Outline of the Chapter

This chapter discusses the concept of neurostimulation of the sacral nerve roots in treating voiding dysfunction. Voiding dysfunction could be divided into two categories according to the underlying cause:

1. Neurogenic voiding dysfunction usually occurs following damage to the central or peripheral innervation of the bladder. A typical example of neurogenic bladder occurs following a suprasacral spinal cord injury. The primary function of the sacral stimulation is to enhance bladder evacuation.

2. Non-neurogenic voiding dysfunction affects a larger group of patients who have no apparent lesion in bladder innervation. These patients present with voiding dysfunction very similar to those with neurological lesions. A typical example of non-neurogenic voiding dysfunction is encountered in urge-frequency syndromes, chronic unobstructed urinary retention and patients with refractory urge incontinence. These patients respond to sacral “neuromodulation” of the pelvic floor musculature.

The chapter will describe the two modalities of sacral neurostimulation for different causes of voiding dysfunction.

Sacral Root Neurostimulation for Voiding in Patients with Spinal Cord Injury

Historical Background

The interest in electric stimulation as a means of controlling bladder function dates back to the 1950s. The first attempt to develop an electrical stimulator to treat the paralyzed human bladder was made in 1960 [1]. Since then several reports have been published which describe different systems of neurostimulation to induce voiding.

Direct detrusor stimulation received an initial interest, which faded with time. The advantage of this technique was the simplicity of the procedure of electrode placement. The electrodes were implanted directly on the bladder wall. Nevertheless, the effect was not durable owing to electrode displacement, production of fibrosis or even electrode erosion through the bladder. The need for current densities above the physiological levels was another major drawback [2].

Direct sacral cord stimulation was another possibility that was extensively addressed in the literature during the 1970s. Jonas and co-workers tried to stimulate the spinal cord at the level of the spinal micturition center by surface electrodes. These early trials proved to be a failure because of the proximity of both the micturition and the pudendal nuclei.
making it practically impossible to stimulate the parasympathetic nucleus without stimulating the pudendal nucleus. Nevertheless, these experiments conceived the concept of post-stimulus voiding which was later used in sacral root electrostimulation (see below) [3,4].

Pelvic nerve stimulation was then tried, but likewise proved to be a failure. Many factors were involved since the pelvic nerves were shown not to tolerate the stimulation for long periods of time. Vesico-sphincteric dyssynergia was a problem because of the simultaneous activation of the external urinary sphincter resulting in an increase in the outflow resistance. In humans, the early division of the pelvic nerve to form a broad pelvic plexus made it practically unsuitable for electrode placement [2].

The use of sacral roots electrical stimulation to induce voiding attracted attention in the 1960s. Habib reported his experience with sacral root electrical stimulation in 1967 [5]. Since then several reports has been published on this subject.

**Sacral Root Electrical Stimulation**

Since the early reports of the use of sacral root electrical stimulation, it was apparent that although this technique is by far superior to the other techniques such as direct bladder and spinal cord stimulation, it was still associated with potential drawbacks. The major drawback was the dyssynergic voiding due to simultaneous contraction of the sphincter during bladder evacuation. Nevertheless, the sacral nerve roots were found to be suitable for implanting with cuff electrodes around the nerve roots. Other practical solutions for handling the dyssynergic pattern of voiding made this sacral root electrical stimulation the procedure of choice to induce voiding in paraplegic subjects [2]. Researches on experimental animals conducted in the universities of California and McGill and Toronto Research Laboratories shed light on almost all the practical aspects of sacral root electrical stimulation.

**Dyssynergia Induced by Sacral Root Stimulation**

The S2 root was shown to be the major root supplying the urinary bladder while S1 is the one supplying the external sphincter in canine models. Unfortunately, the S2 root does not contain autonomic bladder supply exclusively. Stimulation of the S2 root will result in simultaneous contraction of the bladder and sphincter leading to dyssynergic voiding [6]. Two major contributing factors were shown to induce dyssynergic voiding with sacral root electrical stimulation: reflex and direct recruitment of the external urethral sphincter musculature. Stimulation of the dorsal root of the S2 sacral nerve, which contains primarily afferent fibers from the pelvic organs, induced a similar response to stimulation of the whole S2 nerve. This response was only eliminated by dorsal rhizotomies proximal to the stimulation electrode, indicating that the mechanism here is through reflex recruitment of the bladder and the external sphincter. On the other hand, stimulation of the ventral root of the S2 nerve induced bladder and sphincteric contraction even after cutting the root proximally, indicating that the mechanism here is through direct recruitment. Cutting the pudendal nerve peripherally while stimulating the ventral root produced bladder contraction without dyssynergic sphincteric contraction. Stimulation of the ventral root proximal cut end did not induce any response [7].

Several studies have been conducted to address the detrusor sphincter dyssynergia induced by sacral root electrical stimulation. Post-stimulus voiding [8], dorsal rhizotomy [9], selective stimulation of the sacral rootlets [10], selective sectioning of the pudendal branches of the S2 root [11], pudendal neurotomy and sphincterotomy [9] were proposed over the years with variable success, morbidity and disadvantages. High frequency stimulation of the pudendal nerve to induce fatigue of the external sphincter prior to the stimulation of the sacral root with low frequency current was tested in our institute with good results. The experimental animals were able to void with a minimal post-void residual of urine [12]. Anodal blockade to the somatic contribution in the sacral root with a simultaneous application of a stimulating current allowed selective stimulation of the autonomic efferent branches supplying the detrusor [13].

In a limited clinical trial, Tanagho and co-workers implanted five patients with sacral root pulse generator. They used different combinations of electrode placement. In none of these cases was voiding possible using sacral root electrical stimulation owing to the severe dyssynergia. In another group of seven patients limited dorsal rhizotomy was performed to one or two roots. Only two patients were able to void effectively with the stimulation, one of them after bilateral pudendal neurotomy and levatorotomy. When dorsal rhizotomy was done extensively and combined with pudendal neurotomy all patients were able to void (5/5) compared to 4 patients who underwent extensive rhizotomies without pudendal neurotomies and were not able to void with stimulation [9]. From this study it became clear that it is practically impossible to induce voiding by sacral root electrical stimulation.