Bladder wall movement patterns associated with bladder dysfunction are observed in muscle strips and isolated organs. This study investigates whether multiple acceleration sensors placed on the urinary bladder wall can detect bladder movements in vivo. We implanted a sensing system in Gottingen minipigs containing 4 accelerometers and a submucosal pressure sensor. Consecutive awake voiding cystometry was performed with air-charged catheters in a standard urodynamic set-up as comparators. Measured acceleration signals were separated by frequency-based filtering resulting in linear acceleration and change of sensor orientation. This is the first report of bladder wall acceleration in a voiding animal model, demonstrating potential for long-term continuous measurement of motion.

Methods and Materials

In collaboration with the micro-electronic engineering department, we developed an implant with four accelerometers (Bosch BMA280) and a submucosal pressure sensor (MS5637) as shown in Figure 1.

Following surgical implantation and 7 days recovery, we performed weekly consecutive voiding cystometries. A 3-way air-charged urethral catheter and standard urodynamic set-up was used as comparator.

The acceleration signals consisted of high-frequency oscillatory bursts of linear acceleration and a baseline value. This baseline is determined by the orientation of a particular axis relative to gravity. Change in baseline value (Δa) was calculated by subtraction of the start value from the end value. Total linear acceleration (TLA) from three axes of the same sensor was calculated by root mean square.

We estimated sensor orientations in to plot direction of acceleration vectors in a single 3-dimensional coordinate system (Figure 3).

Start of voiding was adapted from definitions of voiding phase 1 described by Andersson et al. as shown in Figure 2. We compared accelerometer measurements to adjacent 10-second premicturition periods. Values are mean +/- SD unless otherwise specified.

Discussion

Submucosal pressure traces were more consistent on repeated voiding compared to catheter traces. In some cases, catheter sensitivity was decreased in subsequent micturitions.

Accelerometer measurements mark the start of voiding by increased TLA. Baseline accelerometer value during voiding reflects change in bladder wall orientation and volume. This also indicates quite clearly the emptying of the bladder at the end of the cycle.

Conclusions

This is the first report of acceleration data recorded in vivo from an awake voiding animal model from multiple sites in the bladder. We observed an increase in acceleration activity at the start of voiding and change in baseline acceleration during voiding. Analysis of the entire voiding cycle, integrating input of all four sensors will further establish the potential use of accelerometers in the study of bladder motion. This implantable device is the first step towards identifying autonomous bladder micromotions in situ.

References
