

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

## Part 4: Instability and Blow Out

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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 until the pressure did not longer increase linearly. By means of continuous X-ray monitoring and histological examination of the infused kidneys it was found that blow out may occur at pressure levels individually varying from 60 to 180 mmHg. The histological features of this phenomenon are presented and the clinical significance is discussed.

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

## Introduction

In previous reports it has been shown that the completely obstructed porcine pelvi-calyceal system under experimental conditions behaves as a stable elastic unit under pressure conditions lower than 50 mmHg. Under these conditions pressure-volume measurements are reproducible and indicate that after sudden complete obstruction intraluminal pressure rises initially in an exponential manner with volume until pressure values between 15 and 20 mmHg are reached. At higher pressure values there appeared to be a strong linear relation between pressure and volume until pressure values of over 50 mmHg were recorded. In addition a series of experiments was performed in which the completely obstructed pelvis was continuously infused at a rate of 2 ml/min until pressure no longer increased in a linear manner with volume. The results of these experiments are reported and discussed.

## Materials and Methods

The experimental set up, the theory of the P, V, t relations and the general description of material and methods have been presented in part 1 of this series.

In 17 experiments a series of measurements was concluded by emptying the pelvis and awaiting low diuretic output again. Then the pelvis was continuously infused at a rate of 2 ml/min until intrapelvic pressure no longer increased in a linear manner with volume. In 8 of these experiments the infusion was carried out with an urographine solution under continuous X-ray monitor control and pictures were made at intrapelvic pressure values of 40, 60, 80 mmHg and finally at any intrapelvic pressure level at which there was clear dissociation between the pressure and the volume increase. The kidneys were thereafter taken out for histological examination.

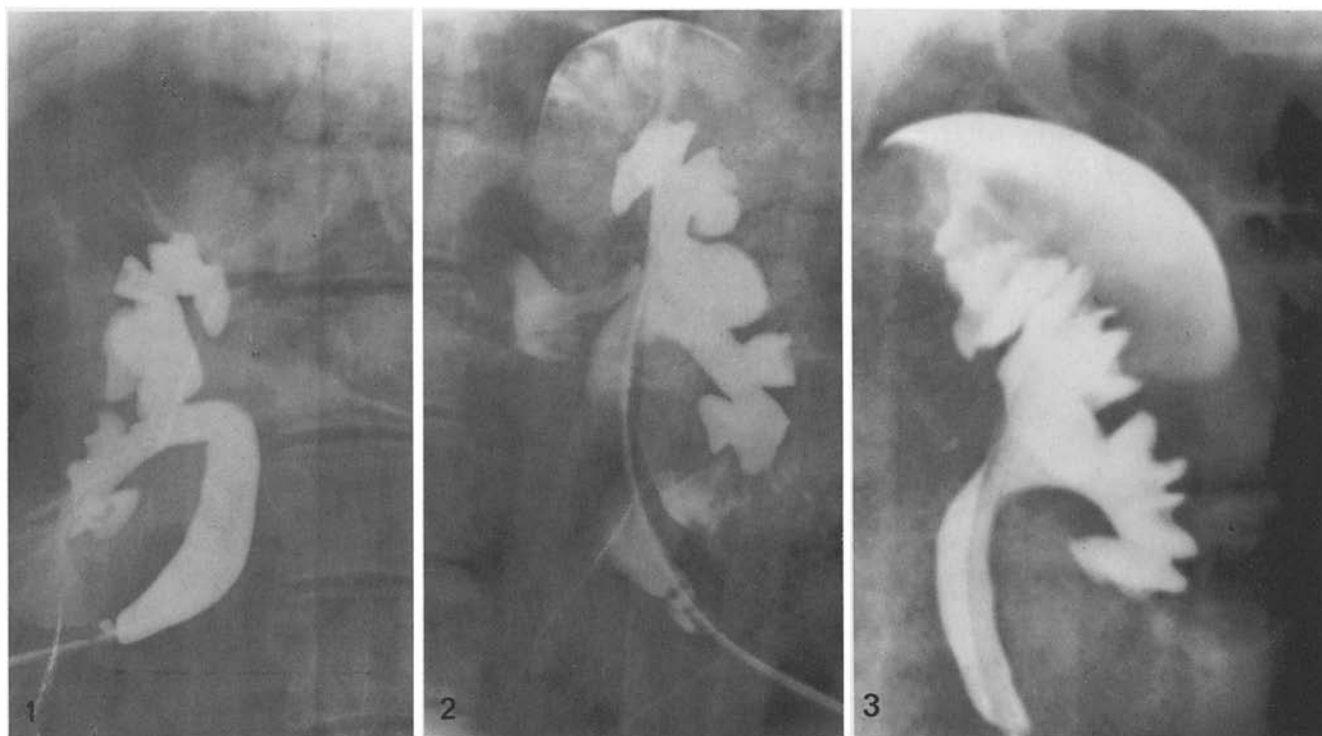
## Results

When the pelvis was continuously infused (2 ml/min) in 17 experiments it appeared that there was a strong individual variation in pelvic pressure level at which dissociation of the pressure volume relation occurred. The recorded pressures varied from 60–180 mmHg. Continuous X-ray monitor observation of the infused kidneys in 8 experiments showed that increasing tubular reflux occurred in all cases at intrapelvic pressure values between 60 and 80 mmHg (Fig. 1).

Subsequently a perirenal extravasate appeared to develop from the moment the intrapelvic pressure no longer increased in a linear manner with volume. Usually the extravasate started around the upper or lower pole of the kidney and in one case is started around the pelvis. The localisation of the leak could not be detected by continuous monitor observation but by examination of the X-ray films channel-like parenchymal lesions were detected in the upperpole of 4 kidneys (Fig. 2 and Fig. 3).

After removal of the kidneys macroscopic inspection revealed little injury in all cases. The most striking observations were that the fibrotic capsula had separated from the parenchyma, which showed patchy pink-blueish discolorations at the circumference (Fig. 4).

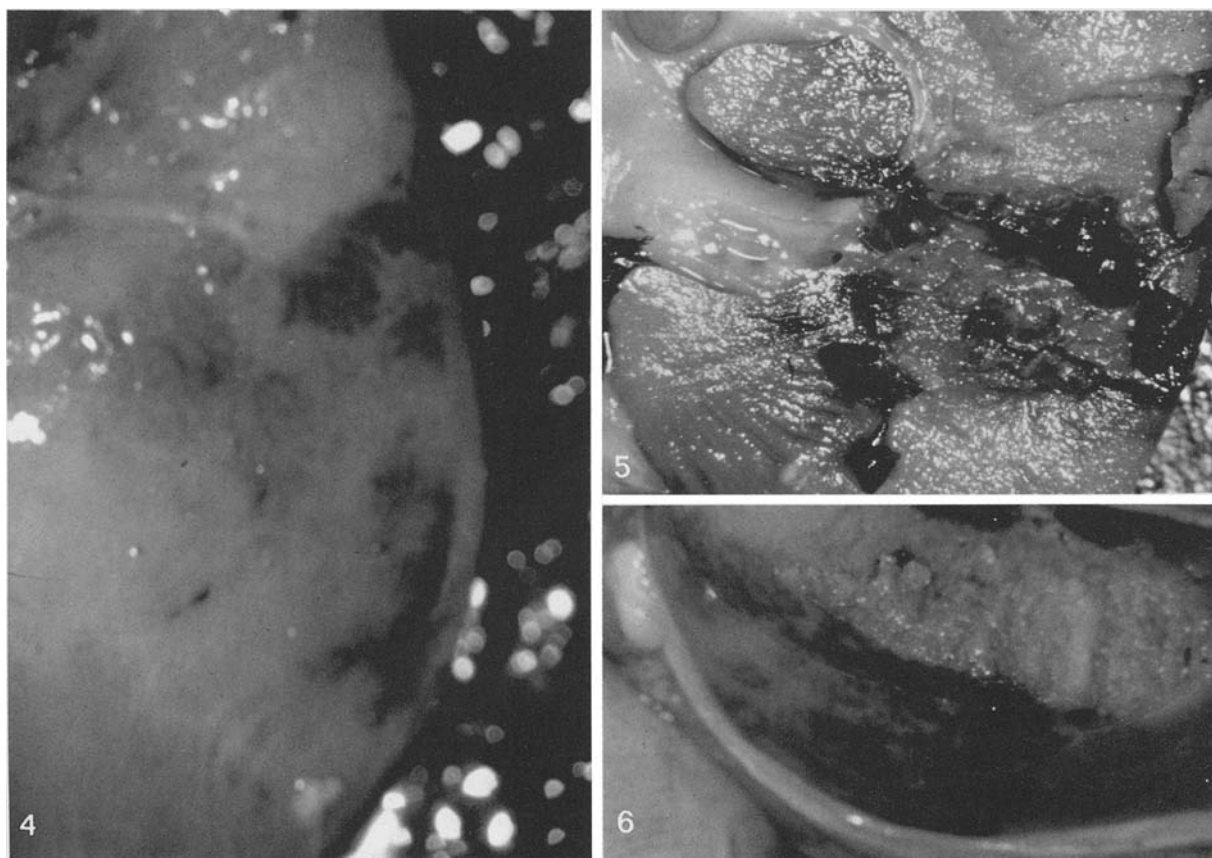
In only one case a tiny, one mm diameter lesion, was seen in pelvis when the kidney was opened by a median longitudinal incision. In all cases very small, for the naked eye hardly detectable lesions were then however discovered

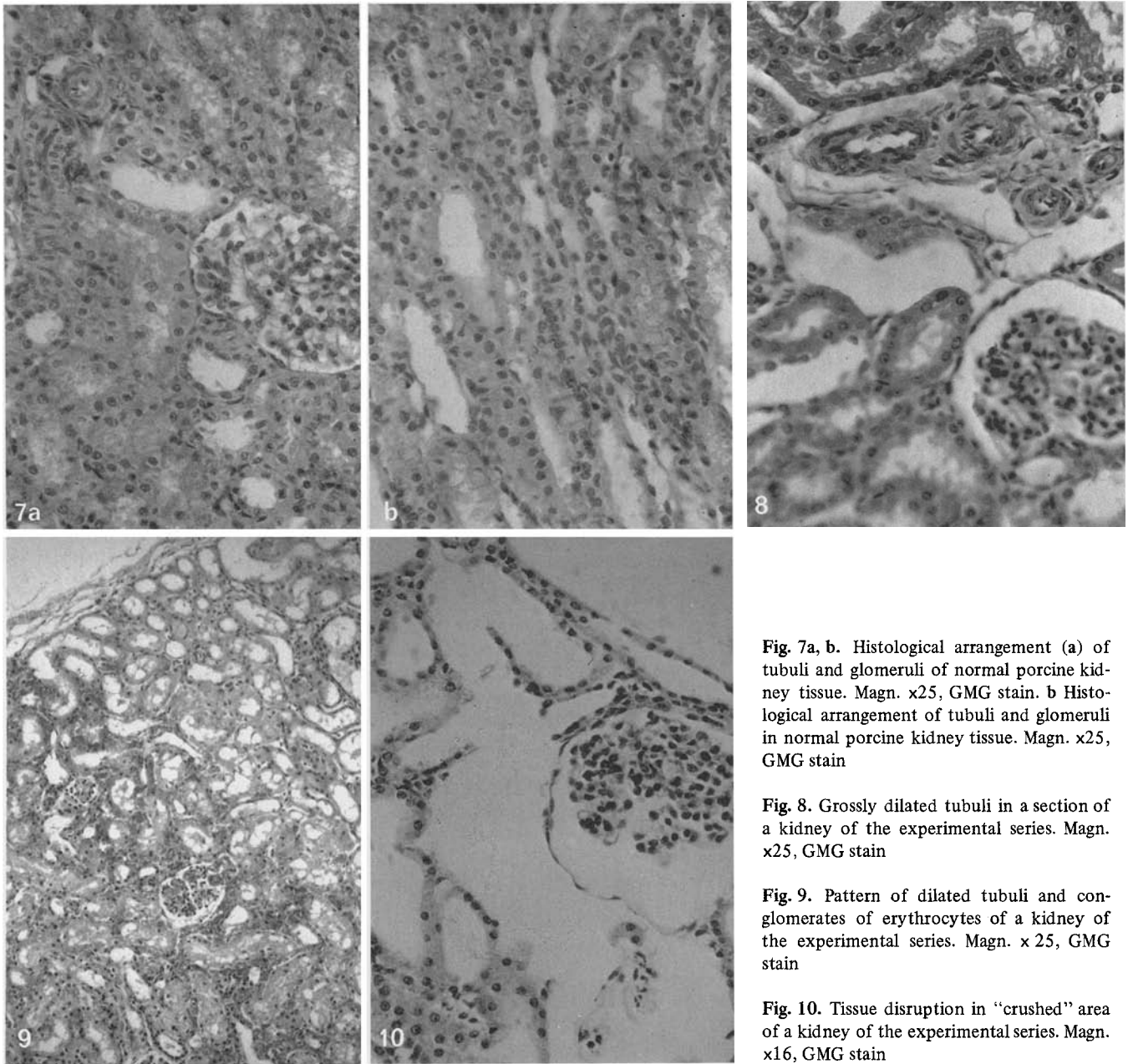


**Fig. 1.** Strong tubular reflux in both poles of the right kidney. Intrapelvic pressure is 80 mmHg

**Fig. 2.** Blow out of contrast medium round the upper pole, the lower pole and the pelvis of the left kidney ( $p > 120$  mmHg)

**Fig. 3.** Massive subcapsular extravasation round the upper pole of the left kidney through channel-like parenchymal lesions ( $p > 120$  mmHg)





**Fig. 7a, b.** Histological arrangement (a) of tubuli and glomeruli of normal porcine kidney tissue. Magn.  $\times 25$ , GMG stain. b Histological arrangement of tubuli and glomeruli in normal porcine kidney tissue. Magn.  $\times 25$ , GMG stain

**Fig. 8.** Grossly dilated tubuli in a section of a kidney of the experimental series. Magn.  $\times 25$ , GMG stain

**Fig. 9.** Pattern of dilated tubuli and conglomerates of erythrocytes of a kidney of the experimental series. Magn.  $\times 25$ , GMG stain

**Fig. 10.** Tissue disruption in "crushed" area of a kidney of the experimental series. Magn.  $\times 16$ , GMG stain

in the upper or lower pole of the organs. In only one kidney a small caliber parenchyma fistula from a fornicial lesion to the circumference could be distinguished.

In all other cases the parenchyma round the fornicial lesions seemed to be intact but had a somewhat crushed aspect (Fig. 6).

Histological preparations were made of over 30 apparent and suspected lesions and on microscopic examination the tubuli appeared to be invariably dilated, the glomeruli and

tubuli contained conglomerates of free erythrocytes and channel-like interstitial parenchymal lesions (Figs. 7–10).

### Summary and Conclusions

The observations in these experiments showed that the recorded pressure-volume instability occurred at a wide range of pelvic pressures, individually varying from 60 to

◀ **Fig. 4.** Patchy pink-blueish discoloration of the upper pole parenchyma

**Fig. 5.** Parenchymal lesions in the upper pole

**Fig. 6.** Crushed aspect of upper pole parenchyma, detachment of the fibrotic capsula and blueish discoloration of the circumference

180 mmHg and was due to "blow-out" of the pelvic volume which usually escaped through microscopic lesions in the renal parenchyma to the convexity of the organ.

Peripelvic extravasation of contrast media after sudden ureteral obstruction under varying clinical conditions has been reported for over 50 years and a literature review about extravasation in connection with passage of calculi has recently been published [2]. The literature study revealed that these extravasates rarely occur in patients who have no detectable abnormality of the peri-calyceal system, but the incidence increases when high doses of contrast medium are given. The lesions cannot, as a rule, be detected by X-ray film examination or surgical exploration and extravasation usually ceases when adequate ureteral passage establishes a decrease of pelvic pressure.

It is generally accepted that most lesions are located in an upper or lower pole calyx fornix and that the extravasates then force a way out into the hilus renalis [1, 3–8]. In view of this literature it is somewhat surprising that in our experiments the pathway for the extravasates were in all examined cases found in the renal parenchyma. This might imply that under these experimental conditions the porcine kidney behaves differently, or, that formerly the microscopic parenchyma lesions have been overlooked. In any case, this question will not be of interest for management of the clinical problem. The questions that in this context still are of interest concern the influence of diuretic activity in varying hydration conditions of the animal, of diuretics

and X-ray contrast media on pelvic pressure in the completely obstructed pelvi-calyceal system. These items will be subject of further experimental study and future reports.

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