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**ORIGINAL RESEARCH**

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**Central Somatosensory Networks Respond to a De Novo Innervated Penis: A Proof of Concept in Three Spina Bifida Patients**

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**ABSTRACT**

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**Introduction.** Spina bifida (SB) causes low spinal lesions, and patients often have absent genital sensation and a highly impaired sex life. TOMAX (TO MAX-imize sensation, sexuality and quality of life) is a surgical procedure whereby the penis is newly innervated using a sensory nerve originally targeting the inguinal area. Most TOMAX-treated SB patients initially experience penile stimulation as inguinal sensation, but eventually, the perception shifts to penis sensation with erotic feelings. The brain mechanisms mediating this perceptual shift, which are completely unknown, could hold relevance for understanding the brain's role in sexual development.

**Aim.** The aim of this study was to study how a newly perceived penis would be mapped onto the brain after a lifelong disconnection.

**Methods.** Three TOMAX-treated SB patients participated in a functional magnetic resonance imagery experiment while glans penis, inguinal area, and index finger were stimulated with a paint brush.

**Main Outcome Measure.** Brush stimulation-induced activation of the primary somatosensory cortex (SI) and functional connectivity between SI and remote cerebral regions.

**Results.** Stimulation of the re-innervated side of the glans penis and the intact contralateral inguinal area activated a very similar location on SI. Yet, connectivity analysis identified distinct SI functional networks. In all three subjects, the middle cingulate cortex (MCC) and the parietal operculum-insular cortex (OIC) were functionally connected to SI activity during glans penis stimulation, but not to SI activity induced by inguinal stimulation.

**Conclusions.** Investigating central somatosensory network activity to a de novo innervated penis in SB patients is feasible and informative. The consistent involvement of MCC and OIC above and beyond the brain network expected on the basis of inguinal stimulation suggests that these areas mediate the novel penis sensation in these patients. The potential role of MCC and OIC in this process is discussed, along with recommendations for further research. **Kortekaas R, Nanetti L, Overgoor MLE, de Jong BM and Georgiadis JR. Respond to a de novo innervated penis: a proof of concept in three spina bifida patients. J Sex Med 2015;12:1865–1877.**

**Key Words.** Spina Bifida; Penis; fMRI, Surgery; Peripheral Innervation; Functional Connectivity; Primary Somatosensory Cortex; Body Image

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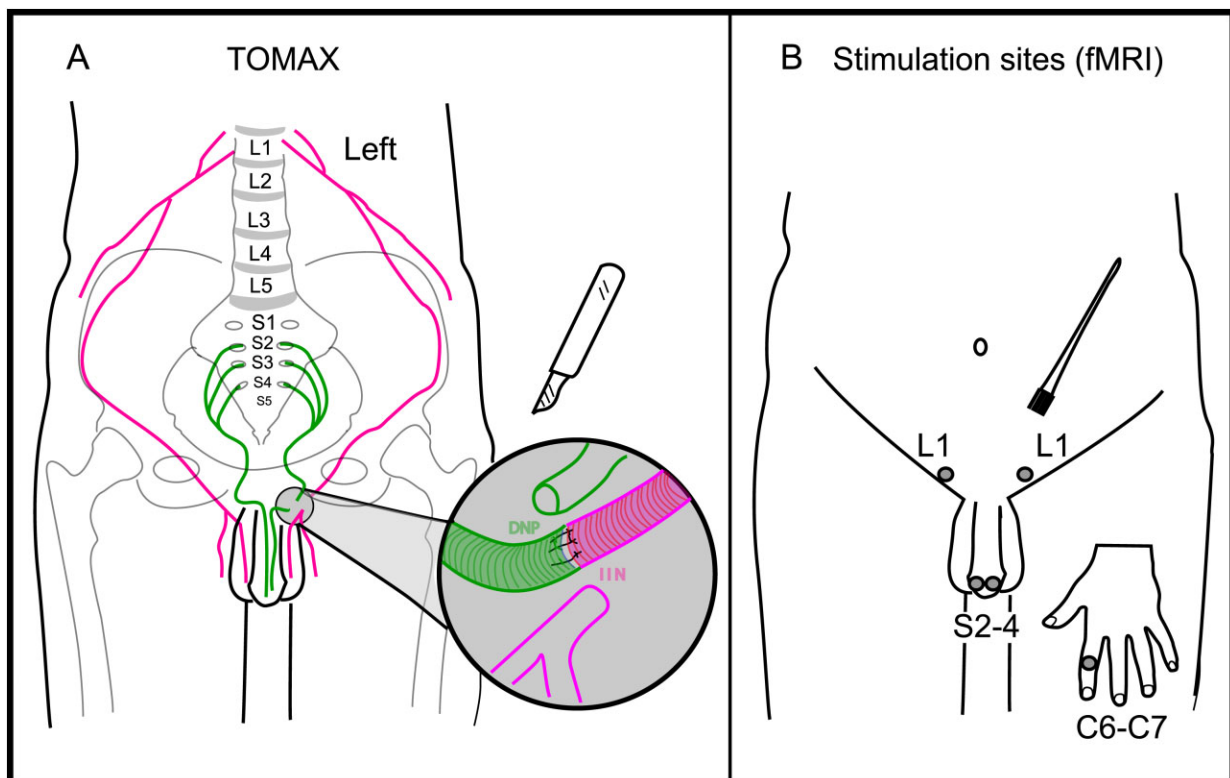
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## Introduction

**M**yelomeningocele, commonly referred to as spina bifida (SB), concerns a malformed or absent sacral spinal cord resulting from incomplete closing of the caudal part of the neural tube at 3–4 weeks gestational age. Men with SB may lack penile sensation, which often leads to high levels of frustration and low subjective sexual health in this group [1–5].

Recently, Overgoor et al. [6,7] described a new surgical technique to innervate the penis in SB patients with a lesion below spinal cord level L1 (Figure 1A). This TOMAX procedure involves two sensory nerves that are normally not connected: the ilioinguinal nerve (IIN) and the dorsal nerve of the penis (DNP). The IIN originates from the medial inguinal area and ventral scrotum, and enters the spinal cord in segment L1. The IIN is usually unaffected in SB involving caudal parts of the spinal

cord. The DNP originates from the dorsal and lateral aspects of the penile shaft and glans, and because its fibers enter the sacral spinal cord as part of the pudendal nerve (spinal segments S2–S4), in SB sensory inflow from the DNP is likely to be disconnected. In the TOMAX procedure, the DNP is joined with the ipsilateral IIN by way of a microsurgical technique (microneurorrhaphy) that involves cutting the two nerves and suturing their epineuria. This procedure, which creates a neural bypass around the sacral spinal cord lesion in SB, takes place at the base of the penis where the DNP lies in juxtaposition with the IIN. TOMAX results in excellent sensation in the glans penis [6–8] and the experience that the penis is a more normal part of the body image [7]. TOMAX-treated SB patients generally experience their new sensations from the glans as pleasant and, in the appropriate context, erotic [6–8], leading to increased sexual health and function. The shift from inguinal sensation to penis



**Figure 1** Surgical bypass and stimulation sites. Panel A depicts the TOMAX procedure. The left IIN (pink) was cut, transposed, and connected via neuroraphy to the left DNP (green). This connection bypasses the sacral defect in myelomeningocele, and enables genital feelings to develop. On the right side, IIN and DNP were not connected. Panel B depicts the body sites (grey circles) that were stimulated during the functional magnetic resonance imagery (fMRI) experiment. The glans penis (innervated by DNP), as well as the inguinal skin overlying the medial aspect of Poupart's ligament (innervated by IIN), were stimulated bilaterally. In addition, the radial aspect of the left index finger was stimulated. DNP = dorsal nerve of penis; IIN = ilioinguinal nerve; L1 = first lumbar dermatome; S2–4 = second to fourth sacral dermatome; C6–7 = sixth and seventh cervical dermatome.

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