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The Pressure Volume Relationship of the Renal Pelvis in Total Obstruction in Pigs

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Summary. The renal pelvic pressure/volume relationship was investigated in 8 pigs with a 10-week total unilateral obstruction. The pressure in the totally obstructed pelves was significantly increased to a mean value of 44 cm H_2O (30.5–64). After emptying, the renal pelves were refilled continuously at a rate of 8 cc per minute to a maximal pressure of 80 cm H_2O. The relationship between pressure and volume showed a cystometric configuration. Capacity at the maximal pressure varied from 32 to 167 ml. The difference in capacity was not related to differences in the pelvic wall connective tissue fraction or the wall thickness. Neither was any relation between resting pressure and capacity found. The investigation demonstrates that total supposedly uniform obstructions exhibit a broad variation in compliance. The broad variation in compliance might be an important factor in the pathogenesis of progression in hydronephrosis.

Key words: Pelvic pressure, Total obstruction, Compliance.

Introduction

The transport capacity of the upper urinary tract is immense, since a flow of up to 20 cc per min can be transported at a pressure of less than 30 cm H_2O [7–9]. Experimentally induced obstructions cause decreased transport capacity. Thus, an increase in flow in cases of obstruction causes an increased pressure and increased peristaltic work [2].

In the clinical situation it has been postulated that an increase in pelvic volume under the influence of diuretics should be a sign of obstruction [13]. This suggestion has been refuted by Coolsaet et al. [3], who hypothesize that a highly compliant, dilated upper urinary tract might protect the kidney parenchyma from further damage, since the pressure effect of a sudden increase in diuresis would be minimized by a readily obtainable increase in volume.

Standardized partial obstructions show variations in the rate of dilatation as well as in the final capacity of the system, which might reflect the difficulties in obtaining a standardized partial obstruction [6].

The aim of the present study was to investigate the pelvicalyceal effect of a standardized total obstruction on the multicalyceal system of the pig.

Material and Methods

Eight female pigs of Danish landrace breed (28–38 kg) were investigated. The investigations were performed under general anaesthesia induced by Sernylan 2 mg/kg b.w. i.m. and maintained with Halothane 1.5–2% and oxygen in a semiclosed system. An $Iodine^{123}$ Hippuran isotope renogram was performed to ensure that there was normal kidney function and drainage. One week later the obstruction was induced. Through a midline incision from the xiphoid process to the symphysis the abdominal wall was opened. The left ureter was exposed proximally and a tube of Silicone with an inner diameter of 4 mm and a length of 3 cm was placed around the ureter. The proximal part of the tube was situated at the pelvic brim. The tube was secured by two mersilene 3–0 sutures. All pigs were treated postoperatively for one week with Pentrexyl® (Ampicillin NFN) 1 g/day.

Nine weeks later the $Iodine^{123}$ Hippuran isotope renogram was repeated. After a further week a second operation was performed. The left kidney and pelvis were exposed retroperitoneally. A pressure catheter was placed into the renal pelvis through the parenchyma, and the resting pressure was measured for 5 min. Thereafter a second catheter was introduced transparenchymally into the renal pelvis. The renal pelvis was emptied and, after a resting period of 30 min, refilled at a rate of 8 ml/min furnished by a roller pump under continuous pressure monitoring. Infusion was stopped at a pressure of 80 cm H_2O,

Before the animals were sacrificed the kidneys of 5 pigs [1–5] were fixed by vascular perfusion through the aorta [5]. In each case five tissue blocks, approximately 20 mm in length, were taken at random from the pelvic wall and embedded in paraffin. Approximately 5 μm thick sections, cut at a right angle to the mucosal surface, were stained with Picro Sirius for connective tissue. The thickness of the pelvic wall was measured from the base of the urothelial layer to the adventitial layer. The measurements were performed on five successive microscopic fields each approximately

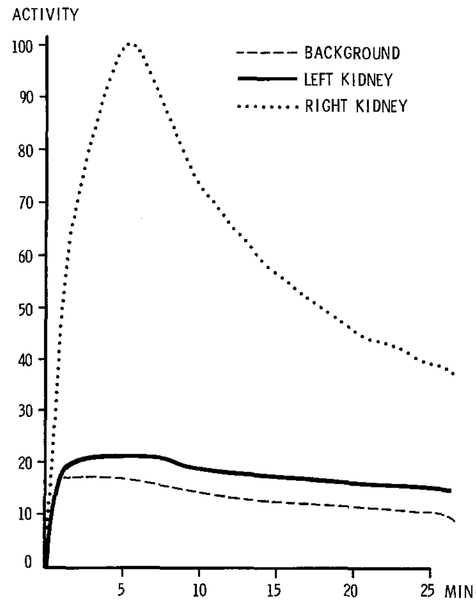

Fig. 1. Iodine[123] Hippuran renography in pig No. 3 subjected to total obstruction for 10 weeks. Practically no function is present on the obstructed side

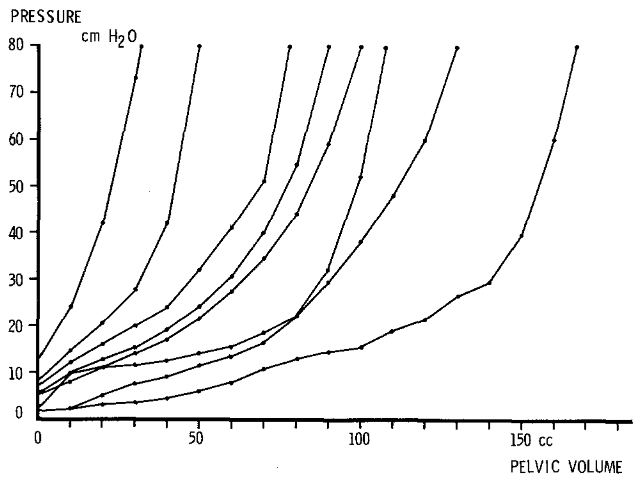

Fig. 2. The pressure volume relationship in 8 totally obstructed renal pelves showing a broad variation in capacities but an overall cystometry configuration

Table 1. Total obstruction. Pelvic pressure, volumes and wall properties

No	Resting pressure cm H_2O	Capacity at resting pressure ml	Capacity at 80 cm H_2O ml
1	45	154	167
2	64	29	32
3	47.5	42	50
4	30.5	91	131
5	39	94	108
6	39	75	100
7	41	60	78
8	46	74	90
Mean	44	77.5	94.5

No		Wall thickness mm	Connective tissue fraction
1		1.8	0.28
2		1.8	0.29
3		1.5	0.42
4		1.5	0.40
5		2.0	0.33
Control	a	0.52	0.12
	b	0.35	0.22

3.5 x 3.5 mm, which were projected on a screen at a magnification of x 40. In each field the thickness of the wall was measured in 5 locations at regularly spaced intervals. The results thus represent the means ± SD of 125 measurements per kidney.

The fraction of the muscular layer of the pelvic wall constituted by fibrous tissue was determined by point counting on projected microscopic fields at a magnification of x 670. Counts on fibrous tissue were recorded in each of 5 successive microscopic fields per section representing a total of 245 points and an area of approximately 2.0 mm^2. The fraction of fibrous tissue was then derived as the number of points on fibrous tissue divided by the total number of points. Two normal pig renal pelves served as controls.

Results

The first renogram showed normal kidney function and drainage in all pigs. At the first operation, the kidneys and the upper urinary tracts were all macroscopically normal. After 9 weeks of obstruction, the kidney function renographically was abolished on the left side (Fig. 1); per-operatively practically no parenchyma was found, and the renal pelvis was grossly enlarged.

The resting renal pelvic pressure was significantly increased to a mean of 44 cm H_2O (30.5–64.0). The highest pressure was found in the smallest pelvic compartment and the lowest pressure in a large compartment, while the rest of the pelves showed practically the same resting pressure regardless of volume (Table 1). The capacity of the pelvis at the resting pressure ranged from 29 to 154 cc (mean 77.5 cc). At a pressure of 80 cm H_2O the volume ranged from 32 to 167 cc (mean 94.5).

Figure 2 demonstrates the cystometry configuration of the pressure/volume tracings with a slow initial rise and a terminal steep rise.

Connective tissue fractions ranged from 0.28 to 0.42 and pelvic wall thickness ranged from 1.5 to 2.0 mm. Table 1 shows that no correlation could be established between the connective tissue fraction and pelvic volume nor between wall thickness and pelvic volume. In Table 1 the wall thickness and the connective tissue fraction of two normal systems are shown for comparison.

Discussion

The method of inducing obstruction by tubing the ureter was chosen in order to avoid damage to the ureteral wall. The method is known to cause total obstruction and causes total parenchymal destruction within 6 weeks [4]. Total obstruction was chosen to avoid doubt about the standardization of the obstruction. By the use of this method it is obviously not possible to evaluate the relationship between compliance and kidney function, but one is limited to study differences in compliance of the obstructed renal pelvis.

The resting pressure in the 8 pigs with a total obstruction was surprisingly high. Previous investigations are conflicting, some showing marginally increased pressures after 6 weeks [6] in contrast to others who have found that the pelvic pressure reaches its maximum within the first few days and becomes normal within 4 weeks [1, 11, 14]. These latter findings have raised questions as to the role of pressure in the pathogenesis of kidney damage in progressive hydronephrosis [14]. The present study adds evidence to the suggestion that increased pelvic pressure is of major importance, as also stated by Schweitzer [11]. This investigation thus supports the theory put forward by Weaver concerning balanced and non-balanced hydronephrosis [12] where pressure is of pathogenetic importance and compliance seems to balance the hydronephrosis.

The differences in capacity were not explicable by differences in the connective tissue fraction or wall thickness. Neither was any correlation found between pelvic pressure and pelvic volume. The pressure/volume relationship showed two phases, a low pressure filling phase and a steep terminal phase. This steep terminal phase was predominant in low capacity systems. The curves were similar to those found by Koff et al. in partial obstructions [6] and add evidence to a filling phase and an overdistension phase. The overdistension phase approximated to a linear relationship between pressure and volume increase and thus correlates to the linear relationship between volume and pressure found in normal dogs by Rosenkilde [10].

This investigation studied only a part of the mechanisms involved in the development of renal pelvic volume changes in obstruction. How changes in capacity take place is still unknown. This is currently under investigation.

References

1. Boyarsky S, Martinez J (1964) Pathophysiology of the ureter: Partial ligation of the ureter in dogs. Invest Urol 2:173
2. Constantinou CE, Djurhuus JC (1981) Pyeloureteral dynamics in the intact and chronically obstructed multicalyceal kidney. Am J Physiol 241:R398
3. Coolsaet BLRA, Griffiths DJ, van Mastrigt R, Duyl WAV (1980) Urodynamic investigation of the wide ureter. J Urol 124:666
4. Djurhuus JC, Nerstrøm B, Gyrd-Hansen N, Rask-Andersen H (1976) Experimental hydronephrosis. An electrophysiologic investigation before and after release of obstruction. Acta Chir Scand Suppl 472:17
5. Elling F, Hasselager E, Friis C (1977) Perfusion fixation of kidneys in adult pigs for electron microscopy. Acta Anat 98:340
6. Koff SA, Thrall JH (1981) Diagnosis of obstruction in experimental hydroureteronephrosis. Urology 17:570
7. Mortensen J, Bisballe S, Jørgensen TM, Tågehøj-Jensen F, Djurhuus JC (1982) The normal pressure-flow relationship of pyeloureter in the pig. Urol Int 37:68
8. Mortensen J, Djurhuus JC (1983) Pyeloureteral dynamics – renal pelvis pressure-flow relationship in pigs. Neurourol Urodynamics (in press)
9. Mortensen J, Djurhuus JC, Laursen H, Bisballe S (1983) The relationship between pressure and flow in the normal pig renal pelvis. An experimental study of the range of normal pressures. Scand J Urol Nephrol (in press)
10. Olsen PR (1979) The renal pelvis and ureteral peristalsis. Scand J Urol Nephrol 13:269
11. Schweitzer FAW (1973) Intra-pelvic pressure and renal function studies in experimental chronic partial ureteric obstruction. Br J Urol 45:2
12. Weaver RG (1968) Reabsorptive patterns and pressures in hydronephrosis with a clinical application. J Urol 100:112
13. Whitfield HN, Britton KE, Kelsey Fry I, Hendry WF, Nimmon CC, Travers P, Wickham JEA (1977) The obstructed kidney: Correlation between renal function and urodynamic assessment. Br J Urol 49:615
14. Zimskind PD, Davis DM, Lewis PL, DeCaestecker J, Berwind RT (1968) Complete obstruction of the ureter: Immediate and longterm effects on the renal pelvic pressure in dogs. Surg Forum 19:538

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