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Disturbed Urinary Transport in the Pelvi-Calyceal System in Calcium-Oxalate Stone Patients

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Summary. This study is intended to elucidate the process of urinary transport through the pelvi-calyceal system (PCS). PCS-motility of a total of 28 PCS was qualitatively and quantitatively determined in 9 stone patients and 14 control persons by examination of contrast medium excretion. From X-ray videograms recorded by means of Siemens urography, four different urinary transport types could be distinguished as well as the duration of the contraction periods and the intervals between the PCS-contractions. In stone patients physiological types of urinary transport are less common (33%) than in control subjects (81.25%). In stone patients the PCS is often characterized by reduced or even absent motility. Calyceal reflux is usually found in the systolic phase of PCS-contractions, which may apparently be regarded as a physiological process.

Key words: Pelvi-calyceal system, Motility, Urolithiasis, Calyceal reflux.

Introduction

The description of urinary transport from the papillae renalis to the pelvi-ureteral junction is characterized by contradictory statements and insufficient knowledge.

The difficulties in the description of the motility of the upper urinary tract result from the use of different techniques in patient examination (e.g. electromanometric pressure measurement, myography, X-ray cinematography) as well as from many different physical parameters, which have been evaluated in different ways or neglected by different authors. With regard to this, Trattner [29] and Efendijew [11] mentioned: age; sex; blood pressure; nutrition; oxygen saturation of the blood; diuresis; stimulation of the nerves in the renal pelvis and in the ureter; hydrogen-ion concentration in the urine; change in position; intrapelvic, intraabdominal and intraureteral pressure; renal filtrational pressure; sympathico- and parasympathicomimetics; bacterial toxins; renal pelvic and calcyeal shapes; envorinmental conditions and psychic stress.

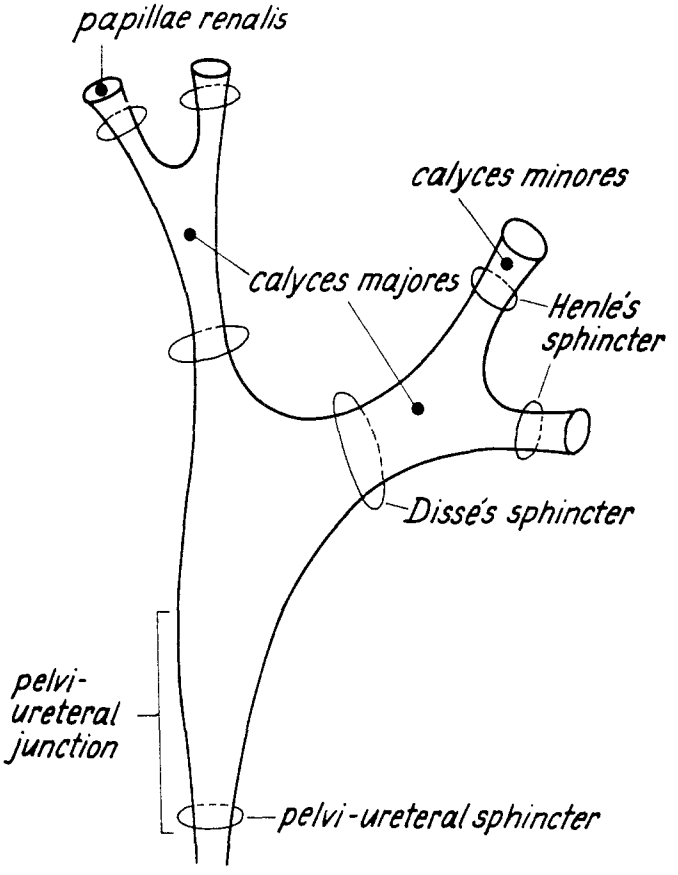

Fig. 1. Groups of muscles in the PCS involved in urinary transport

An attempt has been made to review the present situation concerning ideas on urinary transport in the PCS; cf. Fig. 1. According to Lullies and Trincker [17], the primary urine in Bowmans's capsules is subjected to a pressure of 2.0–2.7 kPa (1 Pa = $75 \cdot 10^{-4}$ mmHg). The basal pressure in the calyces and in the pelvis is 0–0.5 kPa.

Table 1. List of different observations on the motility of renal pelvis and calyces

References	Statement
Ono [21]	movements in the upper calyceal groups
Narath [19]	alternating calyceal contractions
Catel and Garsche [8]	no motility in the PCS
Banjamin [3, 4]	passive function of the pelvis as a reservoir
Staehler [28]	systole spreads distally from the calyceal groups into the renal pelvis
Fey and Quenu [12]	systole proceeds asynchronously in all calyces
Düx et al. [10]	alternating contractions
Mitsuya et al. [18]	simultaneous start in all calyces; spread into renal pelvis
Reboul [23]	initial calyceal peristalsis
Barilla et al. [2]	initial calyceal peristalsis
Boyarski [6]	no pelvic motility
Campbell [7]	pelvic motility only in 24% of test persons
Moix and Noix [20]	systole proceeds asynchronously in all calyces
Schmidt et al. [24]	PCS motility extremely rare
Schmidt [25]	
Efendijew [11]	calyceal contractions proceed asynchronously from proximally towards distally; upper calyx is of special importance
Kiil [16]	calyceal muscles not of essential importance
Puigvert [22]	calyces fill and empty synchronously; pelvic contraction results in backflow into calyces
Hajos [15]	systole normally starts from the pelvi-ureteral junction; pelvic contraction results in backflow into calyces; independent calyceal movement; upper calyx of special importance
Hannappel [14]	primary pacemaker in the most intrarenally situated parts of the pelvis

According to Düx et al. [10], urine flows passively, i.e. into the calyces minores as a result of a pressure gradient. The calyces minores are guarded by Henle's sphincters, which are said to open only above a certain filling pressure. By simultaneously closing Disse's sphincters of the calyces majores, the calyceal necks can be filled [1, 10]. Above a certain dilatation of the cellular geometry of the muscle cells – and thus above a certain filling pressure – the calyces majores contract while Henle's sphincters close and Disse's sphincters open simultaneously, thus transporting the urine bolus into the renal pelvis [1,5, 10].

The pelvi-ureteral junction can be closed by a functionally effective pelvi-ureteral sphincter. Schmidt [25], Hajos [15], Düx et al. [10], Constantinou et al. [9] and others attribute special importance to the pelvi-ureteral junction as a pacemaker. If a certain dilating stimulus is present – especially at the pelvi-ureteral junction – the renal pelvis is believed to release a bolus due to abrupt initial concentration at the site of stimulation. This portion is carried by perstalsis through the ureter into the urinary bladder [29].

Normally Disse's sphincters are closed. Sometimes backward propagation into the renal collecting system has been observed.

According to Hannappel [14], the primary pacemaker is situated in the innermost parts of the renal pelvis. Zimskind [30] described the pelvic contractions as universal and mild.

There are many contradictory statements concerning the chronology of calyceal and pelvic contractions as well as initiation and spreading of contraction and peristaltic wave, respectively. Some authors even express doubts with regard to the presence of pelvic and calyceal motility.

In Table 1 the different descriptions have been listed.

According to Efendijew [11] the peristalsis of the ureter and the frequency of contractions in the PCS depend on shape, size and position of any calculus present, the resulting inflammation and the developing nephrosclerosis are considerably reduced.

Schmidt [25] reported retroperistalsis with pelvic calculi. This effect does not occur with calyceal stones.

Hajos [15] reported that the distance beween calculus and pelvi-ureteral junction was of great importance.

The closer the calculus was situated to the pelvi-ureteral junction, from the ureteral as well as from the pelvic side, the more serious was the disturbance.

All patients with pelvic calculi exhibit hypomotility [11, 15, 25]. According to our comparative investigations into the morphology of the PCS of healthy persons and of stone patients, there exist several statistically proved differences [27]. PCS of stone patients are often larger, more extensive, have more papillae and a higher degree of ramification and order.

Analyses of the flow state in the PCS, performed on static glass and dynamic rubber-PCS-models [26, 27] permit the suggestion that a priori there ought to be reduced motility which promotes calculus formation in stone patients.

Method

For detailed investigations into motility, 23 PCS X-ray videograms recorded by Siemens urography were analysed. Before the investigation patients were not fluid restricted. On the day of investigation all patients were starved. Patients with empty bladders lay in a supine position, and video-recording was performed 5 min after contrast medium injection

- infusion urograms: 100 ml Visotrast diluted with 100 ml saline solution
- normal dosage urograms: 40 ml Visotrast

Two groups of test persons were compared:

Group I: 9 patients with renal stones (5 female; 4 male); 12 PCS (6 female; 6 male) with small calculi in the renal pelvis or in the calyces without evidence of inflammatory changes on urinanalysis and without other urological diseases.

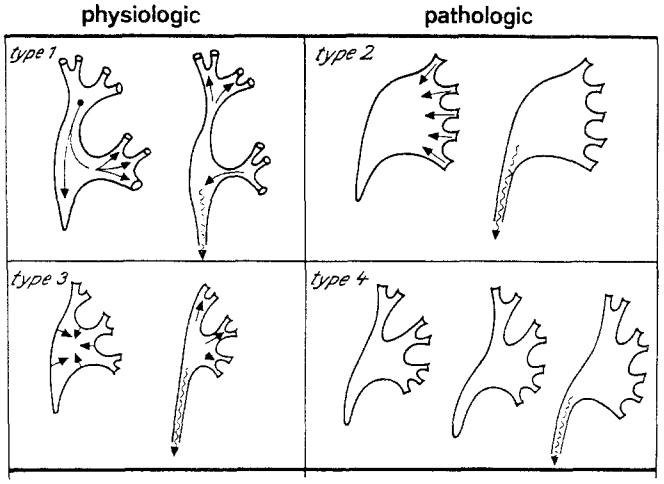

Fig. 2. Types of urinary transport

Group II: 14 healthy control subjects (10 female; 4 male); 16 PCS (11 female; 6 male).

In addition to qualitative analysis, time parameters (e.g. contraction time, contraction intervals) were measured with an accuracy of 1/25 s by means of the time limiter and single frame exposure of the video recorder.

Results

a) Qualitative Statements Concerning PCS Motility

Analysis of the 28 PCS investigations was first performed in a purely qualitative way. The observed patterns of urinary transport from the renal pelvis to the ureter were divided into 4 types:

Type 1 (Fig. 2): A peristaltic wave starts from the upper calyceal group usually from the cranial part of the upper calyx), and continues via the renal pelvis, causing brief reflux into the lower calyceal group, where it initiates a contraction (or peristaltic wave). This in turn is followed by caceal reflux into the upper calyceal group. On exceeding a certain degree of dilation of the walls or filling of the pelviureteral junction, the junction opens, and a small amount of urine is carried by peristalsis to the bladder. This process often coincides with the moment at which the peristaltic wave from the upper calyx major arrives at the pelvi-ureteral junction.

These powerful and abrupt processes occur mainly in dendritic PCS in ranges between tenths of a second and three seconds. This type of urinary transport is termed physiological.

Type 2 (Fig. 2): A contraction, which causes narrowing of the whole pelvis, procedes from the renal pelvis and initiates a peristaltic wave along the ureter due to increased pressure at the pelvi-ureteral junction. Simultaneous calyceal reflux is observed.

These processes occur in the same time range as in type 1. This type of urinary transport is also described as physiological.

Type 3 (Fig. 2): In large ampullary pelves only faint contractions of single calyces minores could be observed, and only faint peristaltic constrictions of the ureter were recorded. These processes are slow and last up to several seconds. The renal pelvis does not exhibit any motility and always remains full. This type of urinary transport is termed pathological.

Type 4 (Fig. 2): This group includes PCS without any motility, neither in the calyces nor in the renal pelvis.

Only faint signs of peristalsis occur in the ureter, which remains distended. This type of urinary transport is also described as being pathological.

Table 2, which lists the frequency of the four transport types described, shows that the two physiological types 1 and 2 occurred in four out of five healthy persons, whereas in stone patients only 1/3 of all PCS examined were considered to be normal in terms of physiological motility.

Types 1 and 2 are frequent in dendritic PCS. This agrees with the investigations of Schulz [27], in which dendritic PCS were more frequently found in healthy persons (74%) than in stone patients (44%) (for a total number of 294 PCS).

Further Qualitative Results

- As a rule the PCS is not completely emptied (very small PCS being an exception) but only a very small urinary bolus is transported from the renal pelvis through the ureter to the urinary bladder.
- The contraction or peristaltic discharge of the urine is often induced by inspiration, 25 out of 28 PCS (89.3%) showing this phenomenon.

Table 2. Distribution of the four transport types observed

group	type 1		type 2		type 3		type 4		total	
healthy persons	10	62.5%	3	18.75%	2	12.5%	1	6.25%	16	100%
stone patients	4	33.3%	–	–	3	25.0%	5	41.7%	12	100%

Table 3. Comparison of PCS motility in stone patients (group I) and healthy persons (group II)

parameter		group I	group II	F	α
number of test persons		9 (5f; 4m)	14 (10f; 4m)		
number of PCS		12 (6f; 6m)	16 (11f; 5m)		
age/years	m.v.	40.7	63.4		
	s.d.	18.6	10.9		
	n	9	16		
mean interval between	m.v.	25.0 s	17.6 s	1.42	< 0.1%
two pelvic contractions	s.d.	15.0 s	8.8 s		
	n	33	75		
mean duration of a	m.v.	3.74 s	1.58 s	2.73	< 0.05%
pelvic contraction	s.d.	1.38 s	0.72 s		
	n	27	73		
mean frequency of contractions in the					
upper calyceal group		0.89 c/min	2.06 c/min	2.31	< 0.1%
lower calyceal group		0.21 c/min	0.47 c/min	2.24	< 0.1%
all calyceal groups		1.10 c/min	2.53 c/min	2.30	< 0.1%
mean frequency of pelvic contractions		1.74 c/min	3.21 c/min	1.85	< 0.1%

Explanations: F: factor between the mean values of group I and group II; α: probable error in a statistically significant difference between the groups; m.v.: mean value; s.d.: standard deviation; n: numbers; c: contractions; f: female; m: male

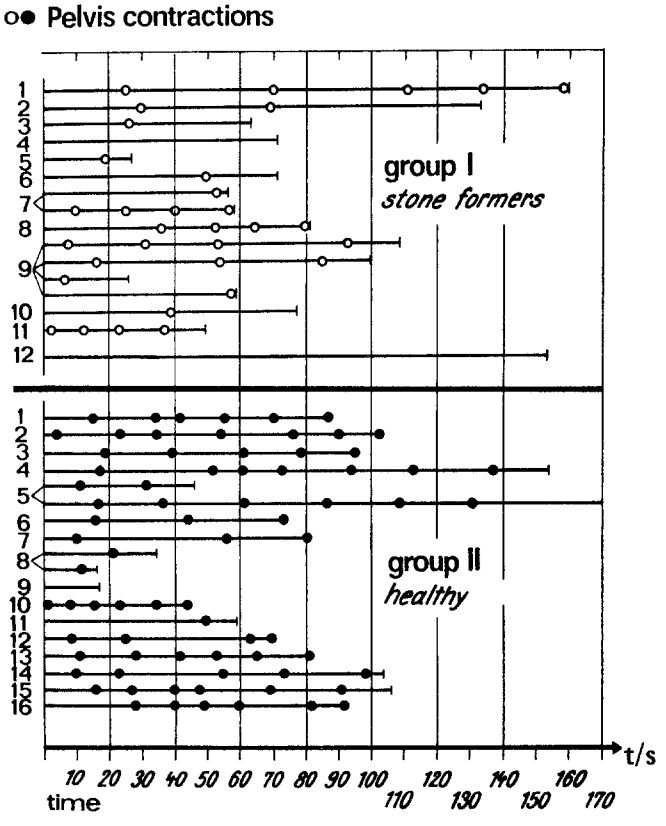

Fig. 3. PCS contractions in dependence on time

• In agreement with Frang [13] and Hajos [15], the calyceal reflux in normally contracting PCS (types 1 and 2) must be considered as physiological.

b) Quantitative Statements

In Table 3 the mean values and standard deviations in quantitative determinations have been listed for both groups examined.

Even from a qualitative point of view, it, can be seen (Fig. 3) that the mean intervals between the contractions and the mean duration of one contraction were significantly increased by a factor of 1.42 and 2.73 in the stone patients. In the control group, more contractions of the single calyceal groups as well as the PCS were recorded in homologous time units.

These statements are of importance because the mean age values of both groups are different; the differences in the time parameters ought to be rather increased because the stone patients are represented by the "younger" group.

Discussion

PCS motility was compared in stone patients and in healthy controls.

The forms of urinary transport observed were divided into four types, two physiological ones (types 1 and 2) with frequent powerful motility and two pathological ones (types 3 and 4) with reduced or absent PCS activity.

A quantitative comparison of several time parameters showed that stone patients exhibit a mean increase

a) in the intervals between two PCS-contractions by a factor of 1.42 and

b) in the duration of contractions by a factor of 2.73, with very poor activity.

Pathological types of urinary transport are found more frequently in patients with natural passage of calculi than in a control group. Schulz [27] previously reported morphological differences in the PCS of stone patients and healthy persons. This observation suggests that in stone patients disturbed motility existed a priori.

Urodynamic examination of the PCS constitutes an important diagnostic test of pathological types of urinary transport.

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