ORIGINAL ARTICLE

Comparison of ambulatory versus video urodynamics in patients with spinal cord injury

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Objective: To compare the data obtained through video urodynamics (VUD) with those obtained through one voiding cycle ambulatory urodynamics monitoring (AUM) in patients with spinal cord injury (SCI).

Methods: A comparative study was conducted in 69 patients with SCI (mean age $\pm$ s.d. 44 ± 16.9 years), 51 men and 18 women, who were subjected to AUM and VUD.

Results: A lack of agreement was observed between the two tests with respect to the cystometric capacity (CC) (ml) (275 ± 197.2 AUM versus 416 ± 198.3 VUD), filling pressure (cm H₂O) (4 ± 5.3 AUM versus 9 ± 12.5 VUD), bladder compliance (ml cm⁻¹ H₂O) (116 ± 114.9 AUM versus 161 ± 179.4 VUD), maximum detrusor contraction pressure (cm H₂O) (87 ± 65.2 AUM versus 47 ± 35.0 VUD), post-void residual (ml) (206 ± 201.5 AUM versus 308 ± 237.7 VUD) and stress urinary incontinence (kappa index: -0.052). Only the CC obtained in the AUM was in agreement with the mean bladder volume gathered from the frequency–volume chart. Agreement was observed with respect to the presence of neurogenic detrusor overactivity (kappa index: 0.307) and bladder outlet obstruction index (cm H₂O) (17 ± 48.0 AUM versus 15 ± 18.7 VUD). There was no clear association between AUM parameters and bladder neck morphology, the presence of radiological detrusor–external sphincter dyssynergy or vesicoureteral reflux observed in the VUD.

Conclusion: The differences between both methods discourage the use of AUM with just one voiding cycle in the evaluation of patients with SCI.

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INTRODUCTION

Spinal cord injury (SCI) causes neurogenic lower urinary tract dysfunction (NLUTD)¹ in a large percentage of cases. NLUTD is a risk factor for renal deterioration mainly because it increases bladder pressure during the filling phase (that is, low bladder compliance (BC)) or increases urethral resistance during the voiding phase (that is, lower urinary tract obstruction).² In addition, NLUTD decreases the quality of life of patients with SCI because it creates urinary incontinence, either by neurogenic detrusor overactivity (NDO) or by stress urinary incontinence (SUI). Furthermore, large post-void residual is another consequence of NLUTD, and this represents a risk factor for lithiasis and urinary infections.

For all of these reasons, the management of patients with SCI requires a correct diagnosis and treatment of the associated NLUTD. According to European Association of Urology (EAU) guidelines, video urodynamics (VUD) is the gold standard test for the diagnosis of NLUTD.¹ In addition, VUD is necessary to evaluate the morphology of the bladder neck and membranous urethra and to identify vesicoureteral reflux.¹ However, VUD is not a perfect physiological test because the density of the radiological contrast media is higher than that of urine, the fluid temperature is lower, the bladder is filled at a faster-than-physiological speed, and the patient is in a foreign environment. A more physiologically normal test is when the bladder is filled with the patient's own urine, as in the case of ambulatory urodynamics monitoring (AUM).

However, the usefulness of AUM in patients with SCI is not clearly established. Previous studies conducted in patients with SCI have compared the data resulting from conventional urodynamic testing with those obtained through AUM testing. Unfortunately, these studies have mainly evaluated the agreement between the two tests with respect to the diagnosis of NDO,^{3,4} but not with respect to other parameters that are also included in the NLUTD, such as BC, SUI, urethral resistance and post-void residual. In addition, these studies have used small sample sizes and have not compared AUM with VUD, which is the gold standard.

The present prospective study was designed to compare the agreement between AUM and VUD with respect to the relevant urodynamic parameters for the management of NLUTD, in an adequate sample of patients with SCI, in order to establish the diagnostic utility of AUM in these patients.

MATERIALS AND METHODS

A comparative study was conducted in a consecutive series of patients with SCI who were referred for neurourology study at the Department of Urology (National Hospital for Paraplegics, Toledo, Spain). The inclusion criteria were the presence of an established SCI (that is, excluding patients in spinal shock) and age ≥ 18 years. The exclusion criteria were the presence of urinary tract infection, the inability to participate in an AUM test because of physical or intellectual impairment, or the inability to stay at our centre for the required time. Patients who met the criteria were invited to participate in the study, and,

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upon accepting, they signed an informed consent. The project was approved by the research committee of our centre.

The needed sample size of patients with SCI² was calculated by considering as clinically significant a mean difference of 50 ml in cystometric capacity (CC) and a standard deviation of 125 ml⁶ with an alpha error of 5% and a statistical power of 80%. A sample loss of 10% was considered acceptable, and the minimum number of patients required was 56. The total number of patients included in the study was 69.

A clinical history was developed for all patients, including age, level and degree of SCI, prescriptions for medications active on the lower urinary tract, and mechanism of bladder emptying. Patients were later subjected to AUM and VUD.

To determine the average bladder capacity (mean voided volume), patients with intermittent bladder catheterization or voluntary voiding were asked to record a frequency–volume chart (FVC) for three consecutive days.

The ambulatory test was conducted based on the specifications of the International Continence Society⁷ during one urination cycle by means of a Luna AUM model (MMS, Enschede, Netherlands). The patient was asked to drink 500 ml of liquids and return to the urodynamic unit when urine loss, urinary urgency or any other sensations of bladder filling were noted. The test was performed in the patient's own wheelchair during the filling phase. The voiding phase was conducted with the patient lying down, or, in the case of voluntary voiding, sitting down (women) or standing (men). In the case of reflex voiding, detrusor contraction was stimulated by tapping. The mean duration of the test was 86 ± 21.2 min (mean $\pm$ s.d.).

The VUD test was conducted with a Solar model (MMS), according to the specifications of the International Continence Society.⁸ The filling rate was 30 ml min⁻¹. The video images were taken during the filling and voiding phases with a Fluorostar image intensifier (General Electric Systems, Milwaukee, WI, USA). The time interval between tests was 10 ± 15.6 days. The VUD was performed in supine position.

The urodynamic tests were independently reviewed by different researchers as follows: AUM by MV and VUD by JS. The following urodynamic parameters were gathered in the filling phase according to the International Continence Society⁹ guidelines: CC, detrusor pressure at CC or filling pressure (Pfill), BC (CC/Pfill), the presence of involuntary detrusor contractions and the presence of SUI. On the one hand, SUI was defined in VUD as the passage of urine through the urethra coinciding with an increase of abdominal pressure. On the other hand, SUI was defined in AUM as urine exiting through the urinary meatus accompanied by an increase of abdominal pressure or by the presence of urine in the patient's diaper without evidence of involuntary detrusor contractions. The following parameters were gathered during the voiding phase: the maximum detrusor pressure (Pmax) during involuntary detrusor contractions in the case of AUM or during voiding in the case of the VUD, the bladder outlet obstruction index and post-void residual.

In addition, the morphology of the bladder neck during filling, configuration of the proximal urethra during voiding (that is, the presence of detrusor–external sphincter dyssynergia) and the presence of vesicoureteral reflux were registered during the video urodynamic test. Volumes were measured in millilitres (ml), pressures and bladder outlet obstruction index in cm H₂O, compliance in ml cm⁻¹ H₂O and flow in ml s⁻¹.

The data were stored in a Microsoft Access database and exported to the statistical software package SPSS version 12 for analysis (SPSS Inc. Chicago, IL, USA). The following statistical tests were used: intraclass correlation coefficient, Student's *t*-test for paired groups and Kappa test to determine the degree of agreement between tests, Student's *t*-test for independent groups, and Fisher's exact test to compare the VUD data with the AUM parameters. Additionally, a graphical representation based on the proposal by Bland and Altman¹⁰ was created to illustrate the difference between the mean values of the two tests. The two-sided significance level was set at 5%. The data are represented by their means $\pm$ s.d.

RESULTS

The 69 patients included in the study had a mean age of 44 ± 16.9 years, including 51 men (74%) and 18 women (26%). Table 1 shows the distribution of patients according to the degree and spinal injury level. The mean age at the time of injury was 26.3 ± 5.30 years.

Table 1 Level and degree of spinal injury

Level	Degree (ASIA)				Total
	A	B	C	D	
C4–C8	1	7	7	6	21
Th1–Th6	6	1	2	0	9
Th7–L2	16	5	5	4	30
L3–cauda equina	0	1	5	3	9
Total	23	14	19	13	69

Abbreviations: C, cervical; L, lumbar; Th, thoracic.

Table 2 Agreement between mean bladder volume measured through the frequency–volume chart and the FVC in the ambulatory urodynamic and video urodynamic testing

	FVC	AUM	VUD
Bladder capacity (ml)	296 ± 82.8	275 ± 197.2	416 ± 198.3
<i>P</i> differences		0.932	0.000 ^a
ICC		0.3172	0.0298
<i>P</i> ICC		0.0261 ^a	0.4294

Abbreviations: AUM, ambulatory urodynamic test; FVC, frequency–volume chart; VUD, video urodynamic test.

N = 47 patients (two patients with CVI did not perform FVC).

^aSignificant.

In 64 cases (93%), patients did not take any medications that were active on the lower urinary tract, 4 patients (6%) were taking anticholinergic medications and 1 patient (1%) was on an alpha-blocker.

The bladder-emptying method occurred through clean intermittent catheterization in 37 cases (54%), voluntary voiding in 12 cases (17%), indwelling catheter in 10 cases (15%), reflex voiding into a condom catheter or through tapping in 7 cases (10%), and through abdominal straining in 3 cases (4%).

Table 2 shows the agreement between mean bladder capacity, as measured with the FVC, and the CC values obtained through AUM and VUD tests. The CC was significantly greater in the VUD than in the AUM test. Table 3 shows the comparison of AUM and VUD data.

Through the VUD test, an opened bladder neck was observed during filling in 17 cases (25%), detrusor–external sphincter dyssynergia in 44 cases (64%) and vesicoureteral reflux in 4 cases (6%). No significant correlation was observed between these data and the data obtained from the AUM test, except between open bladder neck during filling and detrusor overactivity (Table 4).

DISCUSSION

Our study has suggested that AUM and VUD differ significantly in regard to certain urodynamic parameters relevant to the management of NLUTD.

The main limitation of this study is that only one voiding cycle was recorded in the AUM test. One of the advantages of AUM is that it allows the function of the lower urinary tract to be monitored over several hours. In this manner, AUM is sensitive to alterations that occur sporadically. However, the International Continence Society guidelines do not establish a pre-determined registration time; rather, they only recommend recording the expected duration of the data gathering.¹⁰

The FVC was considered to be the gold standard for the study of lower urinary tract symptoms.¹¹ A comparison between the mean

Table 3 Agreement between ambulatory urodynamic and video urodynamic testing

Parameter	AUM	VUD	P differences	ICC	P ICC or κ
CC (ml)	275 ± 197.2	416 ± 198.3	0.000 ^a	0.1743	0.0745
Pfill (cm H ₂ O)	4 ± 5.3	9 ± 12.5	0.006 ^a	−0.0785	0.7407
BC (ml cm ^{−1} H ₂ O)	116 ± 114.9	161 ± 179.4	0.073	0.0689	0.2855
IDC	34 (60%) ^b	49 (71%) ^b	$\kappa = 0.307$		0.008 ^a
SUI	3 (4%) ^b	4 (6%) ^b	$\kappa = −0.052$		0.660
Pmax (cm H ₂ O)	87 ± 65.2	47 ± 35.0	0.001 ^a	0.1106	0.240
BOOI (cm H ₂ O)	17 ± 48.0	15 ± 18.7	0.779	0.3428	0.0021 ^a
PVR (ml)	206 ± 201.5	308 ± 237.7	0.002 ^a	0.3316	0.071

Abbreviations: AUM, ambulatory urodynamic test; BC, bladder compliance; BOOI, bladder outlet obstruction index; CC, cystometric capacity; ICC, intraclass correlation coefficient; IDC, involuntary detrusor contractions; κ , kappa index; Pfill, detrusor pressure at cystometric capacity; Pmax, maximum detrusor pressure during contraction; PVR, post-void residual; SUI, stress urinary incontinence; VUD, video urodynamic test.

^aSignificant.

^bnumber of cases (percentage in parenthesis).

Table 4 Relationship between VUD data and data obtained from the AUM test

Video urodynamics data									
AUM data	Opened bladder neck during filling			Detrusor sphincter dyssynergia			Vesicoureteral reflux		
	Yes	No	P-value	Yes	No	P-value	Yes	No	P-value
CC (ml) ^a	345 ± 226.3	252 ± 183.4	0.094	242 ± 186.6	274 ± 214.0	0.625	175 ± 131.3	282 ± 199.6	0.298
Pfill (cm H ₂ O) ^a	4 ± 3.5	4 ± 5.7	0.938	4 ± 7.1	4 ± 3.5	0.780	2 ± 1.0	4 ± 5.4	0.401
BC (ml cm ^{−1} H ₂ O) ^a	142 ± 135.3	108 ± 107.5	0.288	98 ± 81.0	142 ± 186.3	0.426	98 ± 53.0	117 ± 14.6	0.744
IDC ^c	35%	67%	0.025 ^b	74%	54%	0.288	75%	58%	0.641
SUI ^c	5%	2%	1.000	0%	8%	0.295	0%	5%	1.000
Pmax (cm H ₂ O) ^a	12 ± 25.0	30 ± 42.4	0.103	36 ± 47.6	27 ± 28.6	0.542	14 ± 19.8	26 ± 40.4	0.554
BOOI (cm H ₂ O) ^a	21 ± 23.9	17 ± 46.6	0.875	25 ± 55.4	8 ± 21.5	0.443	12 ± 9.2	18 ± 45.2	0.869
PVR (ml) ^a	265 ± 245.1	188 ± 184.8	0.187	175 ± 191.4	201 ± 209.4	0.690	127 ± 66.5	211 ± 206.4	0.422

Abbreviations: AUM, ambulatory urodynamic test; BC, bladder compliance; BOOI, bladder outlet obstruction index; CC, cystometric capacity; IDC, involuntary detrusor contractions; Pfill, detrusor pressure at cystometric capacity; Pmax, maximum detrusor pressure during contraction; PVR, post-void residual; SUI, stress urinary incontinence.

^aMean ± s.d.

^bSignificant.

^cPercentage.

bladder volume obtained from the FVC and the CC obtained from either test was conducted. We observed that the FVC only had agreement with the AUM because the VUD data had significantly higher values (Table 2). Conventional urodynamic tests performed by Jorgensen *et al.*³ also confirmed that the CC in infants with NLUTD is significantly greater than the capacity measured through AUM. These data suggest that the CC values obtained in VUD are not a reliable measure of the clinical bladder capacity.

Our study also confirmed that Pfill was greater in the VUD test. However, this inequality was maintained upon calculating BC, which was also greater in the VUD test. The agreement of both parameters measured through the intraclass correlation coefficient statistical test was not significant (Table 3 and Figure 1). The Pfill and its derived parameter, BC, depend on the viscoelastic properties of the bladder wall and bladder-filling velocity. There is a direct exponential relationship between Pfill and infusion velocity.¹² Therefore, the Pfill should be greater in the VUD test. In addition, because the BC is inversely related to the magnitude of the Pfill, compliance should be lower in VUD. The higher Pfill observed in our study may also be explained by the greater CC measured through the VUD test. In a study of patients with NLUTD, Ko *et al.*¹³ compared both parameters by performing a conventional filling and another with furosemide-induced diuresis. These authors only found significant differences in

patients with NDO. However, these authors confused Pfill, which is a passive magnitude, with the pressure originated by detrusor contraction. In non-neurogenic patients, Webb *et al.*¹⁴ reported that the Pfill could be significantly lower with a physiological filling during AUM. However, it has been shown that the measurement of the Pfill through AUM is not a reproducible parameter. This could be due to the technical difficulties that result from the lack of a stable reference level during the test.¹⁵ The discrepancy with respect to BC between both tests could be attributed to the reduced reliability of one voiding cycle AUM test when measuring this parameter.

Our study did not show significant differences between VUD and AUM with respect to the diagnosis of NDO, although the kappa index of agreement was low (0.307). The percentage of NDO was greater in VUD (71%) than in AUM (60%) (Table 3). These data differ from those observed in other comparative studies, in which the percentage of NDO is clearly higher in ambulatory studies.^{3,4} A possible explanation for this discrepancy is that the duration of these ambulatory tests was much higher than in our study, and, accordingly, several voiding cycles were recorded. However, in a study conducted with women with urinary incontinence but lacking neurologic injury, and using only one voiding cycle, Dokmeci *et al.*¹⁶ also confirmed that the AUM is more sensitive than conventional urodynamics to detect detrusor overactivity. Patient selection was

Figure 1 Graphic representations of bladder compliance differences and mean values obtained through ambulatory urodynamic and video urodynamic testing (s.d.). The Bland-Altman plot showed that the mean of the differences was significantly lower than zero and that the differences between the values of the two methods increased as these values increased.

another criterion that was different between previous studies and ours. In previous studies, AUM was used as a second test choice in patients with clinical suspicion. This inclusion criterion implies a selection bias. The selection of cases with a high probability of having dysfunction artificially increases the sensitivity of the test by avoiding questionable and negative cases. Nevertheless, we cannot rule out that a single voiding cycle was the cause of this discrepancy.

The prevalence of SUI in our study was somewhat higher in the VUD test (6%), and the kappa index showed that there was no significant agreement between the tests (Table 3). Other studies in non-neurologic patients have suggested that AUM is capable of detecting SUI in patients with a clinical diagnosis of this alteration, but such result has not been confirmed through conventional urodynamics.¹⁷ However, by not conducting a comparative study between the two methods, we have faced the same problem discussed in the previous paragraph, selection bias. The discrepancy between the tests presents a question regarding which of the two tests is more reliable for diagnosing SUI. The advantage of AUM over conventional urodynamics is that the patient has more freedom to perform normal activities and that the monitoring of the lower urinary tract is conducted over a longer period of time. However, as in the case of detrusor overactivity, a single voiding cycle can also be used to diagnose SUI that go undetected through conventional urodynamics.¹⁶ VUD testing is an imaging technique, and this confers an advantage over conventional and AUM testing by providing direct observation of urine evacuation from the bladder and urethral filling. Moreover, it is for such reasons that some authors consider VUD testing to be the gold standard for the diagnosis of SUI.¹⁸

In our study, Pmax was significantly higher in AUM compared with VUD (Table 3). In cases of bladder outlet obstruction, detrusor pressure during voiding was increased in patients with NLUTD. The main cause for obstruction is an increase in urethral sphincter activity during voiding (that is, detrusor-external sphincter dyssynergia).⁹

Figure 2 Graphic representation of BOOI differences and mean values measured through ambulatory urodynamic and video urodynamic testing (s.d.).

Swithinbank *et al.*¹⁷ did not find significant differences between these tests in regard to the Pmax during involuntary detrusor contractions in patients with NLUTD. However, other authors¹³ have found that voiding detrusor pressures in patients without SCI are greater in AUM than in conventional urodynamics. In our study, the bladder outlet obstruction index, which measures urethral resistance, was similar in both procedures (Table 3 and Figure 2). Consequently, we conclude that the higher voiding pressure during AUM can be attributed to the fact that detrusor contractility is greater when physiological filling occurs than with artificial filling, as shown in other studies.¹⁹

The post-void residual was also higher in VUD testing than in AUM testing (Table 3). The explanation for these data could also be related to a greater contractility occurring during the AUM test.¹⁹

Finally, in our study, we did not observe any AUM parameter correlated with important VUD data, such as bladder neck morphology during filling, the presence of radiological dyssynergia or vesicoureteral reflux. We only observed a lower prevalence of NDO in patients with open bladder neck, which can be explained by the higher frequency of low SCI in these patients.

The influence of one voiding record is not clear in the observed differences between the two methods. For this reason, it would be of interest to conduct a study to clarify this question.

In conclusion, we cannot exclude that the cause of the discrepancy between the two methods is the recording of a single voiding cycle. Thus, the differences between both methods discourage the use of AUM with just one voiding cycle in the evaluation of patients with SCI.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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