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Experimental Study of the Pressure-Volume and Pressure-Time Relations in the Completely Obstructed Pelvis of the Porcine Kidney

Part 3: Stability of the Pelvicalyceal System

T. K. Donkervoort and G. L. van Rij

Department of Experimental Surgery (Head: Prof. Dr. G. den Otter), Medical Faculty, Free University, Amsterdam, The Netherlands

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Summary. In a series of experiments with pigs the completely obstructed renal pelvis was filled with Ringer's lactate at a constant rate of 2 ml/min. At various pressure levels lower than 50 mm Hg the relations pressure vs infused volume and pressure vs actual intrapelvic volume were repeatedly measured. It was concluded that the measurements were reproducible and that the pelvicalyceal system is -under these experimental conditions- a stable elastic unit.

Key words: Research, Ureteral obstruction, Porcine upper urinary tract, Pressure-volume-time relations.

Introduction

In previous reports it has been shown that when the completely obstructed porcine pelvicalyceal system is infused at a constant rate (2 ml/min) intraluminar pressure rises initially in an exponentional manner with volume until pressure values between 15 and 20 mm Hg are recorded. At further filling a marked linear relation between pressure and volume was found until pressure values of over 50 mm Hg were recorded. When, however, a completely obstructed renal pelvis is repeatedly filled until high intrapelvic pressures are reached one may expect that at a certain moment the elastic wall structure of the pelvicalyceal system is no longer capable to respond with an increase in wall tension that is adequate to maintain a "stable" volume pressure relation. The question arose as to what extent the pelvicalyceal system was stable and to what extent the obtained results were reproducible under the experimental stress and strain conditions.

A series of experiments was done to find an answer to these questions and in this report the results of the experiments concerning the reproducibility of the P-V relations and the elastic stability of the pelvicalyceal system at pressures lower than 50 mm Hg are presented and discussed.

Methods

The experimental setup, the theory of P, V, t relations and the general description of methods and materials have been presented in Part 1 of this series.

1. In 13 experiments the renal pelvis was infused (2 ml/min) repeatedly until peak pressure values of 15, 20, 25, 30, 40 and 50 mm Hg were reached. After the desired pressure was reached the pelvic content was rapidly extracted and the mean volume (MV) was calculated for each of the P_p levels examined. Next the difference between the last V_{out} (V_1) and the mean V_{out} was calculated and expressed as a percentage difference (%diff) from MV. For the various P_p levels examined, mean values and standard deviations were calculated of the percentage different values.

2. In 9 experiments the pelvis was repeatedly infused until P_p values of 15, 20, 30, 40 and 50 mm Hg were recorded. When the desired pressure value was reached the actual pelvic volume was measured by rapid extraction, this time after the pressure had stabilised. Of the repeated procedures at each pressure level mean values of V_{out} were calculated and the difference between the V_{out} of the last measurement and MV was expressed as percentage difference. Next, for each of the pressure levels examined mean values and standard deviations were calculated of the percentage difference values.

Results

Table 1 shows the ranges, mean values and SD of the percentage difference values that were calculated for the last V_{out} and mean V_{out} values in 13 experiments, in which the

Table 1. The relation between MV and V_1. %diff = $100 \cdot (V_1 - MV)/MV$

P_p	*N*	Range %diff	Mean %diff	S.D. %diff
15	8	−14 – +20	2	10
20	13	−16 – +22	−1	10
30	12	0 – +17	5	4
40	12	−14 – +10	0	7
50	12	− 3 – +12	4	5

Table 2. The relation between MV and V_1 after stabilisation. %diff = $100 \cdot (V_1 - MV)/MV$

P_p	*N*	Range %diff	Mean %diff	S.D. %diff
15	6	0 – +10	5	4
20	9	–8 – +17	3	8
30	9	0 – +18	6	6
40	9	0 – +7	3	2
50	8	–5 – +3	0	3

pelvis was repeatedly infused to P_p values of 15, 20, 30, 40 and 50 mm Hg. The results show that at repeated infusion at any of the examined P_p levels V_{out} did not significantly increase.

Table 2 shows the ranges, mean values and SD of the percentage difference values that were calculated for the last V_{out} and mean V_{out} values in 9 experiments, in which the pelvis was repeatedly infused to P_p values of 15, 20, 30, 40 and 50 mm Hg and V_{out} was measured after the pressure had stabilised. The results show that at repeated infusion V_{out} did not significantly change at any of these examined P_s levels.

Conclusions

The results indicate that at pressure values lower than 50 mm Hg the recorded pressure-volume relations are reproducible and that the pelvicalyceal system behaves, under these conditions, as a stable elastic unit. Under pathophysiological conditions of sudden complete intrapelvic obstruction the rate of diuretic inflow depends on the hydration of the animal, the rate at which intrapelvic pressure rises as well as the level at which pelvic pressure and diuretic inflow come to an equilibrium.

When there is low diuretic activity an exponential increase in pressure apparently reduces diuretic output to near zero level at intrapelvic pressure values slightly higher than 20 mm Hg. When, however, diuretic output is high the initial exponential pressure increase slows further inflow after which the linear pressure-volume relation causes the diuretic inflow to decrease in an exponential manner until equilibrium is obtained at a pressure level between 30 and 40 mm Hg. When the stress and strain cannot be met by the elastic properties of the wall structure "blow out" has to develop. Both the relation between diuretic output and intrapelvic pressure in sudden complete obstruction and the phenomenon of "blow out" of the pelvicalyceal system will be subject to further study.

T. K. Donkervoort
Department of Experimental Surgery
Medical Faculty
Free University
Van de Boeckorsstraat 7
1001 BT Amsterdam
The Netherlands