Defining the Therapeutic Window for Spinal Cord Stimulation Using Evoked Compound Action Potential (ECAP) Recordings—Results From the Evoke Study

Jan-Willem Kallewaard, MD, FIPP[1]; Harold Nijhuis, MD[2]

[1]*Rijnstate Hospital, Velp, The Netherlands;* [2]*St. Antonius Hospital, Nieuwegein, The Netherlands*

INTRODUCTION

Spinal cord stimulation (SCS) is an established treatment for chronic pain; however, long-term success remains suboptimal [1,2]. Current SCS therapies are fixed-output and do not account for large variation in electrical field strength reaching the spinal cord (SC) due to changes in distance between the stimulation electrodes and the SC [3]. The data for this poster are reported from two prospective studies in which Evoked Compound Action Potentials (ECAPs) were used to measure SC activation and determine the therapeutic window (TW) individually for each patient.

MATERIALS AND METHODS

In Avalon (ACTRN12615000713594), 50 subjects were implanted and programmed in closed-loop; in Evoke (NCT02924129), 134 subjects were randomized into open-loop (OL-SCS) or closed-loop (CL-SCS). ECAPs, a measure of SC activation, are recorded following each stimulation pulse in both groups (Figure 1). Each subject's TW is individually determined in-clinic as the ECAP amplitude range between sensation perception threshold and the maximum SC activation level that the patient can withstand (Figure 2). A comfortable level of SC activation is also determined per patient. Without a measure of SC activation (e.g., ECAPs), TW can only be based on subjective perception of intensity; however, stimulation can produce variable SC activation (ECAP amplitude) as the electrode to SC distance varies (e.g., with changes in posture; Figure 2).

Using the out-of-clinic usage data the following are determined:

- The number of stimuli spent within, below, and above the defined levels of SC activation
- The most frequent SC activation that the patient experienced (Mode ECAP amplitude)

RESULTS

In the Evoke Study, CL-SCS subjects spent significantly more time in the TW (91.1% CL-SCS vs. 59.5% OL-SCS, p<0.001; Figure 4) despite having equivalent therapeutic ranges (Figure 3). Additionally, the mode ECAP amplitude was closer to the comfort level in CL-SCS whereas it was sub-threshold for OL-SCS patients. Long-term data from the Avalon Study showed a similar percentage of stimuli in the TW (83%-97%; Figure 5).

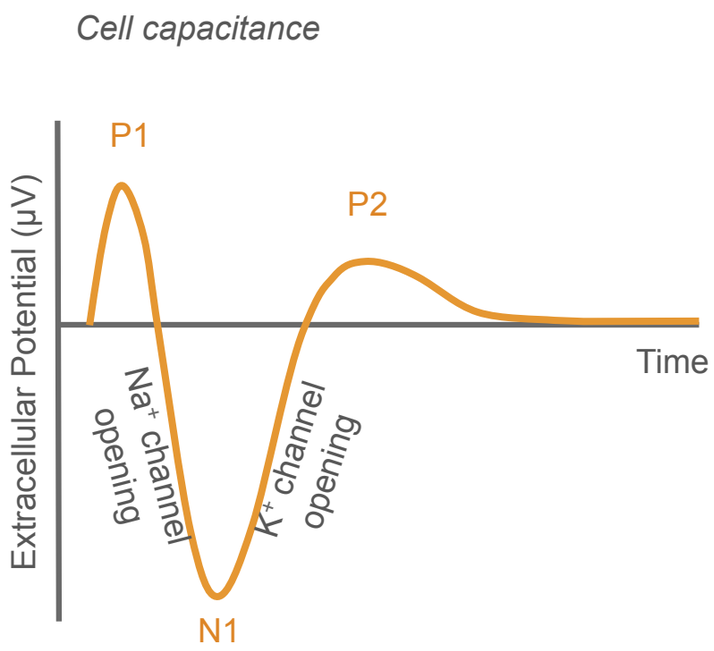


Figure 1: Schematic representation of an ECAP.

ECAPs have a well-defined shape with 3 peaks: 2 positive and 1 negative, labelled P1, N1, and P2, in order of appearance. The first P1 peak stems from capacitive coupling between the inside and outside of the fibers. The N1 and P2 peaks result from ionic flow (sodium [Na+] and potassium [K+]) in and out of the fibers that form the well-known compound action potential.

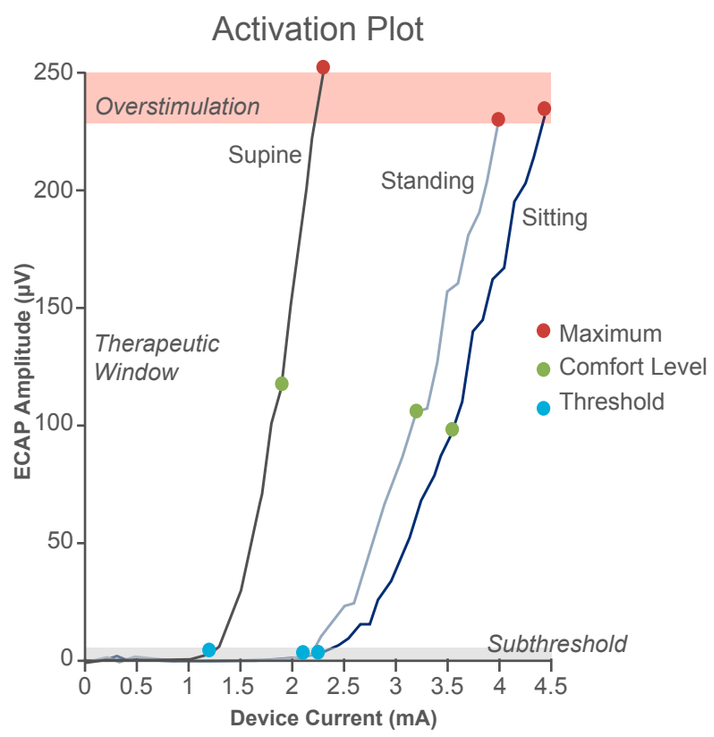
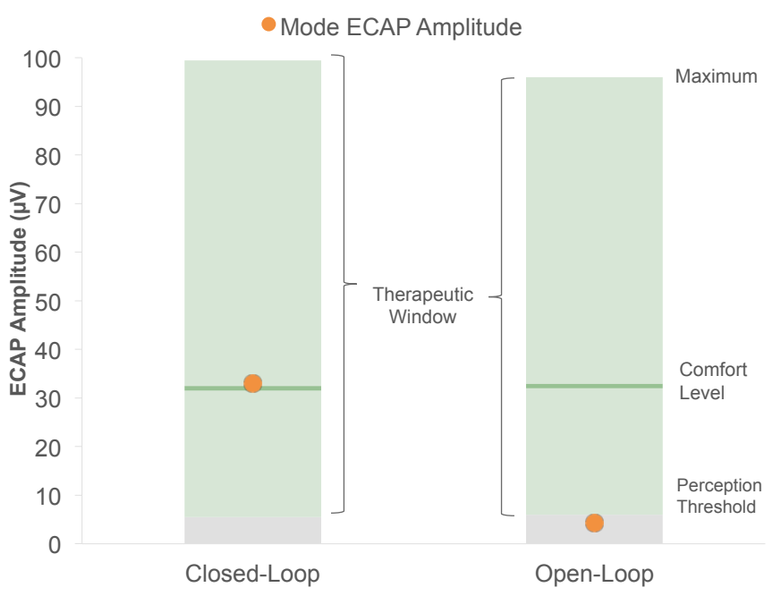


Figure 2: SC activation plots in different postures from a single Evoke Study patient.

This shows variation in activation based on output current (mA) in 3 different postures.



Perception Threshold: the SC activation level at which the patient first feels a change in sensation.
Comfort Level: a therapeutic level of SC activation prescribed for the patient.
Maximum Level: the maximum SC activation level that the patient can withstand.
Therapeutic Window: SC activation levels from patient perception threshold to the maximum level.
Mode ECAP Amplitude: the most frequent SC activation level for a given period.

Figure 3: SC activation relative to the therapeutic window in the Evoke Study.

Both cohorts have equivalent TW, but OL-SCS runs the device closer to threshold and the CL-SCS group runs it near the in-clinic comfort level.

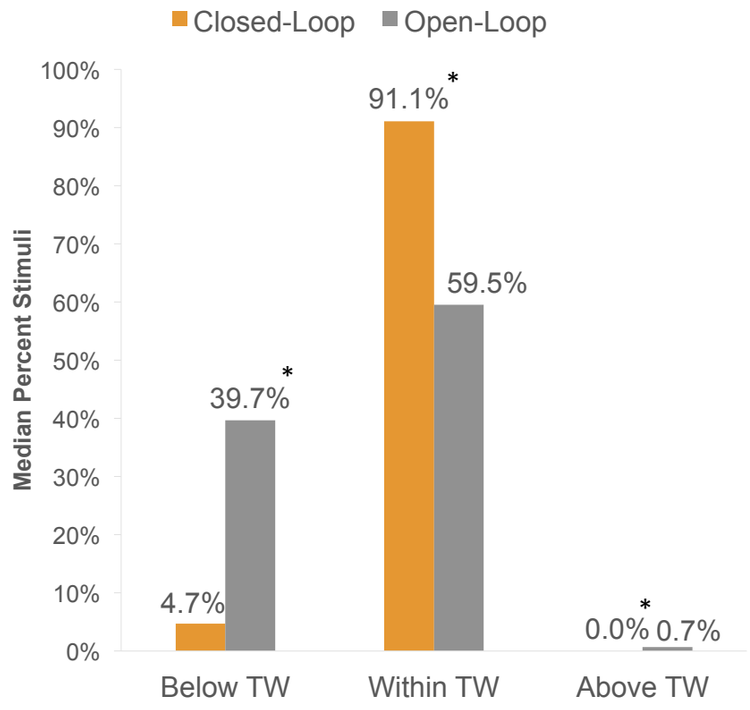


Figure 4: Comparison of stimuli below, within, and above therapeutic window in CL-SCS versus OL-SCS in the Evoke Study at 3 months.

Asterisks indicate statistical significance between the median values for the two groups.

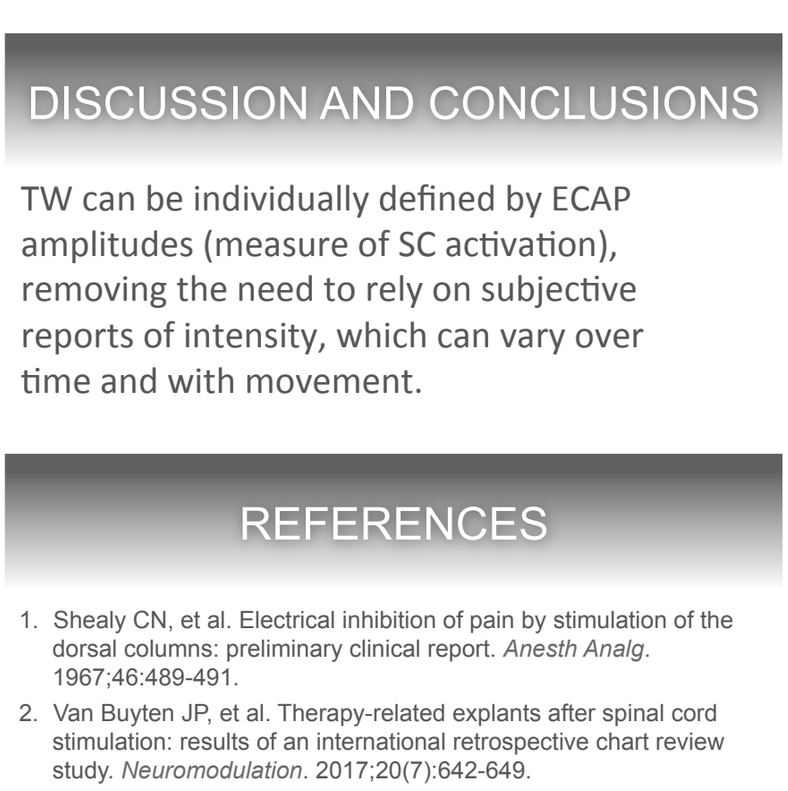


Figure 5: Median percent stimuli below, within, and above the TW from the 3-month to 12-month visits in the Avalon study.

DISCUSSION AND CONCLUSIONS

TW can be individually defined by ECAP amplitudes (measure of SC activation), removing the need to rely on subjective reports of intensity, which can vary over time and with movement.

REFERENCES

1. Shealy CN, et al. Electrical inhibition of pain by stimulation of the dorsal columns: preliminary clinical report. *Anesth Analg*. 1967;46:489-491.
2. Van Buyten JP, et al. Therapy-related explants after spinal cord stimulation: results of an international retrospective chart review study. *Neuromodulation*. 2017;20(7):642-649.
3. Ranger MR, et al. Changing body position alters the location of the spinal cord within the vertebral canal: a magnetic resonance imaging study. *Br J Anaesth*. 2008;101:804-809.

FINANCIAL SUPPORT: This study was conducted with support from Saluda Medical.