INTRODUCTION

Ambulatory urodynamic monitoring (AMB) with natural filling is a useful additional test for patients with lower urinary tract symptoms that cannot be explained by findings from a conventional cystometry (CONV) with non-physiological filling (1). In adult practice it is predominantly required for women with urinary incontinence which cannot be categorized by a CONV although there are limited published data on comparative diagnostic accuracy (2-6). The two techniques share basic principles but differ in a number of aspects that may have a bearing on urodynamic measurements (1). Pressure measurements during AMB are generally obtained using catheter-mounted microtip transducers positioned in the bladder and rectum rather than air or fluid filled lines connected to external transducers. These allow greater mobility but are more prone to artifact. Allowing the patient to be mobile is a key feature of AMB but the frequent changing of position alters the relative height of the rectal and bladder transducers making frequent signal quality control during bladder filling necessary. The change from non-physiological filling to natural filling may alter detrusor contractility (2,6) and cystometric capacity (7). The previous lack of simultaneous uroflow recording during AMB which hampered interpretation of the voiding phase has been corrected in current devices that include this facility (4,5).

The published literature regarding measurement variation suggests that values for voiding pressure and maximum flow rate are higher with AMB compared to CONV, and that voided volume is lower (2-4). However, a more recent study in men with possible bladder outlet obstruction with integrated flow rate recording showed no difference in detrusor pressure at maximum flow ($p_{detQmax}$) (5).

In view of these conflicting findings we set out to determine whether there were any differences in voiding pressure and flow measurements between CONV and AMB with integrated flow rate recording that may be attributable to the different filling rates. We focused on the main patient group in whom AMB is requested: women with overactive bladder syndrome and urinary incontinence. This study will not evaluate the filling phase results.

MATERIALS AND METHODS

Subjects

This was a retrospective cohort study which included subjects assessed over a period of eigth years with the following criteria: 1) Female sex, 2) Investigation for overactive bladder and urinary incontinence, 3) Underwent both CONV and AMB, 4) Interval between CONV and AMB of less than 24 months, 5) Saline filling medium used for CONV (contrast medium may alter Q_{max}), 6) Not using medication active on the lower urinary tract and 7) No history of prior pelvic surgery. All patients provided written informed consent with guarantees of confidentiality.

Conventional Cystometry

The test was carried out in compliance with International Continence Society (ICS) standards current at the time of testing (8). Bladder and rectal pressures were measured with a fluid-filled 4Fr urethral catheter and a 4Fr catheter with the tip covered with a vented fingercot, respectively. The pressure lines were connected to external transducers placed at the upper edge of the symphysis pubis and zeroed to atmospheric pressure. Filling through a 10Fr urethral catheter was carried out in supine position with 0.9% saline, at a rate of 100 mL/min. Voiding occurred in the sitting position with all catheters in situ.

Ambulatory Urodynamic Monitoring

The test was carried out according to International Continence Society (ICS) standards (1) using an in-house recording system (Urolog®, Regional Medical Physics Department, Freeman Hospital, Newcastle upon Tyne, UK). Bladder and rectal pressures were measured with microtransducers mounted on the tips of 6 Fr urethral and rectal catheters (Gaeltec Ltd, Isle of Skye, UK) the latter covered by a vented fingercot. These were calibrated to atmospheric pressure and to 30cmH_2O. Both were connected to a portable device that recorded data at a frequency of 1Hz. Filling was carried out physiologically by means of allowing patients to drink sufficient fluid to enable multiple fill-void cycles to be recorded over the course of three hours. Voiding occurred in private, in the sitting position, with maximum flow rate and voided volume measured using a standard gravimetric urine flowmeter.

Subsequently, digital data were transferred to a computer and analysed in detail. Setting used for flow measurement was the same for both study modalities.

Measurements recorded

All CONV measurements were done first and AMB measurements were done blinded to the CONV results. We recorded measurements of intravesical, abdominal (rectal) and subtracted vesical (detrusor) pressures at the end of filling ($p_{ves,}$ $p_{abd,}$ p_{det}), detrusor pressure at maximum flow rate ($p_{detQmax}$), maximum flow rate (Q_{max}), maximum detrusor pressure (p_{detmax}) and voided volume (V_{void}). When more than one fill–void cycle had been recorded during AMB, measurements from individual cycles were summed and the average taken. Free flows were not considered due to the relative high number of patients that needed to urinate before CONV or that voided low volumes. The following derived parameters were calculated: urethral resistance (UR = $p_{detQmax}$ / $Q_{max}{}^2$), bladder outlet obstruction index (BOOI = $p_{detQmax}$ – 2 Q_{max}) and bladder contractility index (BCI = $p_{detQmax}$ + 5 Q_{max}) (9). The presence of after-contractions, defined as a terminal rise in detrusor pressure not accompanied by an increase in flow rate, was also examined. No systematic maneuver to exclude artifacts from true after-contractions was done (10).

Statistical analysis

The paired Student's t test was used to compare the results of CONV and AMB continuous variables. Data were entered in the Stata 8.1 program (Stata Corporation, 2003) and statistical significance was assumed if p<0.05.

Bland-Altman statistics were used to assess the agreement of each variable between CONV and AMB. Briefly, the difference between the 2 tests was calculated in each patient. Thereafter, a graphical plot of the mean of these differences estimated systematic error (bias) from one test to the other. The standard deviation (SD) of the differences provided an estimate of random variation (11).

RESULTS

We identified 30 women being investigated for overactive bladder syndrome and urinary incontinence who met the inclusion criteria, whose urinary incontinence could not be categorized by CONV. They had a median (range) age of 50 (14-73) years and AMB was carried out at a mean (SD) of 11 (6) months after CONV. None had severe genital organ prolapse. The median number of voids analyzed from AMB was 2 (range 1-4) with 9 (10%) of a total of 86 voids being excluded from measurement due to bladder line displacement (n=5) or V_{void} < 150 mL (n=4). The main symptoms presented by the patients are given in Table-1.

When comparing the results of CONV and AMB, measurements of p_{ves} and p_{abd} at the end of filling, and Q_{max} were significantly higher from AMB recordings. There were no differences in p_{det} at the end of filling or in $p_{detQmax}$ and p_{detmax} during voiding. There was no statistically significant difference in V_{void}. Related to the difference in measurements of Q_{max}, all derived urodynamic parameters were significantly different between CONV and AMB. Both BOOI and UR derived from AMB measurements were lower, and BCI was higher (Table-2). Figure-1 shows simple plots of the

Table 1 - Main symptoms presented by 30 women eligible for urodynamic test review.

Symptoms	Number of cases (%)
Overactive bladder syndrome without incontinence	7 (23%)
Overactive bladder syndrome with incontinence	5 (17%)
Mixed urinary incontinence	12 (40%)
Overactive bladder syndrome without incontinence and stress urinary incontinence	2 (7%)
Stress urinary incontinence	3 (10%)
Insensible urinary incontinence	1 (3%)

results of AMB against CONV and Bland-Altman plot for $p_{detQmax}$, $p_{detmax,}$ Q_{max} and V_{void}. Figure 2 shows Bland-Altman plot for BOOI. There was only 1 patient with a clear after-contraction in CONV (of 32 cmH_2O versus p_{detmax} of 30 cmH_2O) and no clear after-contractions recorded on AMB.

DISCUSSION

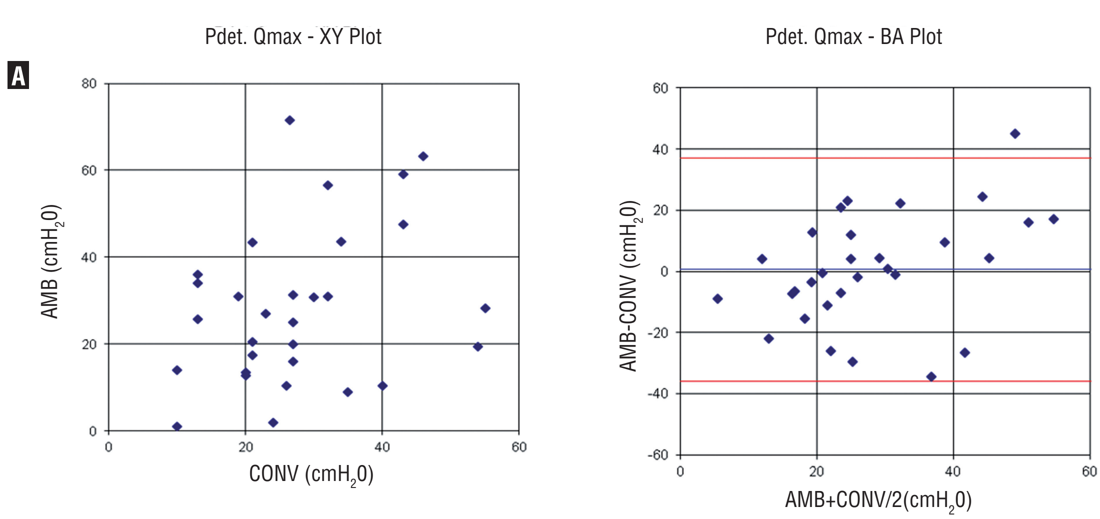
We sought to determine whether measured voiding variables from CONV and AMB differed amongst women being investigated for bladder storage symptoms. The study has the following

Table 2 - Summary statistics for intra-individual differences in urodynamic measurements during conventional cistometry (CONV) and ambulatory urodynamic monitoring (AMB).

Measurement Mean (SD)	CONV (n = 30)	AMB (n = 30)	P Value
End filling vesical pressure (cmH_2O)	24 (11.0)	42 (8.4)	< 0.001
End filling abdominal pressure (cmH_2O)	18 (9.2)	37 (7.7)	< 0.001
End filling subtracted vesical (detrusor) pressure (cmH_2O)	6 (5.2)	5 (8.3)	0.549
Detrusor pressure at maximum flow (cmH_2O)	28 (12.0)	28 (18.0)	0.851
Maximum flow rate (mL/s)	15 (8.2)	20 (8.6)	< 0.001
Maximum detrusor pressure (cmH_2O)	42 (21.2)	41 (19.8)	0.952
Voided volume (mL)	387.50 (145.52)	327.98 (123.33	0.061
BOOI	-2.2±20.6	- 12.5±23.9	0.009
UR	0.3±0.4	0.10±0.10	0.01
BCI	102.8±42.2	131±48.3	0.002

BOOI = Bladder Outlet Obstruction Index; **UR=** Urethral Resistance; **BCI =** Bladder Contractility Index

Figure 1 - Simple plot of the results of conventional cystometry (CONV) against ambulatory urodynamic monitoring (AMB) and plot of the difference between the methods against their mean (Bland-Altman method). A) Detrusor pressure at maximum flow rate, B) Maximum detrusor pressure, C) Maximum flow rate, D) Voided volume



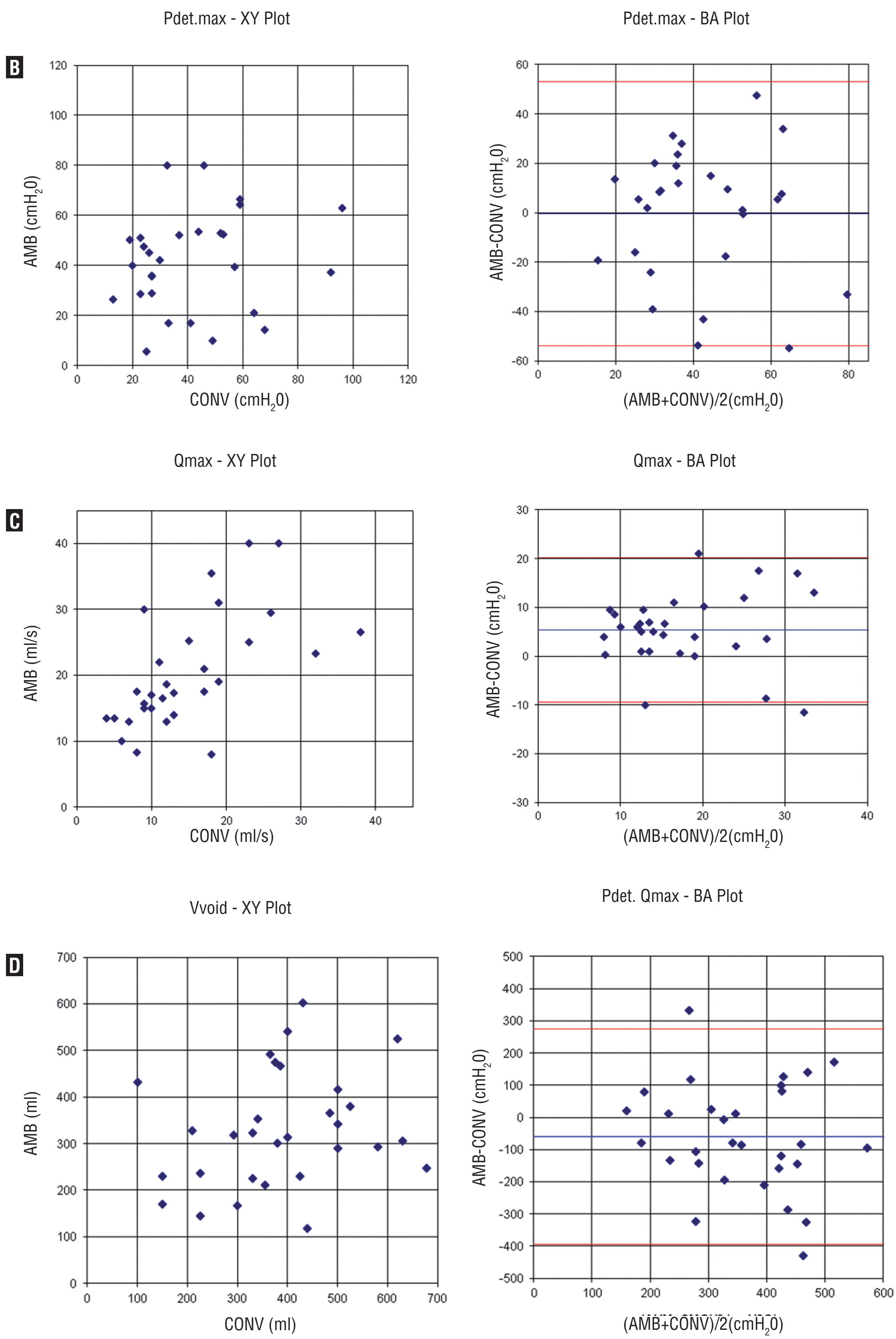
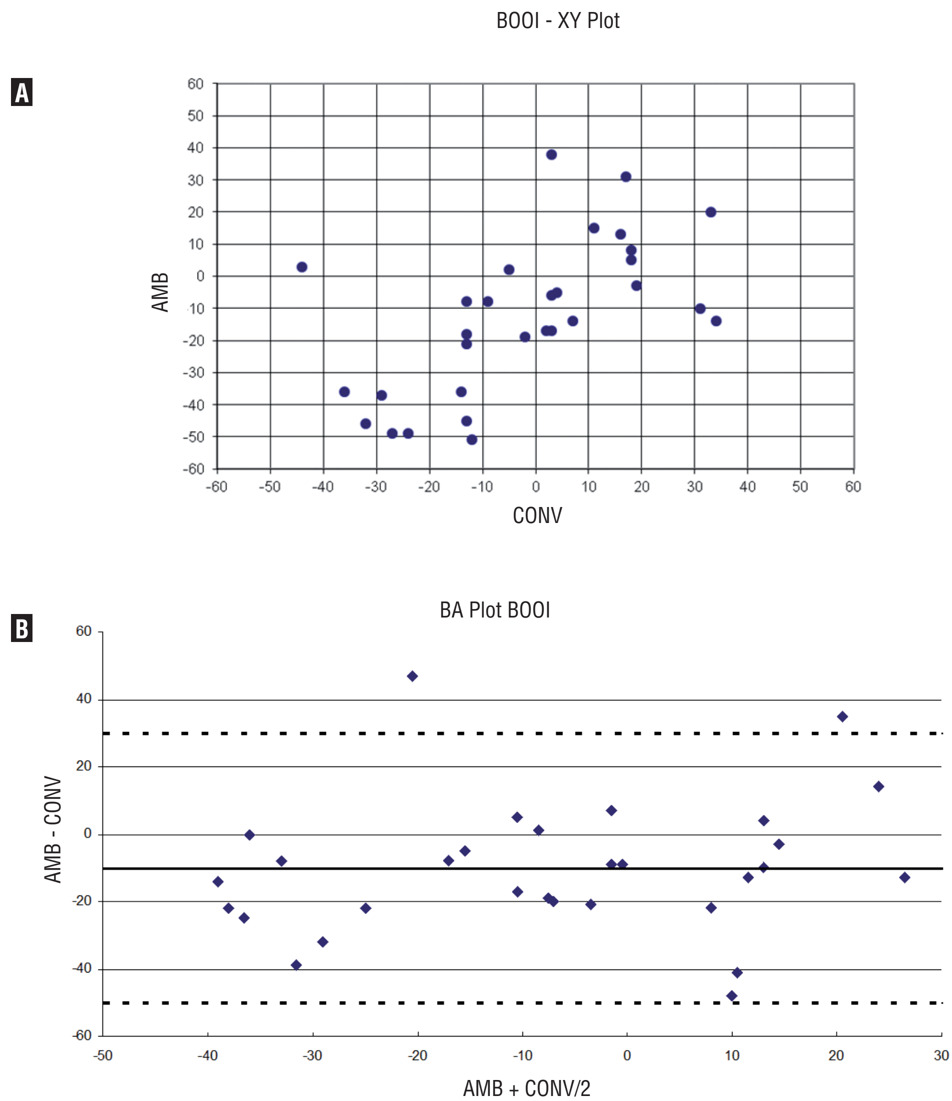

B
Pdet.max - XY Plot
AMB (cmH2O)
CONV (cmH2O)
Pdet.max - BA Plot
AMB-CONV (cmH2O)
(AMB+CONV)/2(cmH2O)
C
Qmax - XY Plot
AMB (ml/s)
CONV (ml/s)
Qmax - BA Plot
AMB-CONV (cmH2O)
(AMB+CONV)/2(cmH2O)
D
Vvoid - XY Plot
AMB (ml)
CONV (ml)
Pdet. Qmax - BA Plot
AMB-CONV (cmH2O)
(AMB+CONV)/2(cmH2O)

Figure 2 - Bladder outlet obstruction index (BOOI): simple plot of the results of conventional cystometry (CONV) against ambulatory urodynamic monitoring (AMB) and plot of the difference between the methods against their mean (Bland-Altman method).



strengths: 1) It studies a homogenous patient population from the commonest group undergoing AMB, 2) It uses a standard ICS approved technique with proper quality control using the same technique each time, 3) AMB was performed with synchronous flow recording, 4) AMB measurements were done blinded to the CONV results and 5) No irreversible treatment was given between studies. The limitations of the study are the following: 1) Retrospective study, 2) AMB was always carried out after CONV rather than in a randomized order, 3) Only women who had a non-diagnostic CONV were included, 4) The studies were separated by a variable time period with the possibility of changes in disease status and 5) Included women who did not generally have symptomatic voiding dysfunction.

The subjects in the study varied in age. This has the benefit of making the results generable across the variety of age groups that require urodynamic evaluation of voiding. Due to small numbers we were unable to describe variation in voiding measurements between age groups although this should not affect our results since we examined intra-individual comparisons.

It is likely that the higher p_{ves} and p_{abd} recorded at the end of filling during AMB reflect the predominantly upright position of subjects during the storage phase for AMB. The difference in transducer location, pressure measurement technique, and differential changes in the relative height of the tips of bladder and rectal catheters may have contributed to this difference. Supine filling during CONV results in a negative offset from the reference point of several cmH_2O owing to the distance between the bladder and rectal catheter tips. In AMB the microtip transducers are zeroed individually to atmospheric pressure and record true bladder and rectal pressures related to the position of the catheter tips (2).

Careful quality control during both CONV and AMB adhering to International Continence Society standards (1,8) should be effective in minimizing any systematic error caused by these differences in p_{ves} and p_{abd} in subtracted bladder (detrusor) pressure measurements. Reassuringly this was the case for our study with no bias in measurements of p_{detmax} and $p_{detQmax}$ between CONV and AMB.

Our protocol for AMB requires synchronized recording of urinary flow rate by direct wired connection of the uroflowmeter output to the ambulatory measurement box through an auxiliary channel. Pressure and flow recordings can then be displayed continuously for measurement. The higher values for Q_{max} seen with AMB (on average 33%) might be explained at least partially by the presence of both 4Fr and 10Fr urethral catheters during CONV. Some evidence in support of this contention comes from intra-individual comparison of Q_{max} with and without the presence of a urodynamic measurement catheter with studies in healthy (12) and symptomatic women (13-15) showing relative differences of between 28% and 64% using 6Fr, 7Fr and 9Fr catheters.

Another potential factor influencing flow rate is V_{void} (16,17). A CONV study comparing voiding measurements in women at bladder volumes close to modal V_{void} from frequency/volume charts with V_{void} at maximum cystometric capacity showed that Q_{max} was lower at the smaller volume, whilst $p_{detQmax}$ was the same for both volumes (18). Our study showed no statistical difference in V_{void} between CONV and AMB. Additionally comparison of the average V_{void} on CONV (390 mL) and that from AMB (330 mL) on the Liverpool nomogram would predict that Q_{max} would be 9% higher during CONV (17). From this background it seems unlikely that the trend to lower V_{void} during AMB was a factor in the observed higher values for Q_{max} resulted. Moreover, Groutz et al. found higher Q_{max} in symptomatic women (mainly patients with urinary incontinence) with voided volumes over 400 mL (13). It therefore appears unlikely that lower values of maximum flow rate in CONV might be explained by bladder overdistension as stated by other authors (7).

Bladder mechanical power is directly proportional to detrusor pressure and urinary flow. During micturition, bladder detrusor does not generate a specific pressure or flow, but rather provides mechanical power. Bladder outflow resistance determines how such power is divided into pressure and flow (19). Our results showing on average no differences for p_{detmax} and $p_{detQmax}$ between CONV and AMB and higher Q_{max} in AMB are consistent of stronger bladder contractions during AMB. However the presence of both 4Fr and 10Fr catheters during CONV may have been responsible for lower Q_{max}, by reducing urethral cross sectional area although if this was the case a compensatory increase in voiding pressure would be expected.

Considering the sample size and the standard deviations with CONV and AMB of the not significant results $p_{detQmax,}$ p_{detmax} and V_{void}, this study had an 80% statistical power to detect a difference between means of 11 cmH_2O for $p_{detQmax}$, 15 cmH_2O for p_{detmax} and 99 mL for V_{void}, with a significance level (alpha) of 0.05 (two-tailed).

Comparison between our measurements and those described in previous studies using different recording devices in different patient groups is shown in Table-3. Using an older generation device p_{detmax} measurements were found to be higher from AMB in three previous studies from our institution concerning men with bladder

Table 3 - Comparative urodynamic measurements from conventional cystometry (CONV) and ambulatory urodynamic monitoring (AMB).

Reference	Sex Number of subjects	Clinical group	Catheters used		P_{detmax} cmH$_2$O		$P_{detQmax}$ cmH$_2$O		Q_{max} mL/s		V_{void} mL	
			CONV	AMB	CONV	AMB	CONV	AMB	CONV	AMB	CONV	AMB
Webb[2] 1991	Male n = 20	Prior to elective prostatectomy	4Fr + 10Fr	6 Fr	78	107†*			4	9*	180	179
Robertson[4] 1996	Male n = 122	Prior to elective prostatectomy	2.1mm + 4Fr	2. 1 mm	90	103*	80	85	9.5	10.2	271	225*
Rosario[5] 1999	Male n = 69	Equivocal obstruction	8Fr	7 Fr	57.6	58.1	49.6	49.7	8.9	12.9*	364	304*
Heslington[3] 1996	Female n = 22	Uncomplaining	4Fr +10Fr	6 Fr	36	46*					420	212*
This study	Female n = 30	OAB symptoms and urinary incontinence	4Fr + 10Fr	6 Fr	42	41	28	28	15	20 *	388	328

OAB = Overactive bladder; **† =** Contraction pressure; *** =** Statistically significant difference

outlet obstruction (2,4) and uncomplaining women (3). Our results showing no difference in detrusor pressure measurements are consistent with a later study which also used an AMB device with integrated flow rate recording but in men with equivocal obstruction on CONV (5). Considering the very low rate of occurrence of after contractions in our study, we have no evidence to support the speculation voiced by Heslington et al. that the higher values of p_{det} during voiding measured by older devices were due to misinterpretation of the commonly observed after-contractions in the absence of synchronized flow recording (3). However it should be noted that Rosario et al. found significant more after-contractions on AMB than on CONV and pressure rises of the after-contractions on AMB were higher than p_{detmax} of the same patients (5).

Findings from theses regarding differences in Q_{max} were inconsistent, with two studies finding higher values from AMB (2,5), and one study no difference (4). It should be noted that the tested population for these studies was men with suspected outlet obstruction. The different patient group and consequent overall higher flow rates in our study makes comparison difficult although it is noted that the trend in all studies is toward higher Q_{max} measurements from AMB.

Differences in V_{void} again showed a consistent trend towards lower values in AMB reflecting the known difference between voided volumes found on a voiding diary and maximum cystometric capacity on CONV with non-physiological filling (3-5). The lack of a statistically significant difference in our study and that from Webb et al. (2) may represent a change in AMB technique with better encouragement of fluid intake.

CONCLUSIONS

Although this was a retrospective study with the associated methodological limitations the findings are of value since they provide previously undocumented comparative intra-individual voiding data between CONV and AMB for the patient group who most commonly require both investigations as part of their diagnostic assessment. We have confirmed that current AMB devices which allow real-time quality control and synchronous uroflowmetry provide reliable pressure measurement. Clinicians should however be aware that measurements from AMB recordings give higher values of Q_{max} but similar values for $p_{detQmax}$ which may partly reflect an overall lower catheter caliber, physiological filling but perhaps also the more 'normal' voiding conditions. A prospective study that controls urethral catheters calibre and voided volume is required to clarify the effect of bladder filling rates on voiding parameters among these patients.

ABBREVIATIONS

AMB = Ambulatory urodynamic monitoring
CONV = Conventional cystometry
p_{ves} = Intravesical pressure
p_{abd} = Abdominal pressure
p_{det} = Detrusor pressure
$p_{detQmax}$ = Detrusor pressure at maximum flow rate
Q_{max} = Maximum flow rate
p_{detmax} = Maximum detrusor pressure
V_{void} = Voided volume
UR = Urethral resistance
BOOI = Bladder outlet obstruction index
BCI = Bladder contractility index

CONFLICT OF INTEREST

None declared.

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Correspondence address:
Juan Pablo Valdevenito, MD
Rodrigo de Triana 4333, Depto 72
Las Condes. Santiago, 7550455, Chile
Fax: +56 22 207-0768
E-mail: jpvaldevenito@yahoo.com