Instantaneous Changes in Prefrontal Cortex Neuroexcitation and Bladder Hemodynamics Non-Invasively Detectable with Near Infrared Spectroscopy during Sacral Neuromodulation

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Building Interdisciplinary Research Careers in Women's Health

BACKGROUND

- Urge urinary incontinence (UUI) is a condition classified by urinary urgency, frequency, and nocturia and is **more common in women**
- Sacral Neuromodulation (SNM) is an effective treatment for women with UUI, **Figure 1**
- Near infrared spectroscopy (NIRS) is a non-invasive technique which can quantify hemodynamics by measuring the concentration of oxygenated hemoglobin (O_2Hb) of a biologic tissue such as muscle (i.e., bladder detrusor)
- Functional near infrared spectroscopy (fNIRS) is a non-invasive technique which can quantify oxygenated hemoglobin (O_2Hb) as a marker for neuroexcitation and refers to brain monitoring
- The objective of this study was to determine if acute changes in SNM produce variation in the anterior bladder wall blood flow and/or cortical brain neuroexcitation that could be quantified with NIRS

METHODS

- Cross-sectional experimental design
- Participants were recruited from a single academic center within urology and urogynecologic clinics
- Inclusion criteria:
  - SNM implanted >6 months and <7 years prior for UUI
  - No neurologic comorbidities affecting bladder sensation
- Exclusion criteria:
  - Non-English speaking
  - Pregnant
- Participants were instructed to hydrate with 2L Gatorade G2 and completed natural filling protocol with two bladder fills (until 100% sensation of fullness) and void cycles
- Throughout natural bladder filling, continuous bladder NIRS and brain fNIRS were recorded using Artinis Brite and PortaLite devices, **Figure 2.**
- The SNM controller was connected via Bluetooth and the device was cycled between ON (baseline program setting) and OFF for 3 minutes increments during both low and high bladder fullness sensation states
- O_2Hb signals were processed to remove motion artifacts and physiologic noise (i.e., breathing) with segmentation and low pass filtering
- One-minute segments of fNIRS and NIRS signals, isolated before and after device stimulation cycles, were compared for O_2Hb differences and signal pattern comparisons

Figure 1. Sacral nerve neuromodulation device implant example. Lead is positioned at the S3 sacral nerve root.

Figure 2. Brite fNIRS brain headcap with emitters and receivers over prefrontal cortex. PortaLite NIRS device for positioning over anterior bladder wall.

Table 1. Participant Characteristics

Characteristic		Mean (Standard Deviation)
Age, years		58.4 (±15.1)
Race, n(%)	White	6 (60%)
	Black	3 (30%)
	Declined	1 (10%)
Ethnicity, n(%)	Non-Hispanic	8 (80%)
	Declined	2 (20%)
BMI, kg/m^2		33.2 (±9.5)
Median Time Since Implant, months		17 [6.5, 46]
OAB Total Score (ICIQ-OAB)		10 (±3.2)
Fluid Intake, ounces/day		70 (±26)

BMI= body mass Index, OAB=overactive bladder

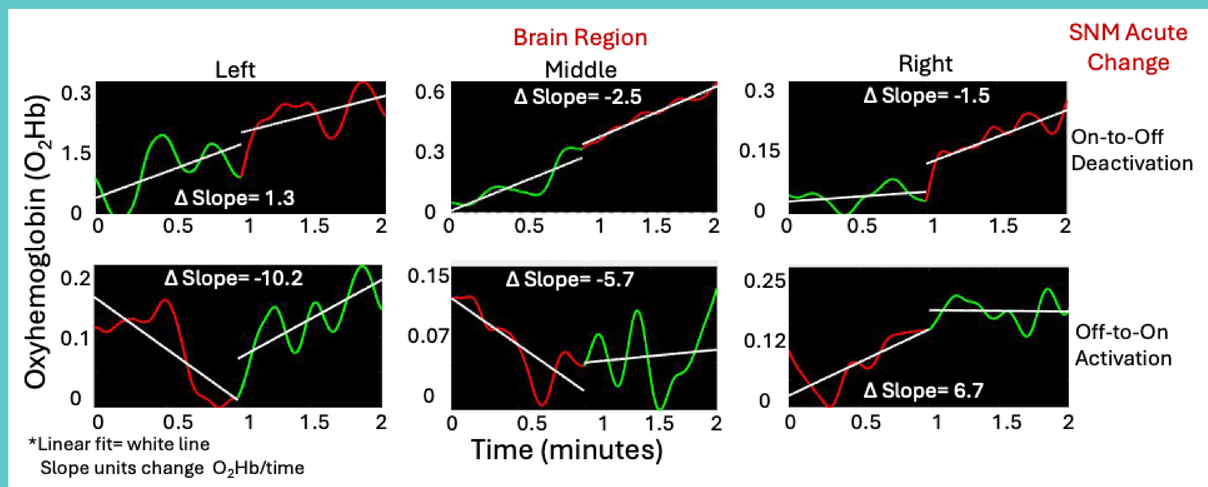

Figure 3. Averaged fNIRS signals by prefrontal cortex brain region (columns) comparing SNM device Deactivation (first row) and Activation (second row) showing responsive changes. Green lines indicate SNM device being turned on, while red indicates device being turned off. White lines are averaged linear trends lines used to calculate the displayed differences in slopes

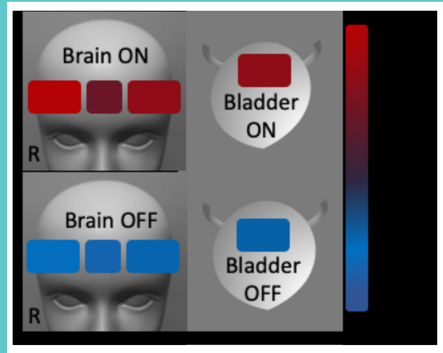

Figure 4. Anatomic representation of change in oxyhemoglobin (O_2Hb) in the prefrontal cortex of brain and anterior wall of bladder with sacral neuromodulation (SNM) **device activation** (OFF➔ON) for one participant's adjustment change cycle. PFC regions were grouped and averaged into right, middle and left. Blue-Red heatmap superimposed on brain regions and bladder, where red colors indicate increased oxygenation (bladder) and neuroexcitation (PFC).

RESULTS

- A total of 10 biologic women completed the study with a total of 14 device adjustment cycle pairs (ON to OFF and OFF to ON)
- Participants had a mean age of 58±15.1 years and mean BMI of 3.20±9.5, see demographics **Table 1.**
- In the *prefrontal cortex (PFC*), a change in the slope of O_2Hb over time, representing a change in neutral excitation, was detected in all brain regions (Right 100%, Middle 70%, Left 80%) during the activation portion of cycling the SNM device (OFF to ON), **Figure 3**
- While during deactivation of the SNM device (ON to OFF), the averaged slopes of O_2Hb over time appear steady or unchanged in all *PFC regions*, **Figure 3**
- Deactivation of the SNM appears to display a hold-over effect past the 3-minute data collection window
- The slope of O_2Hb over time measured over the *anterior bladder wall* similarly displayed acute changes in 75% of SNM cycles indicating the detection of changes in bladder hemodynamics, **Figure 4**

CONCLUSION

- Standard NIRS and fNIRS can non-invasively detect changes in O_2Hb in the anterior bladder wall and PFC caused by acute SNM adjustments
- These findings suggest SNM affects both the anterior bladder wall and the PFC in the control of voiding
- Further study is needed to see if these non-invasive techniques can be applied to optimize SNM treatment through measurement of neuroexcitation

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