women (mean age 34.8 years, range 19-48; mean parity 1.6, range 0-3). Urodynamic measurements were made using an 8F dual-tip microtransducer and custom-made amplifier system, having a frequency response of 0 to 1 kHz and a resolution of 0.25 cmH_2O, with a sampling rate of 128 Hz, a rate far higher than commercially available urodynamic systems. The raw measurement data was exported to an IBM PC for post urodynamic processing to determine the degree of technical artifacts for careful data screening of successful trials, and to estimate various urodynamic parameters. Cross spectral density, coherence, and transfer functions were estimated. All the numerical calculations were performed using MATLAB V4.3 signal processing toolbox programs.

RESULTS & CONCLUSIONS: The coherence spectra between the two pressure signals are well correlated below 14 Hz and 7 Hz for cough and Valsalva, respectively. This indicates that a higher sampling rate of greater than 28 Hz (at least twice the frequency band from the Nyquist principle) is needed for urodynamic measurements in stress continent women but most commercially available urodynamic systems do not have this capability. Therefore, a new technology applying a higher sampling frequency may be required for future urodynamic investigations of normal and pathologic outlet function.

Frequency distributions from the coherence plots during cough and Valsalva are shown in Table 1. Importantly, the spectral distributions of the two maneuvers are statistically different with the cough coherence spectra having higher magnitudes and wider frequency bands than the Valsalva spectra. The transfer function gain spectra in the frequency bands are essentially flat for cough, meaning the two pressure increases has a certain fixed ratio or strong linearity [1,3]. Though having a similar trend, the Valsalva gain spectra has more variations in their flat spectra so that a much weaker or nonlinear relationship between the two pressures may exist. In a concurrent study with 46 stress incontinent women, the cough leak point pressure is correlated with pressure transmission (correlation coefficient, ρ = 0.55) but not with MUCP (ρ = 0.07), while Valsalva leak point pressure is associated with MUCP (ρ = 0.63) but not with pressure transmission (ρ = -0.17). Therefore, the two dynamic tests may address different aspects of female continence, and the urodynamic results can not be extrapolated from each other.

The phase quantity of the transfer function within the frequency bands is essentially negligible for both cough and Valsalva, while some small variations are noted again for the flat Valsalva spectra. The phase quantity is a measure of time delay between the two signals. The estimated time delay is on the order of a few milliseconds. Skeletal muscles have 40~100 msec time delay between the mechanical stimulus and muscle force production. It has been reported that the striated urethral sphincters are composed of type I slow twitch fibers [2]. Therefore, during stress events active muscle activity may not contribute primarily to the urethral pressure increase. Other indirect evidence is that most anti-incontinence surgeries can cure SUI successfully without augmenting neuromuscular components.

In conclusion, this research strongly suggests that cough and Valsalva induce different dynamic responses in the pelvic floor and furthermore, that pressure transmission during stress appears primarily attributable to a passive structural propagation of the abdominal pressure increase [4].

Table 1. Frequency distributions of the urethrovesical pressure signals from coherence (γ^2) plots.

	Frequency where γ^2 = 0.5 [Hz]	Frequency where $\gamma^2 \approx$ 0.0 [Hz]
Cough	14.0 (3.9)†	21.7 (3.3)‡
Valsalva	6.8 (5.4)	11.8 (9.9)

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3

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THE ACCURACY OF A NON-INVASIVE BLADDER PRESSURE MEASUREMENT WITH AN EXTERNAL CATHETER

AIMS OF STUDY

In a previous study it was shown, that the bladder pressure non-invasively measured with an external catheter correlated well with the simultaneously invasively measured bladder pressure in non-obstructed patients. In obstructed patients these pressures correlated less well but both were significantly higher than the pressures measured in non-obstructed patients [1]. It was also shown that an accurate non-invasive diagnosis of infravesical obstruction seems possible in male patients on the basis of the non-invasively measured bladder pressure and a separately measured maximum flow rate [2]. However, especially in obstructed patients, a low flow rate prolongs the pressure measurement with the external catheter which might result in premature sphincter closure and thus an unreliable pressure reading. The aim of the present study was to calculate a minimal flow rate at which a non-invasively measured pressure still accurately reflects the invasive bladder pressure.

METHODS

Data, measured in a group of 52 patients during an invasive and non-invasive urodynamic test in an earlier study [3], was re-analysed. Based on the results of the invasive test, the patients were stratified in a group of non-obstructed and a group of equivocal and obstructed patients according to the provisional ICS method for definition of obstruction [4]. During the non-invasive test, the bladder pressure was measured using an incontinence condom (Laprolan®) guided over the invasive catheter and attached to the penis. A tube was connected to the outflow opening of the condom to guide the urine into a flow meter (Dantec®). A pneumatic valve was fitted over this tube, to interrupt the flow rate. A pressure transducer, installed at the level of the external catheter, recorded the pressure in the condom when the flow rate was interrupted. After filling the bladder through the invasive catheter, this catheter was connected to a pressure transducer to measure the internal bladder pressure, p_{int}, simultaneously with the external pressure, p_{ext}. The difference between both pressures was plotted as a function of the flow rate measured just before interruption, $Q_{interrupt}$.

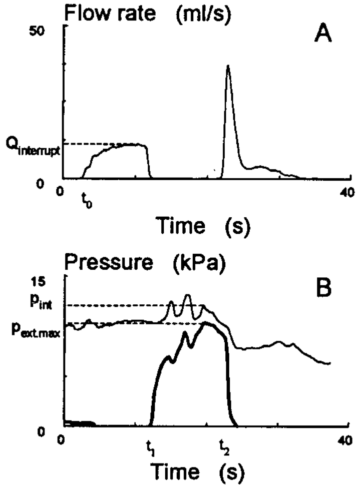

Fig. 1 The flow rate (panel A) and the invasive (thin line) and non-invasive (thick line) bladder pressure (panel B) simultaneously measured in a male patient using the external catheter.

RESULTS

Figure 1 shows a typical registration of the recorded signals. At time t_0, the patient started voiding through the external catheter, panel A. Between time t_1 and time t_2 the flow rate was interrupted at $Q_{interrupt}$ by closing the valve and p_{int} was simultaneously measured with p_{ext}, panel B. After measuring a maximum external pressure $p_{ext.max}$, the valve was re-opened and the patient continued voiding. Figure 2-A shows for the non-obstructed patients (open circles) as well as the equivocal and obstructed patients (closed circles) p_{int} - $p_{ext.max}$ as a function of $Q_{interrupt}$. The mean pressure difference in the group of non-obstructed patients was 1.3 ± 1.5 kPa, mean ± SD. The cumulative percentage of patients that fell within 1 standard deviation of this mean was plotted as a function of $Q_{interrupt}$ in figure 2-B. This figure shows the successive degradation in non-invasive bladder pressure measurement accuracy when the flow rate through the external catheter decreased.

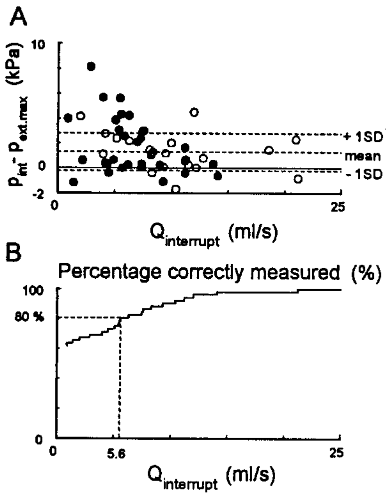

Fig. 2 The difference between the invasive and non-invasive bladder pressures measured in obstructed (closed circles) and non-obstructed (open circles) patients (panel A) and the successive degradation in non-invasive bladder pressure measurement accuracy with decreasing flow rate (panel B).

CONCLUSIONS

A diagnosis of infravesical obstruction may be based on a separately measured maximum flow rate combined with an isovolumetric bladder pressure. This pressure can be measured non-invasively during interruption of the flow rate using an external catheter. As this condition sometimes causes a premature sphincter closure, especially in obstructed patients, the isovolumetric pressure might sometimes be unreliable. In the present study we quantified this unreliability in terms of a flow

rate cut-off value. When the interrupted flow rate exceeded 5.6 ml/s, the non-invasive bladder pressure reflected the invasive bladder pressure in 80% of the non-obstructed, equivocal and obstructed patients in this population.

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4

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A NEW METHOD FOR NON-INVASIVE ASSESSMENT OF BLADDER PRESSURE DURING VOIDING COMPARED WITH SIMULTANEOUS INVASIVE URODYNAMICS

Aims of study

We have developed a new method for measuring bladder contraction pressure non-invasively during voiding. A penile cuff (1) is inflated incrementally, after voiding has commenced, until flow is interrupted. The cuff pressure is then released to allow flow to continue. This cycle can be repeated until voiding is complete. As with the condom catheter method (2, 3), reliance is placed on bladder contraction being maintained and the urethra remaining open during interruption so that, when fluid is stationary, pressure in the penile urethra equals bladder pressure (plus height difference). The method also relies on penile urethral pressure being equal to cuff pressure, which our preliminary work has confirmed for wider cuffs (approximately 1.5 times penile diameter). The method overcomes the problem of leakage associated with the use of a condom catheter, is less intrusive of the patient's privacy, and is quick and easy to apply. This study compares measurements made using the new technique with data obtained simultaneously from invasive urodynamics in healthy volunteers and patients. Particular aims were 1. to compare the interrupting cuff pressure with the simultaneously recorded isovolumetric bladder pressure, and 2. to observe the effect of the interruption on bladder pressure.

Methods

7 healthy volunteers (mean age 42, range 34 to 53) and 8 patients with voiding symptoms (mean age 60, range 50 to 75) underwent conventional, medium fill urodynamics using a 8F double lumen bladder catheter (MediPlus). A 5.4 (or 4.6) cm wide paediatric blood pressure cuff was fitted around the penis, the bladder was refilled and the subject was asked to void. Once voiding was underway, the cuff was inflated in steps of 10 cm H_2O, each step lasting for 0.75 s (and 0.5 and 1.0 s in repeat studies for the volunteers). When flow stopped the pressure was released so that flow could continue and the cycle was repeated until voiding ended. Precautions were taken to avoid straining. Flow rate (adjusted for delay) was plotted graphically against cuff pressure for each cycle of inflation and pressure at interruption of flow (*Pcuff.int*) was measured from this graph. The invasively measured bladder pressure at the time of interruption (ie: the isovolumetric contraction pressure, *Pves,isv*) was measured and compared with the interrupting cuff pressure (*Pcuff.int*). The difference between the isovolumetric pressure and the bladder pressure at maximum flow rate was measured (*Pves,isv - Pves,Qmax*). Abdominal pressure (*Pabd*) during voiding was also measured.

Results

The graph of (delay adjusted) flow rate against cuff pressure typically shows first a plateau region and then a steady decrease as the interrupting pressure is approached (Figure 1). This allows *Pcuff.int* to be measured more accurately by extrapolation (where the line drawn crosses the pressure axis). For each inflation cycle performed, the pair of values *Pcuff.int* and *Pves,isv* was plotted as a point on an X-Y scatter plot (Figure 2; healthy volunteers ◆, patients ▲). The line of identity is shown. For all the data, the Pearson correlation coefficient is 0.92 and the difference *Pcuff.int - Pves,isv* is 12.3 ± 9.8 cm H_2O (mean ± standard deviation).