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Peristalsis of the Pyeloureter in Pigs Measured by Videodensitometry

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Summary. The peristaltic activity of the upper urinary tract was investigated by means of a simple videodensitometric system. Through a transparenchymally placed catheter contrast medium was infused into the renal pelvis with perfusion rates increasing from 1 to 15 ml/min. Sequences of 3–5 min were recorded by means of a Siemens image amplifier on videotape for later analysis. Photodiodes were placed on the screen over the calyces, renal pelvis and ureter at a distance of 5 cm. An amplifying system and a UV recorder were used for registration. Peristaltic frequency, transmission velocity and average bolus volume were measurable in 8 out of 10 pyeloureteral units. Additionally, calyceal activity was detectable in one case. The tracings obtained by videodensitometry were reproducible and easy to analyse. Conversion of videorecordings to analogue signals for analysis might be a possible future clinical diagnostic method.

Key words: Videodensitometry, Pyeloureteral peristalsis, Bolus volume.

Introduction

Radiological evaluation of the upper urinary tract is based on the static X-ray photo or on cineradiography. These investigations are non-invasive except for the infusion of contrast medium, but subjective and non-quantitative. Experimentally dynamic but highly invasive methods such as pressure-flow investigations and electromyography are employed [2]. In an attempt to develop dynamic non-invasive quantitative methods to evaluate the upper urinary tract, two methods have been evaluated. Ultrasonic detection of peristalsis was suggested [1], but the possibility of differentiating ureter from the surrounding tissue was limited. Videodensitometry as advocated by Tscholl et al. [4] seems more promising. By means of this method it is possible to register the passage of contrast medium in the ureter during X-ray image amplification. The major advantage of the method is that a quantitative expression of ureteric activity is obtained without interference with the motility of the ureter. The disadvantage is that complicated and expensive electronic equipment is needed.

The purpose of the present investigation was to describe a simple videodensitometric system and to determine the possibility of obtaining relevant parameters of urine transport such as peristaltic frequency, peristaltic transmission velocity, average bolus volume, calyceal and pelvic activity and relative filling.

Material and Methods

Ten pyeloureteral units in female pigs of Danish landrace breed weighing 30–40 kg were investigated. The investigation was performed under general anaesthesia induced by Ketamin (Ketalar®) 8–10 mg/kg body weight and maintained in a semiclosed system with Halothane 1.5–2% in oxygen. A 5-F catheter with the tip in the renal pelvis was placed transparenchymally. The catheter was connected to a perfusion system (Multifix Constant®) with contrast medium (Diodon® 17%). The bladder was opened to allow free flow from the side investigated. Over a period of approximately 60 min the pelviureteral unit was perfused with flow rates from 1 to 15 ml/min. Pelviureteric activity was registered manometrically and by means of an X-ray image amplifier (Siemens) recorded on videotape (Philips VCRN 1512).

Measuring Principle

The principle of the videodensitometric method is a quantitative conversion of light intensity to analogue signals. The measuring chain consists of a video recorder, photodiodes, amplifier and recorder. The video monitor used in the present study was an ordinarily-marketed recorder. Light intensity on the video screen was measured by a number of photodiodes sized 2 x 4 mm type BPX90. As displayed by the tape, the photodiodes were placed on the screen at various positions on the pyeloureteral system over the calyces, the pelvis, the pelviureteric junction and along the ureter with a distance between the photodiodes of 5 cm. The signals from the photodiodes thus measured the amount of contrast passing through the location of the photodiode on the pyeloureteral system. The signals were amplified by a Bryans galvanometer amplifier (40502). Analogue signals were recorded on a UV recorder (Bryans 45000) (Fig. 1).

The analogue signals obtained are shown in Figs. 2A + B. The following parameters were obtained from the densitometric tracing:

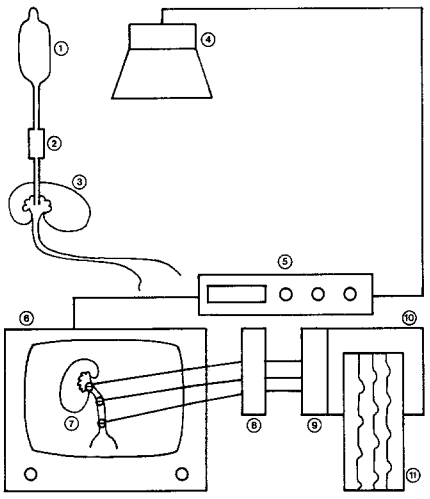

Fig. 1. The experimental set-up: 1) Contrast medium container; 2) Roller pump; 3) The transparenchymally placed catheter; 4) X-ray amplifier; 5) Videorecorder; 6) Videomonitor; 7) Photodiodes (BPX 90) placed on the videomonitor; 8) Videointegrator; 9) Amplification unit; 10) UV recorder; 11) Schematical illustration

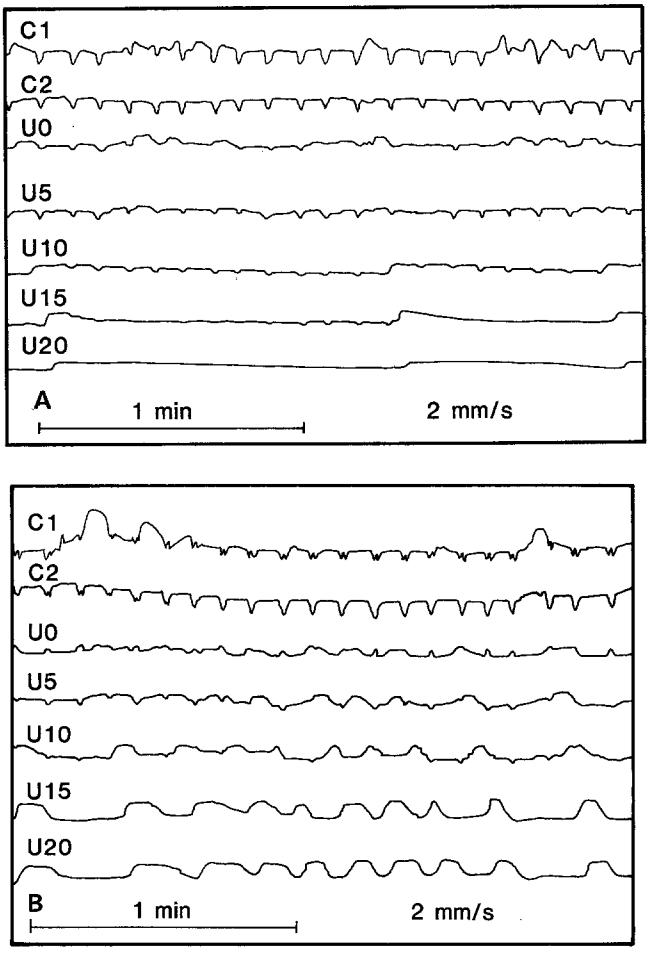

Fig. 2A, B. Actual sequence of a tracing including calyceal (C_1 and C_2) and ureteral activity (U_0 – U_{20}). A Shows a phase of regular 4–1 calyceal – ureteral activity. B In the upper sequence the peristaltic activity is irregular. To the left high frequent activity originates in the calyx and is transmitted to ureter. In spite of high frequency peristalsis the pelvis shows an increased content (downward deflection of tracing C_1 and C_2). To the right the peristalsis becomes slower and more effective.

1. The transmission velocity of peristalsis defined as the distance between two photodiodes divided by time elapsing between two contractions.

2. The frequency of peristalsis defined as the reciprocal of time elapsing between two contractions.

3. Relative filling of non-occlusive areas: In some situations, e.g. rapid increase in diuresis and sudden onset of obstruction, an increase in the pelvicalyceal volume occurs. This is apparent on the videodensitometric tracing. As a decrease in the light intensity based on the increased content of the system (Fig. 2B).

4. Mean bolus volume.

Results

Analysis of 2 of the 10 units was not successful. In one, the X-ray picture was not steady, in the other the ureter was atonic throughout the investigation. The results are therefore based on 8 full investigations of ureteric activity. In another case it was additionally possible to register changes in the pelvicalyceal filling and calyceal activity, although not consistently.

Characteristically, ureteric activity could be traced as shown in Fig. 2A. This tracing was obtained at a ureteric flow of 2 ml per min. The positive deflections on the tracing signify contractions and negative deflections indicate increasing ureteric contrast content. Respiratory artefacts are shown as either positive or negative deflections. The calyceal tracing (C_p) shown in this example of calyceal activity a ratio of 4:1 compared to the distal part of the ureter. The tracing U_0 was obtained at the pelviureteric junction and showed activity of the same frequency as registered in the calyces. The tracings from the ureter showed active contractions and the passive filling. Contractions are depicted as steep positive deflections occurring in this case at a frequency of 0.8 per min. The duration of the contractions before refilling from the proximal part of ureter was 2–3 s. The overall shape of the bolus obtained from videodensitometry tracing was wedge-shaped.

The change of peristalsis with increasing flow is exemplified in Fig. 2A and B. In Fig. 2A the flow is 2 ml/ureter/min and the frequency of peristalsis 0.8 per min. In Fig. 2B the flow is 10 ml/min and the frequency of peristalsis varied from 1.4 to 6.7 per min. The higher frequency episodes are shown to be secondary to a relative obstruction.

The relationship between peristalsis and transmission velocity is also illustrated in Figure 2B. When the frequency of peristalsis is changed from 1.4 to 6.7 per min the transmission velocity is changed from 2.5 to 1.0 cm/s. The average bolus volume in the example given in Figure 2A was 2.5 ml.

In Fig. 2B, where the change in peristaltic frequency occurs, the change in relative filling of the proximal part of the pyeloureteral system is also shown. During the fast frequency there is a negative deflection of the pelvic and calyceal tracing with a positive increase when the peristaltic activity decreases.

Discussion

The present investigation shows that for analysis of upper urinary tract activity by means of a simple videodensitometric system the same parameters can be obtained as from more traumatic and invasive investigations of pelviureteral peristalsis. The only possible artefact caused by using this method could be the change in viscosity of the fluid in the pyeloureter or a direct toxic effect of the contrast medium on the contractile cells of the ureter. Comparative investigations of the pressure-flow relationship in the pyeloureter have on the other hand not shown such an effect.

Calyceal activity was only detected in one case. This is comparable to what is found by a traumatic method where calyceal activity is neither found by electromyography or by pressure registration.

The peristaltic frequency of the ureter was easily recorded. In previous investigations of ureteral activity electromyography has been used [2, 3]. The practical problems of such measurements raise questions about the clinical application. The invasiveness is significantly reduced by the use of videodensitometry. The relationship between flow and peristalsis can also be visualized by this method. It was shown that abrupt changes in flow lead to a high frequency of peristalsis. This high frequency peristalsis causes a decrease in the transport capacity of the pyeloureter as illustrated by an increase in the relative filling of the pelvicalyceal compartment. The relationship between peristalsis and transmission velocity was equally easy to obtain. It was previously shown that a high frequency of peristalsis leads to a slow transmission velocity of the peristalsis [3].

It has been suggested that bolus volume related to frequency of peristalsis in the upper urinary tract is a parameter of major importance in characterizing the system [2, 3]. Videodensitometric investigation requires a known flow through the ureter. The increasing use of percutaneous puncture of the renal pelvis for antegrade pyelography and/or pressure measurements provides the possibility of obtaining these two parameters from videodensitometric measurements. Hitherto, high flow rates have been employed, but the present simple method makes it possible to characterize the system in a more physiological and dynamic way. Using videodensitometry as advocated in the present paper it is possible to obtain a thorough characterization of pyeloureteral systems in the clinical situation very simply, cheaply and without major invasion. Besides the image amplifier, the electronic equipment necessary for the investigation consists of a recorder, a few photodiodes, and amplifiers. The video take-up gives a radiation dose comparable to urography and therefore the method seems of significant potential for future improvement of radiological diagnostic procedures of the upper urinary tract.

References

1. Baker DW (1971) Factors in the development of measurement techniques for transcutaneous studies of ureter function. In: Boyarsky, Gottschalk, Tanagho, Zimskind (eds) Urodynamics. Academic Press, New York London, p 425
2. Constantinou CE, Djurhuus JC (1981) Pyeloureteral dynamics in the intact and chronically obstructed multicalyceal kidney. Am J Physiol 241:R398
3. Djurhuus JC (1980) Aspects of renal pelvic function (thesis), Copenhagen
4. Tscholl R, Keller U, Spring P (1976) Investigation of urine transport in the ureter of the pig by x-ray video-densitometry. I. The effect of increasing diuresis on velocity and rhythm of concentrations: Relationship between pressure wave and urine bolus. Invest Urol 13:404

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