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Peristaltic Activity in the Normal Renal Pelvis of the Pig During Standardized Perfusions

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Summary. The peristaltic activity in 36 normal pig pyeloureters in 19 pigs was investigated during various steady flow rates. Flow rates of 2, 4, 6, 8, 10 and 20 ml/ureter/min resulted in a mean frequency of 4.5, 4.9, 4.4, 4.2, 4.2 and 5.1 peristaltic events/min respectively. The frequency of peristalsis was thus independent of flow rate and also of baseline pressure but showed a weak relation to the magnitude of the mean perfusion pressure. The peristaltic activity is generally constant at all physiological flow rates in the steady state. This standardized study therefore confirms previous observations in showing that urine transport mainly is regulated by changes in the bolus size.

Key words: Pyeloureteral peristaltic activity, Standardized perfusion, Urine transport.

Introduction

Anatomical [6] and physiological [2, 7] studies have shown that the peristaltic activity of the pyeloureter and ureter is regulated by a hierachy of pacemakers in the proximal part of pelvis and the calyces.

Both in vitro [10] and in vivo investigations [3] have clearly demonstrated that sudden changes in the pressure load on the renal pelvis causes immediate changes in the peristaltic frequency of the pelvis and ureter. These changes are, however, brief and in spite of a sustained increase in the stimulus mediated by pressure, the frequency of peristalsis returns to its previous value. Therefore, sudden pressure flow changes only seem to have a modulating effect on the peristalsis of the pyeloureter.

It was previously shown that the peristalsis of the pelvis and ureter may be regulated by the bolus volume at very low urine output and that it reaches a saturation frequency at flow rates of 1–2 ml/ureter/min [2]. Peristalsis might exert its major effect at low flow rates. At higher flow rates changes in transport are mainly caused by changes in bolus size. Bolus size is increased proportionally to the increase in urine output. Probably at these high flow rates the peristaltic contraction exhibits a partially obstructive effect on urine transport [9].

At present, data on the modulation of peristalsis are based on analysis of the response to diuretics. Since it has been shown that the peristaltic frequency response is influenced by the rate of rise in the stimulus studies on standardized alterations may show different aspects of the peristaltic response to flow alterations.

The object of the present study is to analyse the eventual changes in peristaltic activity during standardized changes in flow rate with special reference to the pressure flow relationship of the upper urinary tract.

Material and Method

In 19 pigs weighing 30–40 kg thirty-six pyeloureters were studied. The investigation was undertaken under general anaesthesia induced by Ketalar^{R} (ketamin NFN) 10 mg/kg b.w. given intramuscularly and maintained with halothane 1.5–2.0% in oxygen with the pigs on spontaneous respiration.

Through a midline incision extending from the symphysis pubis to the xiphoid process the kidneys and the proximal part of the ureters were exposed retroperitoneally. The bladder was opened in the midline. Two 6-F catheters were guided one after another through the ureterovesical junction into the ureter, up into the pelvis and out through the renal parenchyma. They were both withdrawn until the distal tip with side- and endholes were placed in pelvis. One catheter mediated pressure registrations measured by Siemens strain gauge 746 transducers and amplifiers with the transducer placed at the level of the kidney. The other was used for perfusion and connected to a roller pump. An 8-F catheter with side- and endholes placed in the distal part of the ureter was used for measurements of the baseline diuresis. A resting period of 30 min was allowed before investigations were initiated.

During a 10 min period the baseline intrapelvic pressure and the baseline diuresis were measured. Thereafter the sampling catheter was removed. Under continuous pressure measurements the renal pelvis was perfused consecutively with flow-rates of 2, 4, 6, 8, 10 and 20 ml/min. As perfusion fluid isotonic saline heated to 37° was

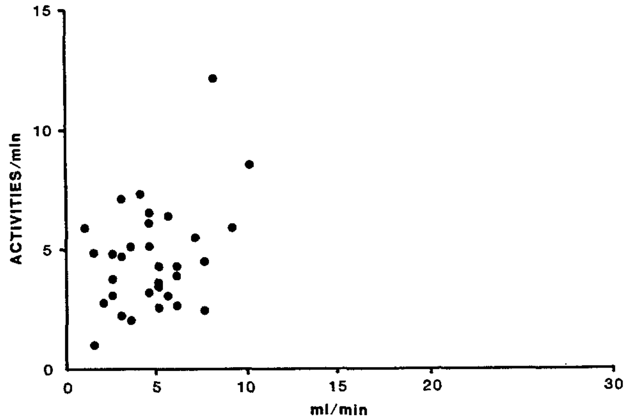

Fig. 1. The relationship between the baseline peristaltic frequency and the baseline diuresis. Independent of the size of the urine output the systems may have a high as well as a low baseline frequency

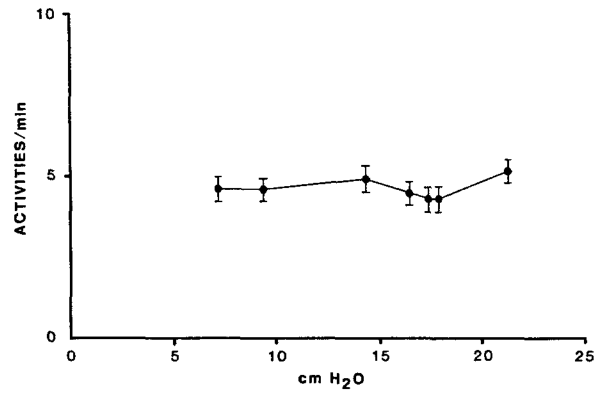

Fig. 3. The relationship between the mean value of frequency and the mean pelvis pressure at the single flow rate. The mean value of the frequency is almost the same at all flow rates

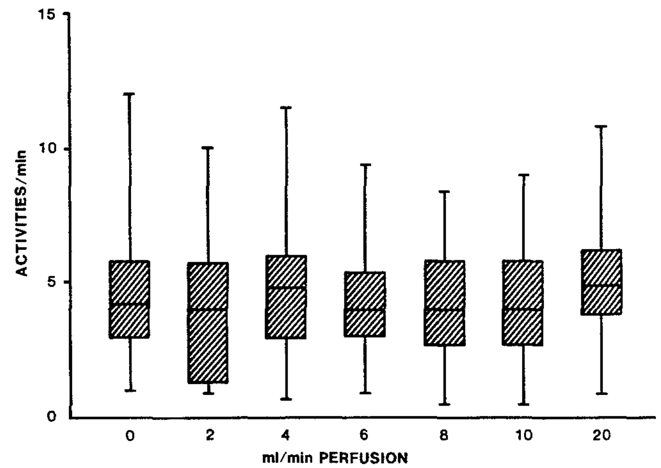

Fig. 2. A bars and whiskers diagram of the frequency distribution at the single flow rate. The distribution is almost unchanged through all flow rates

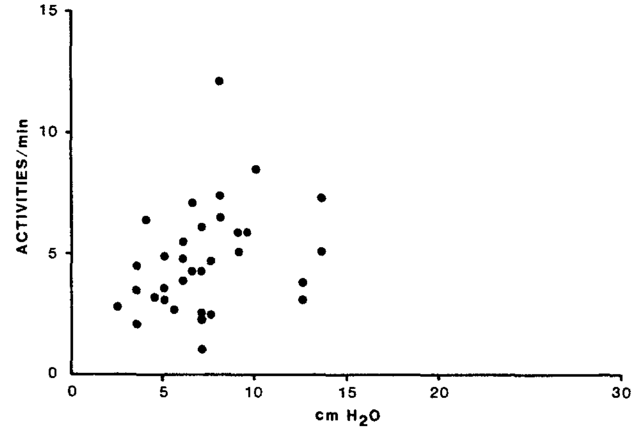

Fig. 4. The relationship between the baseline frequency and the baseline pressure. Independent of the size of the baseline pressure the single system might have a high as well as a low baseline frequency

used. The perfusion rates were increased whenever the pelvic pressure had been stable for at least 5 min [8].

Analysis. The lowest pressure between pyeloureteral contractions at stable level was used for analysis. The peristaltic frequency was calculated and averaged over a period of five minutes at stable pressure by summating the peristaltic contractions at stable pressure level. This sum was then divided by time.

Results

All 36 systems were macroscopically normal. The baseline diuresis was stable within each investigation but varied from animal to animal from 0.1 to 1.0 ml/min. Figure 1 shows that there was no relationship between the size of the baseline diuresis and the baseline peristaltic frequency. Systems with low diuresis had high baseline frequency and vice versa. The correlation coefficient was 3.76.

The 36 mean frequencies showed a normal distribution at all flow rates. Apart from one result the baseline frequencies were between 1 and 9 activities/min. This distribution was almost unchanged irrespective of flow rate. Apart from single systems, which showed some variation in frequency, especially in the flow interval 0–4 ml/min, flow rate did not alter the frequency of peristalsis (Fig. 3).

There was no correlation between baseline pressure and baseline frequency (R = 3.08; Fig. 4). A high baseline pressure was accompanied by a high as well as a low baseline frequency and vice versa. Since the frequency in the single system was independent of flow rate and pelvic baseline pressure, it was to be expected that the frequency would be unrelated to the perfusion pressure. Correlating the mean perfusion pressure to the mean perfusion frequency (Fig. 5) there was, however, a weak relationship between these two parameters (R = 4.73). On the other hand it is apparent from the figure that a low and a high perfusion pressure

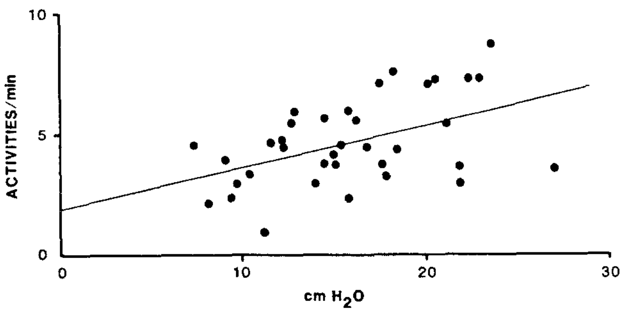

Fig. 5. The relationship between the mean peristaltic frequency and the mean perfusion pressure. The mean peristaltic frequency is increased with increasing mean pressure

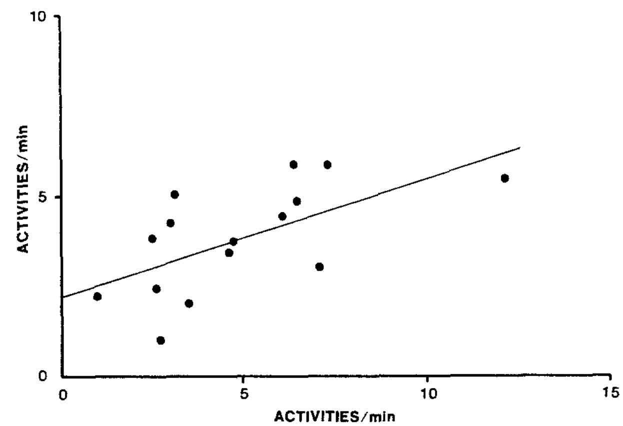

Fig. 6. The peristaltic frequency relationship between left and right during the baseline period

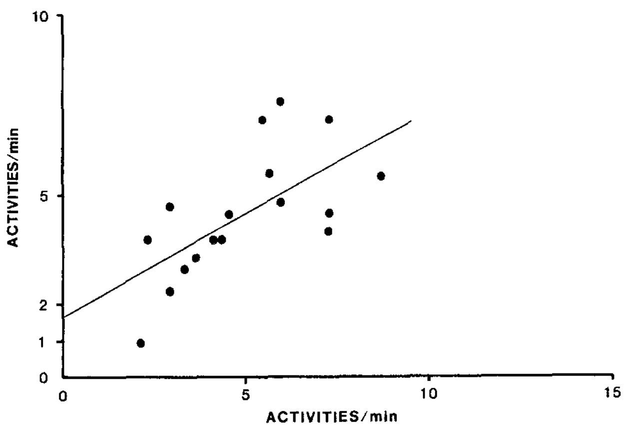

Fig. 7. The figure shows the peristaltic frequency relationship between left and right sides during perfusion

might be related to either low or high frequency. No correlation between pressure and frequency was found at the single flow rate.

The relationship of frequency between left and right side within each animal is shown in Figs. 6 and 7. Figure 6 shows that during during the baseline period there was a good relationship between the two sides (R = 6.16). During perfusion there was a fair relationship between the two sides as shown in Fig. 7 (R = 6.42).

Discussion

The present investigation concerns analysis of the peristaltic activity in the upper urinary tract as function of flow rate variation. It could be argued that direct measurements of the muscular activity by electromyography were not performed. However, the present investigation was concerned with the pressure flow relationship in the upper urinary tract [9]. In order to decrease the degree of invasion of the physiological system electrodes for electromyographic measurements were avoided. Moreover, previous investigations have shown that the electromyographic activity of the renal pelvis always is accompanied by a pressure wave [4]. Analysis of the pressure waves on the pressure tracing should therefore give a representative expression of the peristaltic activity of the renal pelvis. Extrapyeloureteral activity such as pressure excursions induced by respiration and pulsation were easily recognizable and were therefore clearly discernable from the activity of the renal pelvis.

Occasionally there was doubt whether a pressure increase constituted one long contraction or two contractions. The values of the peristaltic activity rate therefore should be considered as the lowest values.

The present investigation showed that there was no correlation between baseline pressure flow and peristalsis. There was unaltered frequency of peristalsis at a steady state regardless of flow rate. The frequency range was unaltered in the pig pyeloureter at all perfusion rates employed. There was a weak correlation between the mean perfusion frequency and the mean perfusion pressure and a correlation of the frequency between right and left side also showed a weak correlation. It was thus shown that the single system holds a dominating frequency in steady state and that this frequency is independent of pressure and flow. This is in agreement with previous findings [5]. In that study there was a frequency drop immediately after a pressure drop and a frequency increase concomitant with a pressure increase. It was moreover shown that steady state pressure caused a return of the frequency to the inherent frequency. In contrast to these findings [1] it was shown that a frequency increase from 1.5 to 6/min induced by an increase in diuresis from 0.1 to 2.5 ml/min, especially when the increment in diuresis was fast. This could possibly be explained by differences in method. In the latter study changes in fluid load were induced by diuretics whereas in the present study standardized flow rates were employed.

The present study therefore suggests that the single pyeloureter in the pig has an inherent baseline frequency. The pyeloureter accommodates diuresis almost exclusively by increasing the bolus size. Changes in peristaltic frequency only occur when abrupt changes in pressure occur. Such a transport mechanism is in accordance with a hierarchical pacemakersystem governing peristalsis [1, 6, 7]. The present investigation therefore confirms previous unstandardized investigations of changes in the demand for transport and adds new information concerning the relationship between perfusion pressure and peristaltic frequency.

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