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AN IMPLANTABLE PRESSURE SENSOR TO DETECT THE ONSET OF URINARY BLADDER CONTRACTIONS

Hypothesis / aims of study

Conditional electrical stimulation of the dorsal genital nerve, applied at the onset of an involuntary detrusor contraction can suppress the involuntary contraction [1]. This both maintains low storage pressure and prevents incontinence episodes. The aim of this study was to investigate whether an implantable pressure sensor placed in the bladder wall could be used to detect the onset of bladder contractions.

Study design, materials and methods

Implantable pressure sensors were constructed from small piezoresistive sensor dies mounted on 8x8 mm ceramic substrates. Wires were attached, and the sensors were encapsulated with silicone (MED-4011, NuSil Technology LLC, Carpinteria, CA) so that the final assemblies were lens shaped with diameters of 13.6 mm and heights of ~1.5 mm.
Acute experiments were performed in 6 pigs. A bipolar cuff electrode was placed on a unilateral pelvic nerve to evoke artificial bladder contractions. An abdominal midline incision was made to expose the bladder. Small pouches were made in the bladder wall by blunt dissection. Sensors were placed in the pouches, and they were closed by a suture. During most experiments, two sensors were placed simultaneously. A transurethral double-lumen catheter was placed in the bladder. One lumen was used for artificial filling; the other was connected by a small tube to an external pressure transducer. All pressure transducers were connected to an amplifier and a data acquisition box, both controlled by a computer. The cuff electrode was connected to a custom-made stimulator, also controlled by the computer.
The bladder was filled with 150 ml warm water. Hemispherical bladder contractions were evoked by electrical stimulation, and the pressure was recorded simultaneously from all sensors. Stimulation parameters were monophasic pulses, 30 pps, and pulse width 150 µs. Stimulation was on for 10 s, and there was at least 5 min between consecutive bladder contractions.
Contraction onset was determined by an adaptive threshold algorithm. Baseline pressure was tracked by a 30 s moving average filter. A threshold set at a level of 5 cmH_2O above baseline was used to define the point of onset. The same algorithm was used for all sensors and across all animals.

Results

A total of 70 hemispherical bladder contractions were evoked. Of these, 65 could be detected using the reference sensor. Only these 65 were used for further analysis. Two typical contractions are shown in figure 1. The mean peak intravesical pressure during contractions was 11.4 ± 3.0 cmH_2O (n = 65, range 6.5 to 19.5 cmH_2O). During the 65 contractions, 114 recordings were made from implantable sensors. Onset was detected from 101 of the 114 recordings; however, they were distributed such that all contractions were detected by at least one implantable sensor. The mean onset detection latency of the implantable sensors, compared to the reference sensor, was -300 ms. That is, detection using the implantable sensors occurred prior to detection using the reference sensor. 91 of the 114 recordings from implantable sensors showed a correlation coefficient above 0.9 with the reference signal.

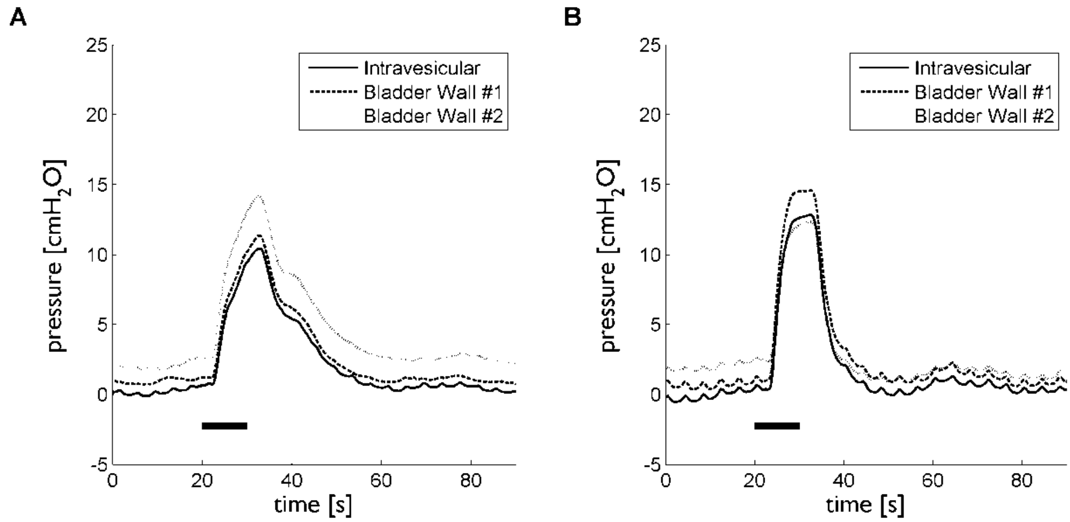
Interpretation of results

Five contractions could not be detected using the reference sensor. In three cases the reason was that the pressure was too low; in two, unreliable signals were obtained.
Experiments were performed both with the pressure sensitive membrane facing the bladder lumen and facing away from the lumen. In general, recordings made with the membrane facing the lumen correspond very well to recordings from the reference sensor. Recordings made with the membrane facing away from the lumen showed poor performance in detecting contraction onset. There was no difference between recordings from pouches located at the bladder base and at the bladder dome.
The evoked bladder pressures were lower than expected. The reason for this is unknown. As a consequence a somewhat low detection threshold of 5 cmH_2O was used. Much of the variation in detection latency can be ascribed to using a general detection algorithm across all animals. Had the algorithm been optimized to each animal, most of the large latencies could be eliminated.

Concluding message

Pressure sensors placed in the bladder wall work well for detecting the onset of urinary bladder contractions. Creation of pouches and placement of sensors were easy. Chronic experiments are necessary to verify the long-term stability. If successful, this would enable the development of an implantable neuroprosthesis for treating neurogenic detrusor overactivity by conditional electrical stimulation.

Figure 1



Typical pressure recordings during evoked bladder contractions. ***A:*** *Wall sensor #1 placed ipsilaterally with respect to stimulation side, at the bladder dome, and with the membrane facing the bladder lumen. Wall sensor #2 is placed at the ipsilateral bladder neck, with the membrane facing the lumen.* ***B:*** *Wall sensor #1 placed at contralateral dome, membrane facing the lumen. Wall sensor #2 placed at contralateral neck, membrane facing lumen. Pressures from implantable sensors are shown at a 1 and 2 cmH$_2$O offset, respectively, to separate the curves. The black bar indicates when pelvic nerve stimulation was on.*

References

1. Hansen J, Media S, Nøhr M, Biering-Sørensen F, Rijkhoff NJM and Sinkjær T: Treatment of Neurogenic Detrusor Overactivity in Spinal Cord Injured Patients by Conditional Electrical Stimulation. J. Urol. 2005; 173:2035-2039.

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Were guidelines for care and use of laboratory animals followed or ethical committee approval obtained?	**Yes**
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