**Improving Walking with an Implanted Pulse Generator for Hip, Knee and Ankle Control After Stroke: A Case Report**
Stroke

Nathaniel Makowski, Rudi Kobetic, Lisa Lombardo, Kevin Foglyano, Gilles Pinaults, Stephen Selkirk, Ronald Triolo
*Louis Stokes Cleveland Veterans Affairs Medical Center, Cleveland, OH, USA*

**Background**: Post-stroke gait is limited by compromised volitional joint control that results from muscle weakness, excessive tone, and poor synergist control. About one third of all patients are left with gait deficits after physical therapy and may benefit from assistance during gait. Peroneal nerve stimulators and ankle foot orthoses provide benefit for patients affected by dropfoot, but patients with more severe deficits require additional assistance. Therapeutic and neuroprosthetic effects of a fully implanted pulse generator (IPG) for multi-joint control to assist walking after stroke were evaluated in this case study.

**Methods**: The participant was a 64 year old male who suffered a hemorrhagic stroke 2 years prior to inclusion in the study. His gait was limited by a combination of muscle weakness, limited independent joint movement, and mild hypertonia. He was a household ambulator with contact guard assistance, but used a wheelchair in the community. He was implanted with an 8-channel IPG and intramuscular electrodes targeting the following muscles: tensor fasciae latae, sartorius, gluteus maximus, short head of biceps femoris, quadriceps, and tibialis anterior (two electrodes). After implantation, a stimulation pattern was tuned to assist with hip, knee, and ankle control. A heel switch in the sole of the shoe on the affected side was used as a trigger to initiate swing and stance phase stimulation. He underwent home exercise with electrical stimulation and stimulation assisted gait training in the laboratory.

Outcome measures included the 10m walk to assess gait speed, 6 minute timed walk to evaluate fatigue, and maximum walk to measure endurance. Assessments were repeated under three conditions: 1) volitional walking at baseline, 2) volitional walking after training, and 3) walking with stimulation after training. Comparisons include evaluating the 1) therapeutic effect (baseline volitional vs. volitional after training), 2) neuroprosthetic effect (volitional after training vs. stimulation after training), and 3) total effect (baseline volitional vs. stimulation after training).

**Results**: After gait training with stimulation, the participant demonstrated both therapeutic and neuroprosthetic benefits. Therapeutic effects increased walking speed from 0.26m/s to 0.31m/s ($p<0.05$) while neuroprosthetic effects increased walking speed from 0.31m/s to 0.59m/s ($p<0.05$) and total effects increased walking speed from 0.26m/s to 0.59m/s ($p<0.05$). The neuroprosthetic and total effects had a clinically relevant effect size on walking speed of greater than 0.2m/s. Maximum walk distance after training increased from 301m without stimulation to 1418m with stimulation.

**Discussion**: Multi-joint control by means of an IPG provides a clinically relevant neuroprosthetic effect on walking speed and distance. In addition, there was a trend in therapeutic benefits on walking speed and distance. These data provide proof of concept that a multi-joint IPG control can provide clinically relevant improvements in gait after stroke.