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NOISE RECORDINGS AT DIFFERENT DEGREES OF OBSTRUCTION IN MODEL URETHRAE WITH DIFFERENT WALL STIFFNESS MADE OF POLYVINYL ALCOHOL CRYOGEL.

Aims of study

At present, an invasive pressure flow study (PFS) is recommended to diagnose bladder outlet obstruction (BOO). An alternative method, perineal noise recording, has been proposed as a non-invasive diagnostic technique to grade urethral obstruction [1]. Noise may be caused by turbulence in the narrowing of the urethra by e.g. an enlarged prostate [2]. We assume that the elastic and viscoelastic properties of the urethra influence the noise production during flow. Recently, it was reported that a flexible and distensible tube, as the urethra, could easily be constructed using Polyvinyl Alcohol (PVA) cryogel [3]. The number of freeze / thaw cycles, the rate of thawing and the concentration of the PVA controls its elastic properties. In the present study, we made three PVA models of the urethra to investigate if noise depends on the degree of obstruction and if the production of noise is influenced by the elastic properties (stiffness) of the model wall.

Materials and methods

We made three PVA models (U1, U2 and U3) of the urethra by pouring liquid PVA in a cylindrical mould (450 mm in length, 16 mm in diameter) with a Y-shaped slit in the centre of the mould to allow flow. Model U1 was freeze-thawed 2 times, U2: 3 times and U3: 4 times. The difference in the number of cycles led to differences in wall-stiffness between the models. Based on previously presented data, the elastic modulus (quantifying stiffness) was approximately $2x10^5$ N/m^2 in U1, $3x10^5$ N/m^2 in U2 and $4x10^5$ N/m^2 in U3 [3]. Each model was placed in a self-made container filled with water, see figure 1. Via a turbine flow meter, one side was connected to a water column representing "bladder pressure", $p_{bladder}$. The other side was connected to an outflow tube. An inflatable cuff, controlled by a second water column, $p_{prostate}$, represented the applied obstruction and was placed around each model. Noise was recorded at a fixed distance of 5 cm from the midpoint of the cuff using a waterproof-made piezoelectric microphone. Five times we recorded noise at three different $p_{bladder}$ values (75, 100 and 150 cmH_2O) in each model. The flow rate was kept constant at 6 ml/s by applying three different $p_{prostate}$ values (~ 60, ~90 and ~140 cmH_2O respectively), resulting in three degrees of obstruction: low, medium and high. The produced noise (amplified 10 times and band-pass filtered between 50-5000 Hz) was sampled at a rate of 10 kHz and stored on a PC. We selected 2^{19} samples (~50 sec.) from each recording to calculate the average noise amplitude, A_{mean}, and the power spectrum of the signal by fast Fourier transform. The power spectrum was quantified by the mean power frequency, f_{mean}, calculated as the quotient of the sum of frequencies times the corresponding power and the sum of the power between 200 and 1000 Hz [1]. The dependence of A_{mean} and f_{mean} values on the degree

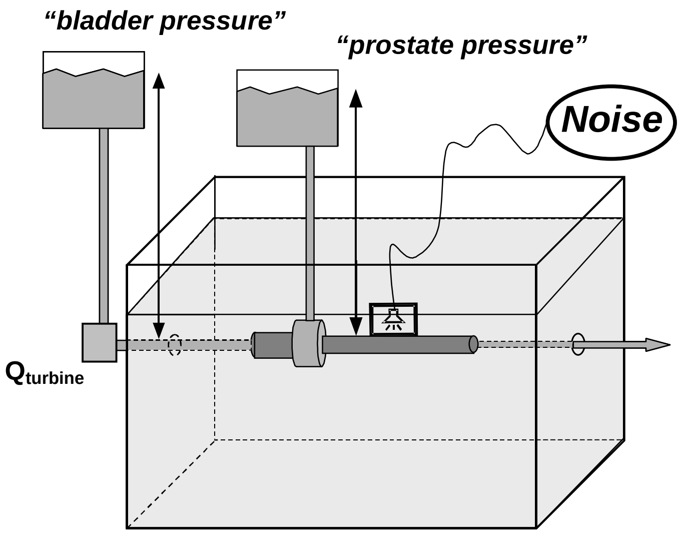

Figure 1 Schematic drawing of the measurement set-up with $Q_{turbine}$ the flow rate measured by the turbine flow meter and an inflatable cuff, placed around the model, with internal "prostate pressure" the applied obstruction (e.g. enlarged prostate).

of obstruction and the wall-stiffness of the urethral model was statistically tested using a Multivariate Analysis of Variance.

Results

The average values of the mean power frequency and the average amplitude (mean ± sd) are presented in Table 1. Both were significantly different between the different degrees of obstruction and between the urethral models with different wall-stiffness ($p < 0.05$). This difference is expressed in an increase in both frequency and amplitude with increasing degree of obstruction. However at each degree of obstruction there is an increase in frequency opposed to a decrease in amplitude with increasing wall-stiffness.

Table 1 Average ± standard deviation of the mean power frequency, f_{mean} (Hz), and the average noise amplitude, A_{mean} (mV), in 5 series of noise recordings in three urethral models with different wall-stiffness at three degrees of obstruction (low, medium, high). The flow rate at each measurement was kept constant.

Obstruction \ Model		U_1	U_2	U_3
Low	f_{mean}	279 ± 16	316 ± 19	349 ± 18
	A_{mean}	922 ± 246	618 ± 110	390 ± 88
Medium	f_{mean}	303 ± 42	324 ± 25	375 ± 31
	A_{mean}	1479 ± 505	834 ± 112	622 ± 76
High	f_{mean}	318 ± 23	349 ± 41	381 ± 43

Interpretation of results

A method for diagnosis and classification of BOO based on perineal noise recording would be non-invasive, inexpensive and patient-friendly. The results show, that substantial elevations of obstruction may be graded on the basis of the mean power frequency and the average amplitude of noise measured externally to the urethral model. The noise is probably caused by turbulence of flow through the model due to the applied obstruction. This study also shows that the noise produced depends on the wall-stiffness of the urethral model. More tests must be done in the model to further investigate the relation between the viscoelastic properties of the wall and the noise production and the location of the microphone along the model, before clinical measurements are in order.

References

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