SELECTIVE NEURAL STIMULATION TO IMPROVE BLADDER VOIDING: CHRONIC EXPERIMENTS IN DOGS

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Abstract-- The high frequency electrical stimulation blockage is one of the recent employed techniques to regain bladder functions that are lost after spinal cord injury. It shows promising results to inhibit the contraction of the sphincter muscle during micturition. To achieve selective stimulation, the S2 sacral root is stimulated with a signal composed of two distinctive trains of bipolar-current pulses. The generation of the stimulus is done with a system composed of an external controller and an implantable stimulator. Chronic tests on 10 mongrel male dogs have been performed for a maximum duration of 8 months. Results from the experiments demonstrated the system’s reliability and effectiveness to perform selective stimulation of the bladder. They also showed the absence of backpressure on urethers or kidneys and a 2/3 to complete bladder voiding after each stimulation.

Index terms-- Selective electrical stimulation, urinary bladder, implantable stimulator, chronic experiments, sacral nerve.

I. INTRODUCTION

Electrical neural roots stimulation can recover partial functionality of failed organs after spinal cord injury. In the case of bladder control, the standard stimulation technique induces a simultaneous contraction of the external urethral sphincter and the bladder muscle (detrusor). Somatic fibers leading to the bladder sphincter are more sensitive to electrostimulation than autonomic fibers innervating the detrusor muscle [1]. This means that a current large enough to provoke detrusor contraction will inevitably activate the external sphincter and prevent micturition. However, the high frequency blockage stimulation of the sacral roots has shown promising results to inhibit sphincter contraction and allowed micturition [2].

This paper concerns the sacral roots stimulation with high-frequency sphincter inhibition method. The employed implantable stimulator is summarized in section II, the stimulation protocol is described in section III and results are discussed in section IV. Conclusions are detailed in section V.

II. STIMULATION SYSTEM

The stimulation system consists of an external controller and an implantable stimulator with its cuff electrode. The controller provides information and energy transcutaneously to the implant. Command words corresponding to the selected parameters are encoded in Manchester format, modulated in amplitude (AM) at 20 MHz and sent through an inductive link. The neuromuscular stimulator rectifies at once the received signal to power up the board while the clock and data are extracted from the encoded bit stream. The waveform consisting of two trains of bipolar-current pulses is then generated to perform selective high frequency block stimulation [3].

III. EXPERIMENTAL PROTOCOL

The chronic study was conducted on 10 adult male mongrel dogs for a maximum duration of eight months. Every dog was stimulated twice a day with a set of parameters corresponding to one of the following three stages. During the first month, low frequency only stimulation (table 1) was used. For the six following months, the high frequency current-pulses train was added to the low frequency train to inhibit sphincter contraction. During the last month, low frequency only stimulation was used to show high frequency block efficiency. In addition to stimulation, monthly intravenous urography (IVU) and voiding cystourethogram (CVUG) were performed.

Table 1: Low and high frequency pulse trains parameter's value.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Abbreviation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude</td>
<td>LFA</td>
<td>0.9 mA</td>
</tr>
<tr>
<td>Frequency</td>
<td>LFP</td>
<td>30 Hz</td>
</tr>
<tr>
<td>Pulse width</td>
<td>LFW</td>
<td>175 μs</td>
</tr>
<tr>
<td>High Frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude</td>
<td>HFA</td>
<td>1.1-1.3 mA</td>
</tr>
<tr>
<td>Frequency</td>
<td>HFP</td>
<td>600 Hz</td>
</tr>
<tr>
<td>Pulse width</td>
<td>HFW</td>
<td>60-100 μs</td>
</tr>
</tbody>
</table>

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IV. RESULTS
Two dogs did not complete the chronic tests due to early cuff electrode breakage. New electrodes were designed and showed good mechanical properties in terms of flexibility and durability. They were all still functional after the chronic experiment duration. For the eight dogs that completed experiment phases, selective high frequency blockage stimulation allowed to increase mean bladder voiding volume by more than 50% and reduce the mean residual bladder volume to 9% as shown in figure 1. This graphic depicts the mean residual volume corresponding to the three stages of the chronic experiment: low frequency during the shock stage, selective stimulation for the combined low and high-frequency pulses trains, and low frequency only stimulation following the selective stimulation.

Also, four dogs evacuated the urine completely leaving no or a negligible amount of urine after high frequency block stimulation. On all eight dogs, the bladder wall and external urethral sphincter showed no damage and the absence of backpressure on urethers and kidneys was observed. Seven dogs showed no neural damage.

Finally, as shown on figure 2, external urethral sphincter relaxation has been observed during selective stimulation. In picture A, the sphincter is contracted while in picture B, it relaxes during stimulation.

IV. RESULTS

The proposed implantable selective electrical stimulator and its controller, the employed stimulation strategies as well as the performed implantation technique allowed to achieve low pressure voiding of the bladder. Mean residual volume for all dogs was lowered to 9% representing an increase of more than 50% in comparison with low frequency only stimulation.

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REFERENCES