Progrès en urologie (2016) 26, 425—431

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ORIGINAL ARTICLE

Detrusor contractility in women: Influence of ageing and clinical conditions

Contractilité du détrusor chez la femme : influence de l'âge et des conditions cliniques

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Received 5 January 2016; accepted 22 March 2016
Available online 21 April 2016

KEYWORDS
Detrusor contractility;
Urodynamics;
VBN modelling;
Women

Summary
Aims. — We assume that the voiding process in women is governed by the detrusor contractility and a ''urethral resistance''. The value of these 2 parameters, respectively named *k* and *U* in the VBN (Valentini-Besson-Nelson) mathematical model of micturition is deduced from the VBN analysis of pressure-flow recordings (PFs). Our objectives were to search for a correlation between these 2 parameters and clinically relevant variables such as chief complaint, urodynamic diagnosis (UD), and age by decades.
Methods. — PFs from 125 non-neurogenic women (mean age 58.0 ± 17.2 years [range 20—90 years]) were retrospectively analyzed using the VBN model. VBN criteria for inclusion were maximum flow rate > 2 mL/s, voided volume > 100 mL, and non-interrupted flow. Evaluated parameters were *k* (without unit) and *U* (unit: cm H_2O). Standard values were $k = 1.0$ and $U = 0$.
Results. — VBN parameter ranges were *k* [0.14—1.55] and *U* [0.0—73.0 cm H_2O]. There was a significant correlation between *k* and *U* for the whole population ($P < 0.0001$) with $k = (.259 + 0.015{*}U)$ ($R^2 = 0.723$) and each chief complaint. For UD, significant difference comparing *k* and *U* in phasic detrusor overactivity with intrinsic sphincter deficiency and urodynamic stress incontinence was noted. In sub-groups defined according to decades of age, the values of *k* and *U* remained similar in sub-groups for those who are less than 50 years old and decreased regularly with ageing.

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http://dx.doi.org/10.1016/j.purol.2016.03.004

Conclusion. — The detrusor contractility can be easily evaluated in women; lower than in men, its range is less spread out but also adjusted to compensate a ''urethral resistance''. Phasic detrusor overactivity and post-menopausal age significantly affect detrusor force value.
Level of evidence.— 3.

MOTS CLÉS
Contractilité du détrusor ;
Urodynamique ;
Modèle VBN ;
Femme

Résumé
Introduction. — Nous admettons que la miction chez la femme est gouvernée par 2 paramètres mécaniques, la contractilité du détrusor et une « résistance urétrale », dénommés *k* et *U*. L'analyse modélisée des instantanés mictionnels (IM) permet leur évaluation. Nos objectifs étaient de chercher une corrélation entre ces 2 paramètres et certaines variables cliniques telles que plainte principale, diagnostic urodynamique (DU), et âge.
Méthodes. — Rétrospectivement, les IM de 125 patientes non neurologiques ont été analysés avec le modèle VBN (Valentini-Besson-Nelson). Cette analyse requérait les conditions suivantes : débit maximum > 2 mL/s, volume uriné > 100 mL et débit ininterrompu. Les valeurs standard des paramètres sont k (sans unité) = 1,0 et $U = 0{,}0$ cm H_2O.
Résultats. — Les valeurs extrêmes des paramètres VBN étaient respectivement pour *k* et *U* [0,14—1,55] et [0,0—73,0 cm H_2O]. Il existait une corrélation significative entre *k* et *U* pour la population totale ($p < 0{,}0001$) avec $k = (0{,}259 + 0{,}015{*}U)$ ($R^2 = 0{,}723$) de même que pour chaque plainte principale. Concernant le DU, il a été trouvé une différence significative pour *k* et *U* entre hyperactivité phasique du détrusor et incompétence sphinctérienne ou incontinence d'effort urodynamique. La stratification de la population en tranches d'âge de 10 ans a permis de montrer que les valeurs de *k* et *U* restaient semblables jusqu'à 50 ans puis décroissaient régulièrement avec le vieillissement.
Conclusion. — La contractilité du détrusor peut être évaluée chez la femme par analyse des IM ; plus faible que chez l'homme, ses bornes sont plus resserrées mais elle s'ajuste à la «résistance urétrale». L'hyperactivité phasique du détrusor et la post-ménopause affectent significativement la contractilité du détrusor.
Niveau de preuve.— 3.

Introduction

Evaluation of detrusor contractility in women is a challenge because voiding pressures are usually low and there is no universally accepted tool to assess its value. Almost all developed methods to estimate the detrusor contractility from standard pressure-flow measurements are based on the bladder output relation [1] and established for male populations.

In women, some studies have been conducted to assess detrusor contractility during a stop test: voluntary stop test [1,2], mechanical stop [3] or continuous occlusion test [4]. The only physiological method is the voluntary stop test but it greatly underestimates the contractility whereas the other methods are less ideal as they can induce discomfort [5].

If some studies concluded that detrusor contractility decreased with age [6] or that female bladders were less strong than male bladders [7], few studies have attempted to quantify the influence of ageing [6].

We started from the hypothesis that female voidings were governed by similar mechanical parameters to male voidings: the detrusor contractility and a ''urethral resistance''. Using the VBN mathematical model of micturition [8,9] our objectives were to analyze pressure-flow (P-Fs) data to evaluate the VBN parameter *k* (simulating detrusor force) in women and to search for a correlation with a ''urethral resistance'' simulated VBN parameter *U*. Next, we sought out a possible correlation between *k* and *U* and three relevant clinical variables: chief complaint, urodynamic diagnosis (UD) and age.

Materials and methods

This study was conducted in accordance with the Declaration of Helsinki. According to the local practice of our ethics committee, there is no formal institutional review board approval required for retrospective studies.

Retrospectively, urodynamic data obtained from a database which consisted of 125 women without symptom suggestive of obstruction (i.e. no hesitancy, straining to void, double voiding, slow stream...), no history of prior anti-incontinence surgery, and referred for evaluation of lower urinary tract dysfunction (LUTD) were analyzed.

Criteria for exclusion were neurological disease, diabetes mellitus, and stage > 2 prolapse.

All patients were evaluated using medical history, review of medications, bladder diary for at least 48 h including voiding times and voided volumes both day and night, physical examination, and dipstick urinalysis. Urodynamic sessions were performed using the Dorado® unit from Laborie (Mississauga, ON, Canada). Cystometry was performed with the patient in the seated position with a 7-F triple-lumen urethral catheter perfused with saline at room temperature using a filling rate of 50 mL/min. Pressure transducers were zeroed to atmospheric pressure at the upper edge of the symphysis pubis. Rectal pressure was recorded using a punctured intrarectal balloon catheter filled with 2 mL of saline according to the report of Good Urodynamic Practice guidelines [10].

Definitions given in the standardization of terminology of lower urinary tract function (ICS [11], its French adaptation [12] and ICS/IUGA joint report for female pelvic floor dysfunction [13]) were used to classify main complaint and urodynamic diagnosis.

VBN criteria for inclusion were P-Fs tracings providing maximum flow rate Q_{max} and detrusor pressure at Q_{max} ($p_{det \cdot Qmax}$) without significant contribution of abdominal pressure (< ± 3 cm H_2O between onset of flow and Q_{max}), a Q_{max} > 2 mL/s, an initial bladder volume (V_{ini}) > 100 mL, and a non-interrupted flow.

Parameters *k* (without unit, standard value *k* = 1.0) and *U* (unit: cm H_2O, standard value *U* = 0) were evaluated from the analysis of PFs tracings using the VBN mathematical model of micturition [8,9].

A short description of the VBN model is given in Appendix 1.

Statistical analysis

Data are presented as mean ± SD and range. Analysis of variance (ANOVA), *t* test, and the Chi² test were used as appropriate. All statistical results were considered significant at $P < 0.05$.

For correlations, results were considered acceptable when $R^2 \geq 0.3$. Statistical analyses were performed using SAS, version 5.0 (SAS Institute, Inc., Cary, NC).

Results

The population comprised 125 women (mean age 58.8 ± 17.0 years). The VBN parameters *k* and *U* were identified from all PF recordings. Their mean value and range were respectively 0.49 ± 0.25 and [0.14 − 1.55] for *k* and 16.1 ± 14.4 cm H_2O and [0.0 − 73.0 cm H_2O] for *U*.

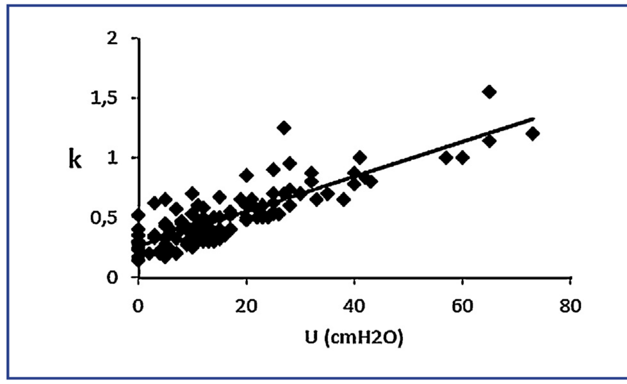

Figure 1. Relationship between detrusor contractility (*k*) and urethral obstruction (*U*) in the whole population. $k = 0.259 + 0.015*U$ ($R^2 = 0.723$).

There was a significant correlation ($P < 0.0001$) between *k* and *U* (Fig. 1): $k = 0.259 + 0.015*U$ ($R^2 = 723$).

Effect of the chief complaint

Main complaint was incontinence (urgency, stress or mixed), urinary frequency, or various lower urinary tract symptoms such as pain, recurrent urinary tract infection, or dysuria (Table 1).

The value of *k* and of *U* was independent of the chief complaint (except between urgency and mixed incontinence where *U* was significantly lower, $P = 0.0340$).

There was a good correlation between *k* and *U* regardless of the complaint.

Effect of the urodynamic diagnosis

Tracings were reviewed independently by 2 urodynamics experienced investigators (Table 2). One hundred and twenty women were categorized as normal (N = 18), phasic or terminal detrusor overactivity (37 PDO and 23 TDO), urodynamic stress incontinence (15 USI), intrinsic sphincteric deficiency (17 ISD) or hypertonic urethra (10 women with urethral pressure at rest > [110—age] + 20%) [14]. For the last 5 women, the diagnosis of functional obstruction was proposed for three and interstitial cystitis was considered for two.

Women with terminal DO or ISD were found to be significantly older than women with phasic DO (respectively $P = 0.0197$ and $P = 0.0029$).

Table 1 Effect of the main complaint on detrusor contractility (*k*) and urethral obstruction (*U*).

Main complaint	Urgency incontinence ($n = 37$)	Mixed incontinence ($n = 32$)	Stress urinary incontinence ($n = 12$)	Frequency ($n = 15$)	Other ($n = 29$)
k	0.55 ± 0.28	0.44 ± 0.21	0.47 ± 0.24	0.49 ± 0.19	0.49 ± 0.28
U (cm H_2O)	19.5 ± 16.1	12.0 ± 12.5	14.6 ± 16.4	15.1 ± 11.8	17.1 ± 14.7
Age (years)	55.3 ± 17.0	64.7 ± 16.7	55.5 ± 16.4	54.6 ± 21.0	56.8 ± 15.7
R^2 for *k* (*U*)	0.643	0.731	0.667	0.725	0.881

Table 2 Influence of UDS diagnosis on *k* and U values. N: normal UDS testing; ISD: intrinsic sphincter deficiency; USI: urodynamic stress incontinence; PDO: phasic detrusor overactivity; TDO: terminal detrusor overactivity; Hyp-ura: hypertonic urethra; Func Obs: functional obstruction; IC: interstitial cystitis.

UDS diagnosis [age range]	N ($n = 18$) [26—90]	ISD ($n = 17$) [34—88]	USI ($n = 15$) [29—79]	PDO ($n = 37$) [20—86]	TDO ($n = 23$) [24—85]	Hyp-ura ($n = 10$) [20—75]	Func Obs ($n = 3$) [28—75]	IC ($n = 2$) [56—72]
k	0.47 ± 0.24	0.38 ± 0.14	0.39 ± 0.14	0.62 ± 0.24	0.49 ± 0.32	0.48 ± 0.20	0.50 ± 0.23	0.23 ± 0.01
P (vs. PDO)	0.0249	0.0007	0.0017		0.0396	Non significant	—	—
P (vs. TDO)	Non significant	Non significant	Non significant	0.0396		Non significant	—	—
U (cm H_2O)	17.3 ± 15.2	8.5 ± 6.6	8.8 ± 6.6	22.2 ± 14.9	17.3 ± 17.9	15.0 ± 13.2	15.2 ± 12.3	2.5 ± 3.5
P (vs. PDO)	Non significant	0.0010	0.0021		Non significant	Non significant	—	—
P (vs. TDO)	Non significant	0.0364	Non significant	Non significant		Non significant	—	—
Age (years)	58.8 ± 16.4	67.5 ± 14.5	58.6 ± 14.6	53.0 ± 18.2	63.5 ± 15.6	43.7 ± 16.9	52.7 ± 23.6	47.4 ± 17.6
R^2 for k (U)	0.867	0.482	0.623	0.597	0.810	0.835	—	—

Table 3 Relationships between *k* and U, and increasing (by decades) age sub-groups.

Age (number)	< 30 years (n = 10)	30–39 years (n = 12)	40–49 years (n = 18)	50–59 years (n = 28)	60–69 years (n = 21)	70–79 years (n = 24)	> 80 years (n = 12)
k	0.60 ± 0.28	0.63 ± 0.18	0.63 ± 0.32	0.54 ± 0.25	0.43 ± 0.13	0.37 ± 0.14	0.30 ± 0.13
U (cm H_2O)	22.6 ± 13.5	22.2 ± 16.0	22.6 ± 19.1	16.1 ± 13.3	13.9 ± 7.5	10.2 ± 8.8	8.4 ± 7.0
R^2 for k (U)	0.835	0.567	0.781	0.617	0.439	0.678	0.757

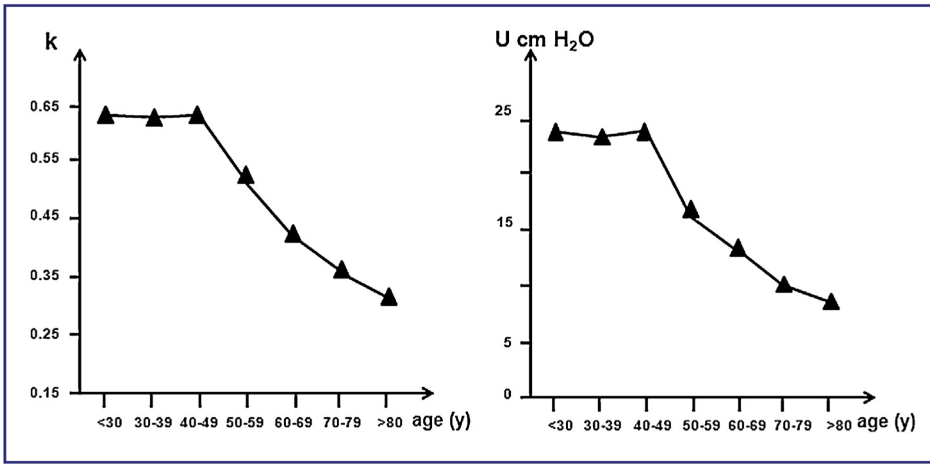

Figure 2. Values of detrusor contractility (k) and urethral obstruction (U) in age groups.

k and *U* values were slightly dependent on the UDS diagnosis. The first result was that the *k* value observed for women with diagnosis of phasic DO (PDO) differed significantly from that observed for women with diagnosis of terminal DO (TDO). The second result was that the *k* value for women with PDO was also significantly different from that of women with urodynamic diagnosis of ISD, urodynamic stress incontinence (USI), or those with normal urodynamics.

The third result was that the *U* value was significantly different between PDO and ISD (P = 0.0001), PDO and USI (P = 0.0021) and between TDO and ISD (P = 0.0483).

Correlation between *k* and *U* was good or acceptable for all diagnoses.

Effect of ageing

Sub-groups were defined according to age; relationship between *k* and *U*, and increasing age sub-groups are given in (Table 3).

The values of *k* and *U* remained similar in sub-groups for those who are less than 50 years old (mean menopause age is 50.1 years in France) and decreased regularly with ageing (Fig. 2). Evolution with ageing was significant: P < 0.0001 for *k* and P = 0.0030 for *U*.

Correlation between *k* and *U* was good or acceptable for all sub-groups.

Discussion

From this study, it appears that as for men, the detrusor contractility is adjusted to the ''urethral resistance'' and this, regardless of complaint or age.

The detrusor contractility begins to decrease at menopause and deteriorates sharply with further ageing.

Methods of estimating detrusor force from PFs have been developed, mainly in men. However, contrary to these studies, evaluation and classification of detrusor force (contractility) remains difficult in women. The methods developed for men: Schäfer's contractility nomogram (and related parameter DECO) [15,16] and the projected isovolumetric pressure (PIP/BCI) [15,17] greatly overestimate the detrusor contraction strength in women [5,18]. A reliable parameter PIP1 (= $p_{det \cdot Qmax}$ + Q_{max}) has been proposed for older women with urgency incontinence [5] but to our knowledge, there is no nomogram or parameter allowing to evaluate detrusor contractility in women over their life span.

In addition, as this parameter is difficult to evaluate, there are few studies on the relationship between detrusor contractility and the primary complaint despite the fact that such a complaint is the motive for requesting a urodynamic study in the first place.

The VBN model analysis of PFs allows the evaluation of detrusor contractility in women.

First there is a strong correlation between detrusor contractility and ''urethral resistance''. This implies that there is an adjustment of the detrusor force to the urethral resistance; that phenomenon is reminiscent of what is observed in men during the early stages of bladder outlet obstruction secondary to benign prostatic enlargement. The points associated with the value of *U* equal to zero are those obtained from voidings with low detrusor pressure and high flow rate. The mechanism of these ''low pressure-high flow'' voidings will be the subject of another study.

Second, *k* and *U* values are slightly related to the main complaint, except for the value of *U* when comparing urgency with mixed incontinence. This result could be the consequence of the fact that women with mixed incontinence are older ($P = 0.0249$) and therefore likely to have a less competent sphincter [19]. While not the purpose of this study, that assumption was verified by comparing the maximum urethral closure pressure MUCP in women with mixed incontinence: 45.2 ± 24.5 cm H_2O compared to those with pure urgency incontinence 83.6 ± 89.9 cm H_2O ($P = 0.0047$).

Third, that study confirmed that, in women with DO, terminal DO is a characteristic of an older population which could be due to structural changes in detrusor muscle with ageing [20]. Another hypothesis is that the decrease in MUCP induces an impossibility to inhibit the voiding reflex triggered by the increase in detrusor pressure [21].

Fourth, k and U values are slightly dependent on the urodynamic diagnosis. The preponderant role of phasic detrusor overactivity to affect the k and U values was highlighted. This behavior is consistent with the hypothesis that the consequence of an uninhibited detrusor contraction triggers a reflex contraction to tighten the urethral sphincteric mechanism to prevent the occurrence of leakage. Over time, this pattern could lead to a reinforcement of the urethral striated sphincter.

A very interesting result was the influence of age on k and U. Their value remained constant until the age of 50. Then the values decreased regularly with ageing [22]. This observation suggests a concomitant progressive deterioration of the detrusor contractility, [23,24] and loss of striated sphincter function [20,25]. Histological and structural changes could be the cause of detrusor dysfunction while sarcopenia and decline in estrogen levels could explain the associated decrease in ''urethral resistance''. Our findings are consistent with the results of the study published by Pfisterer et al. [6]. They reported that detrusor contractility, estimated by the projected isovolumetric detrusor pressure (PIP1), decreased steadily and significantly with age. Our curve showed some difference in shape from the published curve [6]. This is due to their age-stratification; their sub-groups covered ranges from 20 to 40, 40 to 60, and 60 and above, a process that did not individualize the ''natural'' menopause age, which is at 50.1 years in France and 51.3 years in the Western World [26].

The limitations of this study include the fact that this is a retrospective study and the constraints linked to the use of the VBN model: all analyzed PFs must have non-interrupted flow and a voided volume higher than 100 mL, and $Q_{max} > 2$ mL/s.

This study is the first attempt to evaluate the detrusor contractility over the lifespan in women.

Conclusion

The VBN analysis can evaluate the detrusor force in women who void without major straining efforts and a non-interrupted flow. In this study, the detrusor force was lower than in men [8] and the range less spread out. As in men, there is an adjustment of the detrusor force to compensate for a ''urethral resistance''. Detrusor force is greatly influenced by ageing after menopause and by phasic detrusor overactivity.

Funding

None.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix 1. Short description of the VBN model

The Valentini—Besson—Nelson (VBN) mathematical model [8,9] is a quantitative description of the mechanistic phenomena governing micturition which are bladder contractility, elasticity, and viscoelasticity, urethral elasticity and sphincteric compression, turbulent incompressible fluid hydrodynamics, and possible abdominal straining. Each phenomenon considered separately is accurately described in previous reports and can easily be studied. However, when combined, as during voiding, they constitute such an intricate set that to analyze individual recorded voiding and choose between the possible causes of dysfunction (e.g., compressive or constrictive urethral obstruction), elaborate software is needed, e.g., VBN® software. Entries are gender, filling volume and catheter size, outputs are computed voiding curves: flow rate and detrusor pressure vs. time.

The status of the urethral sphincter is described by an ''equivalent compression'' (VBN parameter U). U is a pressure; its unit is cm H_2O. If its value is evaluated from any pressure-flow study, several physiological interpretations can be proposed (a real compression or a change in the effective cross-section).

Detrusor contractility is characterized by the VBN parameter k without unit (simulating detrusor force).

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