Urological Research 3, 51-54 (1975)

REVIEW

Urodynamics

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Received: March 1, 1975

Urodynamics composes the morphological, physiological, biomechanical and hydrodynamic aspects of urine transport (1).

I. Ureterodynamics

The ureteral musculature is a cell syncytium, the single muscle cells are connected with each other by nexus (37, 44). Nexus, are intercellular cell appositions with fusion of the outer lamellae of the basal membranes of the neighbouring muscle cells (9). These are necessary for the conduction of excitation. Some muscle cells in the ureteric wall are innervated directly (44). Here no neuromuscular synapses exist in the sense of real motor end plates with membrane differentiation. Nerve fibres and muscle cells are connected by gutter-shaped coaptations (44). They have the function of a synaptic junction.

Ureteral peristalsis is regulated by myogenic automatism with a pacemaker center in the area of the renal calyces (4, 22, 31, 35, 50, 51). Gosling and Dixon (18, 19) found specific pacemaker cells in the fibrous tissue septa between renal pelvis and renal parenchyma. The autonomous system influences the ureteral peristalsis only secondarily by modulation (35): The sympathetic system regulates, by means of the alphareceptors, the length of period and the impulse intensity of the pacemaker; adrenaline and noradrenaline are positively chronotropic and positively autochthonotropic (23). Autochthonotropic effect means that an oscillation has more chance of producing a conducted excitation with each wave. On the basis of the theory of "multiple coupled oscillators" for the pacemaker process, the oscillation of the whole pacemaker area can be amplified by intensifying the oscillation in each subunit; but it can also be amplified by improving the coupling between the subunits, thereby producing increased synchronisation and summation of all elementary oscillations (23).

Beta-adrenergics influence the ureteral activity in a negative bathmotropic direction. The parasympathetic system has no functional effects on ureteral dynamics (4, 31, 35, 40).

The stimulus induction and conduction, tonus and contractility of the smooth muscle cells, diuresis and flow cannot be measured directly in situ. By urorheomanometry, however, intraureteral pressure and flow velocity are measured simultaneously (35). Intraureteral pressure and flow velocity depend on muscle tonus, diuresis and flow resistance. Therefore the "pressure-velocity-product",

$$P = \frac{\int_0^T v(t)\,dt \int_0^T p(t)\,dt}{T^2}$$

can be considered as a semi-quantitative measure of the transport capacity of ureteral peristalsis. The "pressure-velocity-product" has the dimension of a capacity per square unit:

$$P = \frac{K\,p\,m}{s\,m^2}$$

In the "urodynamic quotient" the flow velocity is quantitatively proportional to the ureteral mean pressure:

$$Q = \frac{\int_0 v(t)\,dt}{\int_0^T p(t)\,dt}$$

Together with the standard parameters of ureteral dynamics, the "pressure-velocity-product" and the "urodynamic quotient" provide evidence of the functional state and capacity reserves of the ureteral musculature (35).

II. Reflux

Urodynamic conditions in bladder and prevesical ureter as well as the anatomical structure of the vesicoureteral junction are the decisive determinants for vesicorenal reflux. Histological investigations and microdissections have shown that the submucous ureter has a three layer muscle wall (15, 30). These three layers are connected by thin muscle bundles. Especially the transureteral and transverse muscle bundles can be important for the effectiveness of the antireflux mechanism. Therefore, the theory that the valve mechanism of the vesicoureteral junction is a simple clack valve in principle, has to be re-examined.

The pathophysiology of vesicoureteral reflux is characterized by four factors (36): transmission of the intravesical pressure to the upper tract and renal parenchyma; disturbance of the propagation of the peristaltic wave by induction of antiperistalsis; permanent maximum urine transport by ureteral peristalsis due to urinary regurgitation; predisposition to urinary tract infection and pyelonephritis by producing a residual volume of urine. When an insufficient vesicoureteral junction is present bladder urine regurgitates as soon as the intravesical pressure is higher than the intraureteral pressure. Whereas the pressure compensation between bladder and prevesical ureter takes place relatively quickly, the pressure increase in the renal pelvis is delayed. This is due to the fact that the functioning ureter has a valve like action and can in part take over the function of the vesicoureteral junction.

III. Bladder Dynamics

The normal function of the urinary bladder, bladder neck and urethra is to ensure continence and normal micturition. Urinary continence during rest- or storage-phase is assured by the passive closure of the bladder neck, according to the base plate theory of Hutch (25) and the passive closure of the urethra (47, 48). This closing is intensified by controlled contraction of the striated sphincter externus in the pelvic floor.

The opening of the "sphincter system" during micturition occurs actively. Based on our own animal experiments, we first thought that the bladder neck was opened by the contraction of the posterior longitudinal muscle fibres in the area of the trigone (34). The relaxation of the pelvic floor and the simultaneous traction on the urethra should have a supporting function. Jonas and Tanagho (26), however, showed that the sphincter mechanism is probably opened by reflex-regulated collaboration of the detrusor, bladder neck and urethra. We therefore have to re-examine the function of the trigone.

In contrast to the upper urinary tract, bladder and urethra are richly innervated organs. Elbadawi and Schenk (16) as well as Schulman et al. (42, 43) believe that the nerve: muscle proportion is 1 : 1 everywhere in the bladder, which means that all muscle cells are innervated individually. Raezer et al. (38) think a topographic variation of the nerve-muscle distribution to be more likely. This difference is due to the fact that Raezer et al. believe that the terminal reticula described by Elbadawi and Schenk are muscle cell membranes, because the histochemically demonstrated cholinesterase is a muscle membrane cholinesterase.

The detrusor probably has several cholinergic receptors, which produce regular contractions in all regions when stimulated by the pelvic nerve. By stimulation of the adrenergic hypogastric nerve the detrusor contraction can be stopped. The hypogastric nerve also acts directly on certain parts of the bladder muscle, especially in the trigonal area, bladder neck and urethra (7, 8, 11, 14, 16, 48): the muscular tonus is intensified by alpha-receptors and lowered by beta-receptors (10, 12, 45, 46). The stimulating effect of alpha-receptor stimulation is much clearer than the inhibiting effect of beta-receptor stimulation. Tanagho, (47, 48), however, rejects this theory of a plurivalent innervation. He considers, that the adrenergic reactions in the bladder neck area and urethra result from vasoactive influence.

Based on the theory of a plurivalent innervation of the lower urinary tract, new pharmacologic principles were devised in order to influence the detrusor and sphincter mechanism (45). Particularly the treatment of neurogenic dysfunction by drugs has shown very interesting results with residual urine and reflux.

The vesicourethral pressure gradient and the functional length of the urethra are very important for urinary continence (13, 17, 20, 21, 24, 27, 49). Furthermore, the geometry of the bladder neck, especially of the vesicourethral angle, is an important factor for continence and micturition (25, 32). Standard urological investigations such as cystoscopy and micturating cystourethrography alone are therefore not sufficient for the evaluation of functional disturbances of the lower tract. Functional diseases need functional exploration. But as there is no functional investigation method which includes all parameters of continence and micturition, we have to combine the examination methods available: uroflowmetry, cystometry, urethral closure pressure profile, pelvic floor EMG.

Modern urodynamics combine morphology and function in a new and promising way (33). Urodynamic research has changed uro-surgical technique and deeply influences urological thinking when concerned with the evaluation of clinical problems at all levels of the urinary system.

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