
Bycroft JA 1,2, Craggs MD 1,2, Knight SN 2, Wood S 2, Donaldson N 3, Shah PJR 1,2

1 Institute of Urology and Nephrology, The Royal Free and University College Medical School, 48 Riding House Street, London W1W 7EY. United Kingdom.
2 Spinal Research Centre, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, Middlesex HA7 4LP. United Kingdom.
3 Department of Medical Physics & Bioengineering, University College London, Shropshire House, 11-20 Capper Street, London WC1E 6JA. United Kingdom.

Email: j.bycroft@ucl.ac.uk
Website: spinalresearchcentre.org.uk

Abstract

Spinal cord injury results in severe dysfunction of the lower urinary tract. This leads to incontinence and ultimately renal failure (if untreated). One method of suppressing neurogenic detrusor overactivity is neuromodulation applied to pudendal afferent nerves, typically at the level of the dorsal penile nerve. Direct stimulation (either electrical or magnetic) of posterior sacral nerve roots is also capable of effecting neuromodulation. We studied five patients with combined sacral posterior and anterior nerve root stimulators, and utilised an automated system of conditional neuromodulation of neurogenic detrusor activity. Automated conditional neuromodulation using posterior nerve roots resulted in a reproducible suppression of detrusor overactivity. This study paves the way for the development of permanently implantable neuroprosthetic devices to restore and maintain function in the neuropathic bladder.

1 Introduction

1.1 Sequelae of spinal cord injury

Suprasacral spinal cord injury frequently results in neurogenic detrusor overactivity (NDO). This is due to the development of aberrant spinal reflexes. In addition patients will usually demonstrate detrusor-sphincter dyssynergia (DSD). Combined, NDO and DSD result in reflex incontinence and high intravesical pressures. Ultimately this may lead to pathological changes within the bladder and vesico-ureteric reflux, and in due course deterioration of the renal system. Anticholinergic medication is frequently combined with intermittent catheterisation to overcome these problems and to increase bladder capacity, however these drugs frequently result in debilitating side effects, such as dry mouth and constipation.

1.2 Neuromodulation and spinal cord injury

Neuromodulation (NM) via dorsal penile nerve stimulation is well established as a method of experimentally suppressing NDO and improving bladder capacity [1]. We have previously described the SPARSI (Sacral Anterior & Posterior Nerve Root Stimulator), that potentially allows for combined NM (via posterior root stimulation) and emptying on demand (via anterior nerve root stimulation) [2][3]. In addition, SPARSI obviates the need for posterior rhizotomy. Traditionally posterior rhizotomy was performed alongside the SARSI (sacral anterior root stimulator) to increase bladder capacity and to prevent reflex incontinence. However posterior rhizotomy is a permanent neuro-destructive process, and leads to loss of reflex erections and ejaculation in males, as well as loss in residual sensation.

1.3 Aims of study

We aimed to test a system of closed-loop automated conditional neuromodulation via implanted SPARSI in five patients.
2 Methods

2.1 Patients

Five male patients with existing SPARSI implants were selected. All drugs modulating the lower urinary tract were stopped 5 days prior to testing. Standard filling cystometry (at 30 ml/min) was performed, under both control and test conditions.

2.2 Cystometry and neuromodulation

Patients were placed in a sitting position, in order to replicate normal wheelchair positions.

Software was devised whereby a waveform generator was triggered for 1 minute when P\text{det} reached a pressure of 10 cmH\textsubscript{2}0. Rectangular pulses of 200 $\mu$s were utilised; frequency of stimulation was 15Hz. Amplitude was set at three times that required to produce a pudendal-anal reflex, which was at levels much lower than that required to produce a detrusor contraction. Combined S\textsubscript{3,4} nerve roots were stimulated to effect neuromodulation. The fill was terminated when a sustained P\text{det} $>$ 35 cmH\textsubscript{2}0 was reached, or voiding occurred.

The equipment configuration is demonstrated in Figure 1.

\textbf{Figure 1 a}

\textbf{Figure 1 b}

\textbf{Figure 1: Equipment configuration and mechanism of action (opposite)}

The overall equipment layout is shown in Figure 1a. Automated posterior nerve root stimulation occurs above a pre-programmed rise in detrusor pressure (10 cmH\textsubscript{2}0), leading to suppression of NDO. Figure 1b demonstrates the mechanism of action of neuromodulation using this configuration. Posterior nerve roots are conditionally stimulated via the standard Finetech-Brindley interface, and NDO is suppressed.
3 Results

All patients demonstrated integrity of posterior nerve roots, via preservation of reflex erections, bulbocavernosal reflexes, ankle jerks and NDO. Automated implant-driven conditional neuromodulation was able to suppress NDO in all patients, resulting in an increased bladder capacity.

The triggering of the automated system by rises in detrusor pressures reliably suppressed contractions, as can be demonstrated in Figure 2.

Figure 2: Automated conditional neuromodulation
The neuromodulation commences as the detrusor pressure passes the threshold for stimulation. This continues for 1 minute. Detrusor suppression is seen to occur (NM arrows). Eventually leakage occurs due to neuromodulation 'breakthrough'.

demonstrate that automated closed loop neuromodulation is possible with chronically-implanted electrodes.

4.2 Concluding remarks
This is the first demonstration of automated closed loop neuromodulation via a permanently implanted device in humans with spinal cord injury. Whilst not necessarily demonstrating a currently feasible modality of management, it provides a great deal of information regarding the specification and capabilities of future devices.

References


Acknowledgements

This work has been supported by a European Commission grant as part of the organisation ‘Restoration of Bladder Function by Neuroprosthetics (REBEC)’ (QLG5-CT-2001-00822).