Development of a Non-Invasive, Catheter Based Method to Activate Urethral Afferents

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Abstract

Recent studies in animal models have shown that bladder contractions can be evoked by electrical stimulation of pudendal urethral afferent nerve fibers, even following spinal transection. Control of bladder activity would be a valuable tool to assist individuals with neurological disorders or spinal cord injury. To investigate these neural pathways in humans, a non-invasive approach is required. This project sought to develop and validate a non-invasive method to activate urethral sensory pathways. A stainless steel ring electrode was fabricated onto a 3.5 French urethral catheter and used for intra-urethral stimulation. Robust bladder contractions were generated via intra-urethral electrical stimulation in 3 cats. Peak responses were obtained in the proximal and prostatic urethra. No responses were observed within the bladder neck, urethral sphincter or distal urethra. Bladder responses were equivalent to those evoked by direct stimulation of pudendal urethral sensory nerves. We intend to use this catheter-based method to investigate the effects of intra-urethral stimulation on bladder activity in humans with spinal cord injury.

1. Introduction

Neurological disease or spinal cord injury (SCI) can result in loss of voluntary control of bladder evacuation, bladder hyper-reflexia, and bladder sphincter dysynergia. The long-term goal of this research is to develop a neural prosthesis to restore bladder function in persons with neurological disorders, particularly spinal injury.

Recent studies have shown that bladder contractions can be evoked by activation of pudendal urethral afferents, even following spinal transection. Fluid flow in the urethra [4] and electrical stimulation of the pudendal urethral sensory branches [3,5,6] have been shown to activate the bladder. In addition, increases in bladder pressure [2,6] and reductions in urethral sphincter activity [6] have been evoked by electrical stimulation of the urethral sensory branch of the pudendal nerve following acute spinal transection. These results suggest the neuronal circuitry required for reflex bladder contractions exist within the spinal cord and may be accessed via urethral afferents.

To determine the feasibility of producing micturition in persons with spinal cord injury via electrical stimulation of pudendal urethral afferent nerve fibers, a non-invasive method is required since the urethral sensory branch of the pudendal nerve is not readily accessible for direct stimulation. It should be possible to activate the urethral sensory branch via the urethra, and previous investigators have used catheter-based electrodes to measure sensory perception thresholds for electrical stimulation of the urethra [1,9]. The objective of this project was to develop and validate a urethral-catheter-based method to activate urethral sensory pudendal nerve fibers.

2. Methods

Three acute experiments were conducted in adult male cats. All animal care and procedures were according to NIH Guidelines, publication No. 86-23, revised 1985, and were approved by the Institutional Animal Care and Use Committee. Animals were anesthetized with ketamine (35 mg/kg, IM), and maintained with alpha-chloralose (60 mg/kg IV). The bladder was cannulated to control bladder
volume, and the cannula connected to an external transducer to monitor bladder pressure. Reflex bladder contractions were generated by filling the bladder with warm saline while obstructing the bladder neck and urethra with a catheter. Bladder volume was adjusted to near the threshold for reflex bladder contractions.

A 3.5 French urethral catheter containing a stainless steel ring electrode was placed into the urethra and the urethra was stimulated at various amplitudes and frequencies along the length of the urethra. The catheter was inserted through the urethra to the level of the bladder and stimuli applied at 1 cm intervals as the catheter was withdrawn along the urethra. Biphasic, 1-500 microsec. constant current stimuli were applied monopolarly between the catheter electrode and a subcutaneous needle.

3. Results

In all three experiments, robust bladder contractions were elicited via intra-urethral electrical stimulation. As shown in Figure 1, robust bladder contractions were elicited by urethral stimulation in the proximal urethra, but not in the bladder neck or distal urethra. Maximal responses were centered in the proximal urethra and prostate. No responses were observed within or distal to the urethral sphincter. In one experiment, the spinal cord was acutely transected at T10. Bladder contractions were still elicited after spinal transection.

![Urethral profile](image)

**Figure 1.** Profile of bladder responses elicited via intra-urethral electrical stimulation. Each symbol type represents a separate experiment. Stimulation frequency was 2 Hz and amplitude was 6 to 9 mA.

4. Discussion

These results demonstrate that it is possible to elicit bladder contractions via electrical stimulation of the proximal urethra, even after SCI. The results were equivalent to those produced by direct stimulation of the urethral sensory branch of the pudendal nerve [2]. The result that no bladder activity was elicited via stimulation in the bladder or bladder neck suggests that pelvic nerve pathways were not involved and supports the hypothesis that pudendal afferents were activated. These locations are also consistent with work showing that excitation of pudendal afferents is caused by distention or fluid flow either in the pelvic pre-prostatic portion of the urethra [7] or in the region of the urethral sphincter [8]. We intend to use this catheter-based method to investigate the effects of intra-urethral stimulation on bladder activity in humans with spinal cord injury.

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References

afferent-evoked bladder and sphincter reflexes in
decerebrate and acute spinal cats. Neurosci Lett
244(3):137-140. 1997.


[8] J.K. Todd. Afferent impulses in the pudendal nerves of

Comparison in young healthy volunteers of 3 different
parameters of constant current stimulation used to
determine sensory thresholds in the lower urinary tract.