Utility of Periurethral Electric Stimulation to Reduce Voiding Frequency in Rats

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Urinary continence is maintained through coordination of electrical (nervous) and mechanical (muscles, ligaments and other structures) systems in the body. During micturition, the central nervous system sends a signal to the detrusor and sphincter muscles to coordinate voiding. Pathological problems can undermine either of the two systems and result in urinary incontinence (UI). Thirteen million people in the United States live with UI. Clinical treatments to date are largely mechanical in nature, restoring function through surgical interventions. However, electrically-based treatments, such as electric stimulation, offer a promising alternative. Here we investigate the utility of electrical stimulation of the periurethral neuromusculature to reduce voiding contractions in well-controlled animal experiments. Female Sprague Dawley rats were anesthetized with a ketamine/xylazine/acepromazine cocktail and the bladder was catheterized through a small incision in the bladder dome and was infused with saline. Continuous filling of the bladder triggered related cycles of voiding which was identified through bladder pressure increases and visual urination. The pubic symphysis bone was cut to expose the urethra and a stimulating electrode was placed in the periurethral region. The electrical stimulation parameters were 2.8 mA of current, 200 us pluses, and 20 Hz. The electrical stimulation was done in fifteen minute intervals. Statistically, the rats without electrical stimulation have an average contraction period of 63.1 sec (+/– 31.3 sec) and the rats with electrical stimulation have an average contraction period of 97.2 sec (+/– 43.0 sec). The results showed that the electrical stimulation of the periurethral neuromusculature in the group revealed 54.0% increase in average contraction period and decrease in voiding frequency. Electrical stimulation of the periurethral neuromusculature increases the voiding interval and void volume for the rats. This suggests the existence of an external urinary sphincter to the bladder inhibitory pathway and supports periurethral neuromusculature stimulation as an alternative to spinal nerve stimulation for the treatment of bladder overactivity.

A Wireless, Passive pH Sensor Based on Magnetic Higher-Order Harmonic Fields

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A wireless, passive sensor was fabricated for remote monitoring of chemical analytes in the human body. The sensor was made of a magnetically soft film (sensing element) and a permanent magnetic film (biasing element) sandwiching a reversibly swelling hydrogel. When subjected to a low frequency magnetic AC field, the sensing element generated higher-order harmonic magnetic fields that were detected with a remotely located detection coil. In the presence of a DC magnetic field (biasing field), such as that generated from the biasing element, the pattern of the higher-order harmonic magnetic fields varied, and the magnitude of change (referred to as the harmonic field shift) was proportional to the strength of the biasing field. The hydrogel, which acted as a transducer that converted variations in the chemical concentration into changes in dimensions, physically varied the separation distance between the sensing and the biasing elements. This causes a change in the magnitude of biasing field experienced by the sensing element, thus changing its higher-order harmonic field shift allowing remote measurement of chemical concentrations. The novelty of this sensor was its wireless and passive nature, which allows it to be used inside a human body for long term chemical monitoring. A scaled-up prototype was fabricated and tested to demonstrate the pH monitoring capability of the sensor. The main structure of the prototype sensor was a polycarbonate substrate containing a larger rectangular well of 36 mm $\times$ 8 mm $\times$ 4 mm on top of a smaller well of 30 mm $\times$ 5 mm $\times$ 2 mm (see Fig. 1). The smaller well was filled with hydrogel made of (poly)vinyl alcohol and (poly)acrylic acid. A commercial magnetoelastic thick film, Metglas 2826MB from Metglas Inc., was attached to the step at the bottom of the larger well and allowed to rest on the hydrogel. The DC magnetic field was provided by an Arnokrome III film (Arnold Magnetic Technologies) of 30 mm $\times$ 6 mm attached at the bottom of the sensor structure. The sensor was placed on the detection coil, and its response was measured with a spectrum analyzer while exposed to test solutions of varying pH. The sensor's harmonic field shift, when cycled between pH 7 and pH 3, was measured and plotted in Fig. 2. As shown in the figure, the hydrogel swelled when the sensor was exposed to pH 3, decreasing the harmonic field shift. The response and recovery times of the hydrogel were below 2 minutes. This experiment proves the feasibility of the technology for real-time, remote monitoring of pH. Further work includes improving the response time and sensitivity of the hydrogel, as well as miniaturization of the sensor.

