

# THE LANCET

## **Supplementary webappendix**

This webappendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Harkema S, Gerasimenko Y, Hodes J, et al. Effect of epidural stimulation of the lumbosacral spinal cord on voluntary movement, standing, and assisted stepping after motor complete paraplegia: a case study. *Lancet* 2011; published online May 20. DOI:10.1016/S0140-6736(11)60547-3.

## Supplemental Figures

**A**

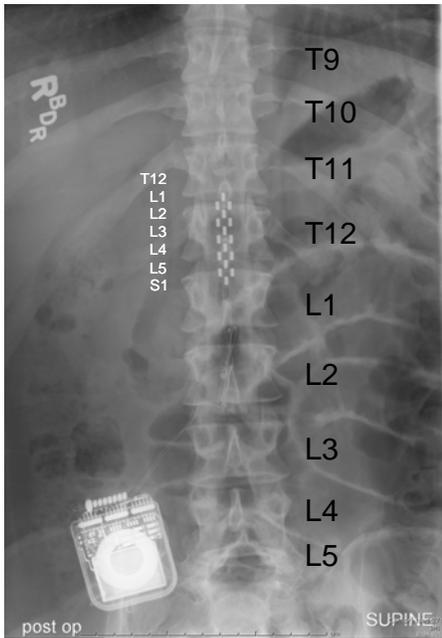


**B**

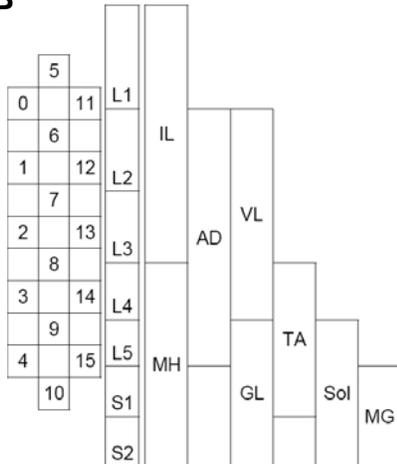
ISNCSCI Examination			
Neuro Level	T2	AIS Grade	B
Motor Score		Sensory Score	
Right Upper Extremity	Left Upper Extremity	Right Light Touch	Left Light Touch
25	25	50	50
Right Lower Extremity	Left Lower Extremity	Right Pin Prick	Left Pin Prick
0	0	38	33

**Radiographic and clinical characteristics of subject with motor complete, but sensory incomplete SCI.** (a) T2 weighted sagittal Magnetic Resonance Image of cervical spine at subject's injury site (C7-T1). Hyperintensity and myelomalacia noted at site of injury. (b) International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) examination of the subject.

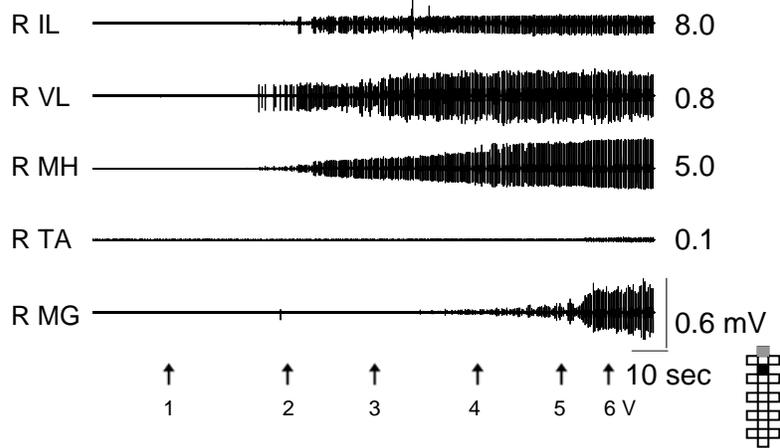
**A**



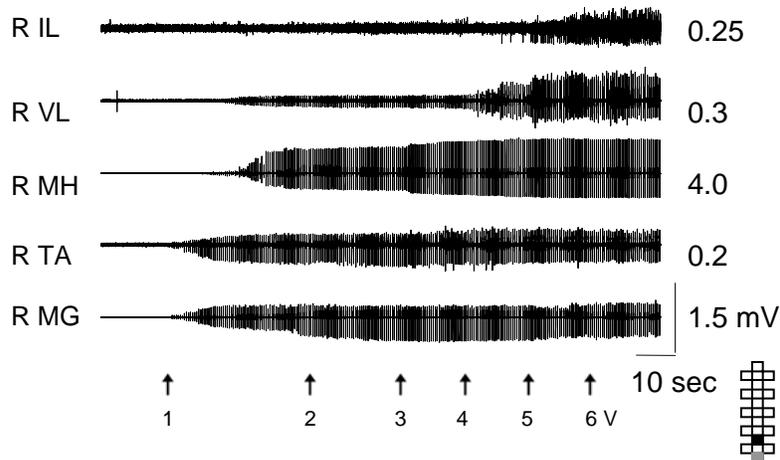
**B**



**C Rostral Stimulation**



**D Caudal Stimulation**



**Localization of electrode array relative to motoneuron pools as identified with motor evoked potentials during surgical implantation.** The voltage thresholds for evoked potentials of proximal muscles are lower when stimulating the more rostral electrodes. The voltage thresholds for motor evoked potentials of the distal muscles are lower when stimulating the caudal electrodes.

(A) Post-operative fluoroscopy of the thoracolumbar spine showing the location of the implanted electrode array and neurostimulator. (B) Depiction of 16-electrode array configuration relative to spinal dorsal roots and corresponding motoneuron pools identified using EMG recorded from leg muscles. (C and D) Motor evoked potentials elicited using epidural stimulation at 2 Hz, 210  $\mu$ s from 0.0 to 7 V with rostral electrodes, and caudal electrodes, respectively. Array diagram illustrates the stimulation configuration; anode electrodes are black and cathode electrodes are gray. IL was measured with fine-wire electrodes. AD, VL, MH, TA, GL, Sol, and MG were measured with surface EMG.

EMG=electromyography. R=right. IL=iliopsoas. AD=adductor magnus. VL=vastus lateralis. MH=medial hamstrings. TA=tibialis anterior. GL=gluteus maximus. Sol=soleus. MG=medial gastrocnemius.

## Supplemental Note

### A. Stand Training Description

### B. Subject's Perspective

#### A. Stand Training Description

Stand training occurred over 80 sessions on a custom designed standing apparatus (Supplementary Video 3). The subject attempted to stand for 60 minutes during each training session. To optimize independent standing stimulation parameters (electrode configuration, voltage and frequency) were modified approximately once per week.

During sitting, the stimulation voltage was increased to the desired level. This voltage was kept constant as the subject went from sit to stand and throughout the standing bout. The subject initiated the sit to stand transition by positioning his feet shoulder width apart and shifting his weight forward to begin loading the legs. The subject used the bars of the standing device during the transition phase to balance and to partially pull himself into a standing position. Trainers positioned at the pelvis and knees assisted as needed during the sit to stand transition. Elastic bungees posterior to the pelvis were set by one of the trainers after the subject achieved full-weight bearing standing. These bungees helped the subject sustain appropriate pelvic tilt and position and allowed him to safely stand with minimal assistance.

During the standing bout, one trainer assisted the subject by applying posteriorly directed gentle pressure at the patellar tendon as necessary to maintain knee extension. The subject was encouraged to stand for as long as possible throughout the session.

Seated resting periods occurred when requested by the subject and reduced in frequency and duration as the training progressed. No stimulation was provided during the rest periods.

During the first stand session, the subject required 7 breaks (stand time: 60 min; rest time 67 minutes). By session 35, the subject was able to stand for 1 bout lasting a full 60 minutes. The total duration of stimulation averaged across all sessions was  $54 \pm 13$  minutes per session.

#### B. Subject's Perspective

Given the uniqueness of the epidural stimulation procedures and the unusual level of commitment of the subject to the objectives of the study, the research team asked the subject his perspective on a range of highly personal topics related to changes in his health and daily living after compared to before the implant. Interpretation of these responses should take into account that he had received extensive rehabilitation for 170 sessions immediately before the implant. The implications of the responses are wide-ranging, but they are implications. On the other hand, some points are noted that might be examined carefully in future studies.

We asked the subject his perspective on the following points:

**Other than the fact that the epidural implant procedures have demanded so much of your time, how has it affected your :**

**sleep patterns?** I am sleeping more soundly, and am able to reach a deeper level of sleep(the dream phase) almost every night. I have also noticed that I need more sleep, at least 10 hours a night and sometimes more after a hard or draining workout.

**daily activity patterns (have you been more or less active?).** Besides the issue of being tired from the workouts, I have had more over all energy. I have been more active during the days than before the implant. This has improved since the first few workouts after the surgery, since at first I could not do

anything and even had trouble transferring after workouts, but this has continuously gotten better every day.

**bladder or bowel function?** In terms of my bladder, I've been able to empty more often on my own, on command, without a catheter. So far I've had no infections as well. In terms of my bowel function, I'm more regular.

**sensory function?** I've been able to feel more sharp and dull sensations in places where I wasn't able to before the surgery, such as through my stomach and legs. Also I'm having better sensation with light touch throughout my midsection and legs. Refer to most recent ASIA exam where I had mostly zeros before surgery and now have mostly ones.

**severity and frequency and timing of spasticity?** My spasticity has increased only when lying down.

**frequency and kind of medical care needed?** Other than when my stitches opened shortly after surgery no medical care has been needed since surgery.

**sexual function?** Erections have been stronger and more frequent and I am able to reach full orgasm occasionally. I had never before been able to do this before the surgery.

**diet, appetite?** I feel like I get hungrier after working out, but other than that no change.

**body weight?** I've gained about 9 kilograms since surgery.

**observable changes in muscle?** My leg muscles have increased by a few inches and I am able to see definition in my quads and calfs. My upper body (biceps, triceps, shoulders etc.) have also gained inches of muscle and I have not lifted a weight since surgery. My overall core has gotten stronger and more stable.

**posture and stability when sitting?** My posture has improved. I'm more stable and have less need to hold onto things to support myself.

**skin lesions or sensitivity to infections?** I have had no infections or skin lesions.

**other functions?** I feel healthier, I have better self esteem and confidence. My legs are heavier and more dense.