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Electrical Stimulation for Control of Bladder Function

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Abstract

Electrical stimulation of sensory fibers in the pudendal nerve can generate either inhibition or activation of the bladder, and this is a promising approach to restoration of continence and micturition in neurological disease or injury. We review studies of pudendal afferent stimulation to excite the bladder and enhance bladder emptying in urinary retention or restore bladder emptying following spinal cord injury.

I. Introduction

The principal functions of the lower urinary tract are to store and expel urine (continence and micturition, respectively). Electrical stimulation of sensory fibers in the pudendal nerve can generate either inhibition or activation of the bladder, and this is a promising approach to restoration of continence and micturition in neurological disease or injury. Differential control of bladder inhibition or excitation can be obtained by selective stimulation based on anatomical segregation of pudendal afferents [5, 6] or by stimulation at different frequencies [1, 4]. We review studies of pudendal afferent stimulation to excite the bladder and enhance bladder emptying in urinary retention or restore bladder emptying following spinal cord injury.

II. Restoration of Efficient Voiding in Urinary Retention

Urinary retention is the inability to empty the bladder completely, and may result from bladder hypocontractility, increases in outlet resistance, or both. Feedback from pudendal afferents is required for efficient voiding, and the loss of pudendal sensory activity leads to a reduction in voiding efficiency [2]. We sought to determine whether electrical stimulation of sensory fibers in the pudendal nerve could improve bladder emptying in an animal model of urinary retention. We measured voiding efficiency (VE=voided volume/initial volume) with and without concomitant electrical stimulation of pudendal afferents in urethane anesthetized female rats [3]. Unilateral electrical stimulation of proximal transected sensory pudendal nerve during distention-evoked voiding contractions significantly improved voiding efficiency. Stimulation increased VE from 29±7% to 40–51% following unilateral transection of the sensory branch of the pudendal nerve and from 18±4% to 39–49% following bilateral transection of the sensory branches of the pudendal nerve. An initial clinical translation of these results to human demonstrated the feasibility of delivering intraurethral electrical stimulation as a means to determine whether electrical activation of pudendal nerve afferents may provide a new approach to restore efficient bladder emptying in persons with non-obstructive urinary retention.

III. Restoration of Micturition in Spinal Cord Injury

Spinal cord injury results in the loss of voluntary control of micturition and reflex micturition with low voiding efficiency. Electrical stimulation of pudendal sensory nerve fibers, which activate spinal micturition circuitry may provide a means to restore efficient

bladder emptying. We measured the bladder pressures and voiding efficiencies generated by selective stimulation of pudendal nerve afferents in adult cats anesthetized with alpha-chloralose. Selective electrical stimulation of the sensory (2 Hz≤*f*≤50 Hz), cranial sensory (*f*≤5 Hz), dorsal genital (*f*≥20 Hz), and rectal perineal (*f*≤10 Hz) branches of the pudendal nerve evoked sustained bladder contractions dependent on the stimulation frequency, *f* [4, 5]. Contractions evoked by selective electrical stimulation resulted in significant increases in voiding efficiency compared to bladder emptying by distension-evoked reflex bladder contractions. Acute spinal transection abolished reflex bladder contractions evoked by low frequency stimulation of the cranial sensory or rectal perineal branches [5], whereas contractions evoked by high frequency stimulation of the dorsal genital branch remained intact [4, 5]. Thus, there appear to be two distinct micturition pathways, a spino-bulbo-spinal reflex activated by cranial sensory afferents and a spinal reflex activated by genital afferents. The genital pathway is a promising approach to restore efficient bladder emptying in persons with spinal cord injury.

IV. Conclusion

Collectively, these studies demonstrate that activity in pudendal afferents can generate activation of the bladder, and that electrical stimulation of pudendal afferents holds promise as an approach to restoration of bladder emptying following neurological disease or injury.

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