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Simultaneous Measurement of Absolute Pressure Values in the Urethra and Bladder

Experimental Model for the Construction of a New Measuring Device

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Summary. In order to improve the accuracy of bladder and urethral pressure recording, a measurement system has been tested experimentally. It is possible to measure absolute pressure values during withdrawal of the catheter only when the system is constantly perfused. The optimum relationship between catheter diameter, perfusion rate, withdrawal rate, measurement inertia and systemic resistance has been analysed.

Key words: Urethral pressure profile - Bladder pressure - Experimental model.

Pressure measurement in the human body has become an indispensable technique for both diagnostic and experimental examinations. The problem of pressure measurement in various hollow organs and ductal systems is the reproducible registration of absolute pressure values. For simultaneous pressure measurement in the bladder and urethra and registration of the urethral profile we have constructed a perfused measuring system including a newly designed catheter.

The ideal measuring system should fulfil the five following criteria:

1. the reproducible registration of absolute pressure values.
2. minimal catheter resistance.
3. minimal inertia of registration.
4. simultaneous measurement in both bladder and urethra.
5. catheters adjustable for various urethral diameters.

MATERIAL AND METHODS

Commercial catheters of Charriere 14 to 20 gauge were used. These catheters were fitted with Polyethylene Microtubes of between 0.38 and 1.67 mm diameter. (Fig. 1). The Microtubes were filled with 0.9% saline or were perfused at various perfusion rates from 0.21 to 12.6 ml/min.

Catheter performance was examined by inserting the catheter into an elastic rubber tube contained within a rigid plastic cylinder (Fig. 2). This model is based on the principle of the well known Starling resistance (3). The cylinder pressure was varied between 0 and 100 mm Hg and recordings made with the catheter stationary and during withdrawal at 5 mm/s. Direct cylinder pressure and pressure obtained via the catheter were simultaneously registered by Statham transducers onto a chart recorder.

RESULTS

A non-perfused catheter did not register the cylinder pressure values accurately during withdrawal. Using a continuously perfused system, absolute pressure values were obtained. Accuracy and reproducibility of measurement depended upon the three factors:

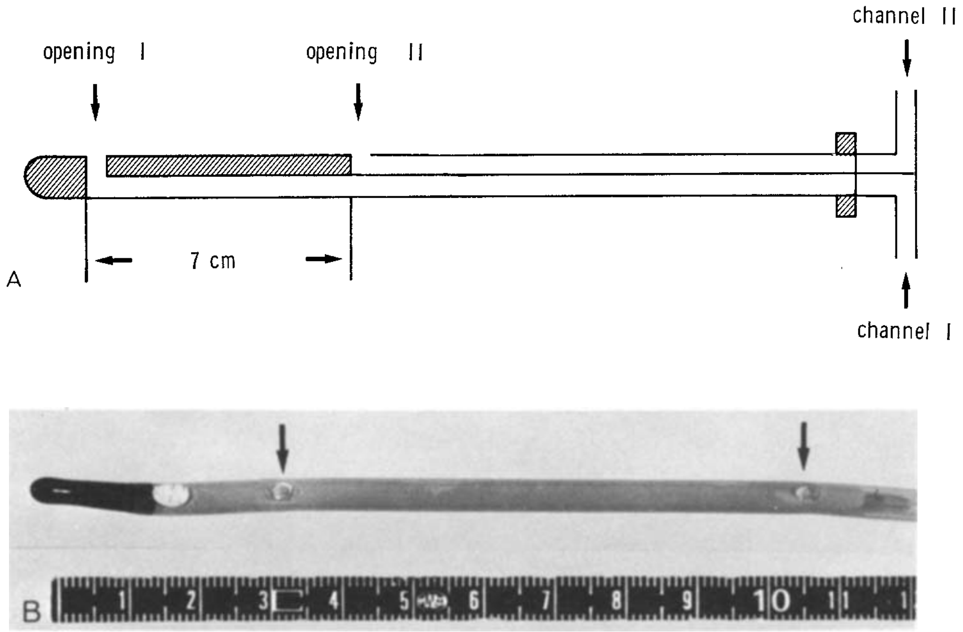

Fig. 1 A and B. A - Schematic drawing of the urological catheter for simultaneous pressure measurement in bladder and urethra. B - The urological catheter (two measurement channels) consisting of a Thieman catheter fitted with 2 polyethylene microtubes (Perfusion-openings marked with arrow)

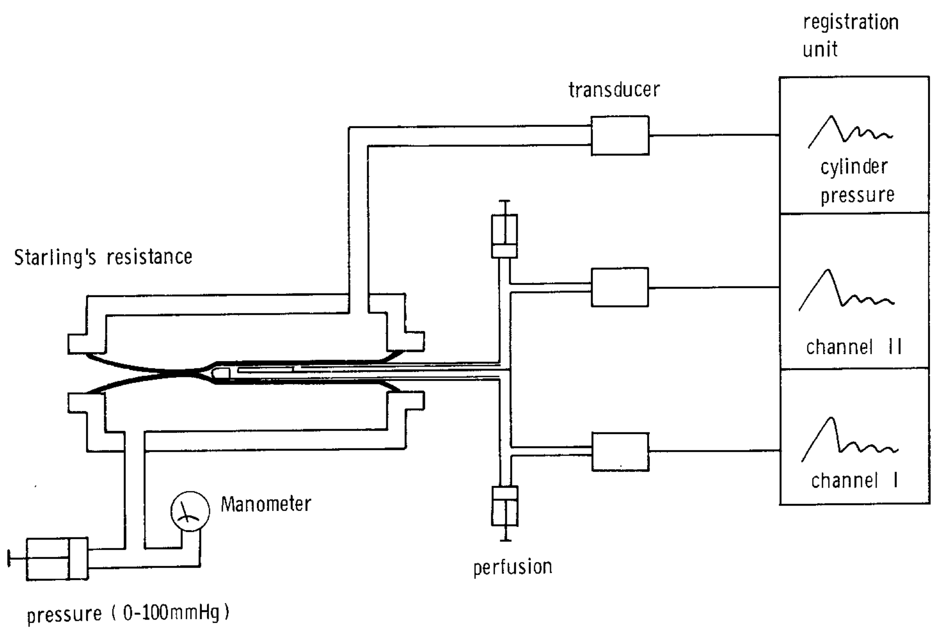

Fig. 2. Experimental set up to examine the charactistics of the catheter in "Starlings resistance". Chamber pressure and the 2 pressure values recorded by the catheter were registered simultaneously

1. withdrawal rate
2. perfusion rate
3. diameter of perfused microtube.

Withdrawal rate was held constant throughout these experiments at 5 mm/s. Figure 3 shows the minimum perfusion rate required in order to accurately register a pressure of 100 mm Hg in relation to the microtube diameter. It shows that registration is not possible when the microtube is of less than 0.46 mm diameter. Using the results obtained experimentally we calculated the regression line $y = 15x - 12.5$ from which it is possible to extrapolate the corresponding perfusion rates for any diameter of microtube. Thus microtube II (diameter 1.14 mm) requires a minimum perfusion rate of 4.4 ml/min in order to accurately register pressure waves of 100 mm Hg.

That a minimal perfusion rate is required in order to register an absolute pressure value is also shown in Figure 4. This is due to the inertia inherent in the system and Figure 4 shows the delay in registration at various perfusion rates for microtube II (diameter 1.14 mm). These figures are obtained while recording a pressure of 100 mm Hg. With a perfusion rate of 0.21 ml/min a time interval of 132 seconds

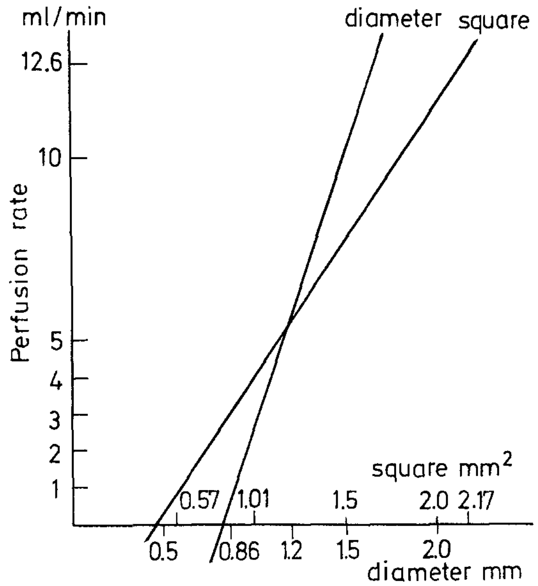

Fig. 3. Minimal perfusion rate to register absolute pressure values, recording pressure waves of 100 mm Hg regarding various diameters of microtubes. (1) Regression line for change in diameter y = 15x - 12, 5, (2) Regression line for change in square y = 7,49x - 3, 56

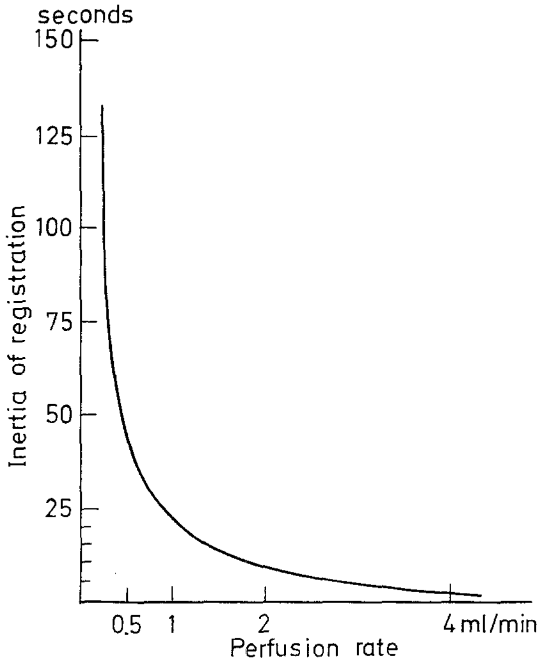

Fig. 4. Time interval necessary to record the given chamber pressure of 100 mm Hg using various perfusion rates (inertia of registration). These values belong to the microtube with diameter of 1,14 mm

is required for the accurate registration of the absolute pressure values. At a flow rate of 4.4 ml/min the delay in registration approximates to zero.

The resistance of the tube will give rise to a constant error in all measurements dependent upon the diameter and the perfusion rate. Figure 5 illustrates the catheter resistance at various flow rates for three different microtubes. Increasing the diameter of the microtube at a constant flow rate reduces the resistance. At the minimum flow rate for the registration of pressure waves of 100 mm Hg, which is 4.4 ml/min for microtube II, the resistance is 7.5 mm Hg. When each microtube is examined at the individually appropriate minimum flow rate required for the recording of pressures of 100 mm Hg the resistance approximates to 7.5 mm Hg.

DISCUSSION

It is evident from these results that a perfused measurement system must be used for the simultaneous recording of bladder pressure and the urethral pressure profile. Non-perfused side-hole catheters do not record absolute pressure values while the catheter is being withdrawn. To record absolute pressure values of 100 mm Hg while withdrawing the catheter a minimum perfusion rate is required for each

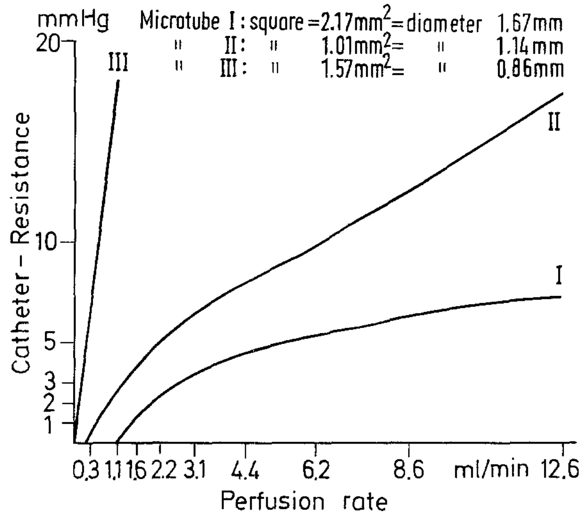

Fig. 5. Systemic resistance using 3 commercial polyethylene microtubes with various flow rates
tube I diameter 1,67 mm square 2,17 mm²
tube II diameter 1,14 mm square 1,01 mm²
tube III diameter 0,86 mm square 0,57 mm²

diameter of microtube (Fig. 3). It is possible to use a lower perfusion rate for simple withdrawal measurement in the urethra (e. g. without coughing or abdominal pressures) for recording pressure waves lower than 100 mm Hg.

The resistance for all tested microtubes using the individual minimum perfusion rates is 7.5 mm Hg. An error in measurement which increases with increasing perfusion rates, is more the result of a systemic resistance than of viscous effects (2). The systemic resistance can be cancelled out because it is added linearly to all absolute pressure values measured during an examination. Therefore absolute pressure of 50 or 100 mm Hg will be recorded by the system as 57.5 or 107.5 mm Hg. This constant factor cancels out when the system is calibrated. Using a higher perfusion rate in a constant diameter microtube, the systemic resistance rises (Fig. 5). By increasing the perfusion rate, the inertia of measurement can be diminished (Fig. 4). So the measurement inertia can be diminished by increasing the perfusion rate, as well as by increasing the diameter of the microtube. However a high perfusion rate causes irritation of the urethral wall, producing a contraction. Therefore minimal perfusion rate and increased diameter should be used.

However if the catheter causes dilatation of the urethra, the recorded pressure values are higher than the real one (2). Therefore the catheter diameter must be related to the diameter of the urethra. In addition the diameter of the microtubes is limited by the inner diameter of the catheter used. For manometric examinations in patients therefore, an assortment of catheters is necessary. The correctly selected catheter, when perfused and withdrawn, is suitable for measuring pressure waves of high frequency such as coughing and abdominal pressure. These findings are contrary to the results of Drouin and McCurry (1).

The experimental model shows a direct dependence of the accuracy in pressure recording on the diameter of the microtubes and the perfusion rate. With the diagrams in Figures 3-5 it is possible to find the optimal correlations for construction and management of the measuring system regarding diameter of microtubes, diameter of catheter, measurement inertia, perfusion rate and withdrawal rate.

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