

COMPARISON OF ACTIVE STIMULATING ELECTRODES OF SACRAL NEUROMODULATION

Hypothesis / aims of study

The programming of sacral neuromodulation (SNM) therapy, assigning one contact of the quadripolar electrode as cathode (-) and one as anode (+), is done manually and repeatedly to ensure the accuracy of stimulation location and intensity. There are many practices being utilized to govern programming, most based on anecdotal experiences of each individual practitioner. In this preclinical study, we have compared motor response threshold and myotome response to SNM with different pairs of stimulating electrodes. Data from this preclinical work suggest that there are several principles that may be referenced to simplify and expedite the programming process in clinical practice.

Study design, materials and methods

Six S3 nerve roots (right and left) were tested for SNM in 3 female sheep. Stimulation leads (4 contacts: 0 most distal, 1, 2 and 3 most proximal, Medtronic 3889) were implanted bilaterally at S3 under fluoroscopic guidance. Electrode 3 was preferentially positioned ventrally to the S3 foramina. Two sensing electrodes (Medtronic 4351) were implanted into the external anal sphincter (EAS) at the 3 and 9 o'clock positions. All leads were tunneled externalized for connection to external instrumentation. Post implantation, weekly anesthetized and awake monitors were initiated, consisting of variable intensity stimulation (0-10V, 10 Hz, 210 μ s pulse width) unilaterally delivered with a Biopac STM100C stimulator - one of the four contacts was assigned as the cathode (-) and another as the anode (+). Electromyography (EMG) responses were collected from lower back, ipsilateral EAS, and/or anus (anal plug). The responding zone was defined as where the first visible motor contraction appeared. Four responding zones were assigned as P (the perineum, tail, or bellows), G (gluteal region), T (thigh region), and F (femoral region).

Results

Examining the visual motor threshold (T_{visual}) between anesthetized and conscious tests revealed no difference (Figures 1A and 1C). T_{visual} s to electrode 3-cathode and electrode 0-anode (3-/0+) stimulation were seen at an average of 0.46 ± 0.14 V and 0.56 ± 0.21 V, in anesthetized and conscious conditions, respectively, representing the most sensitive stimulation. Stimulation on electrode 0 or 1 (e.g. 1-/0+ or 0-/1+) had the highest T_{visual} among tested electrodes (2.28 ± 0.89 V and 2.70 ± 0.23 V, and 1.90 ± 0.32 V and 3.38 ± 0.96 V, in anesthetized and conscious conditions, respectively). In conscious sheep, the maximum tolerable intensities (T_{max} s) to 3-/0+ and 0-/1+ stimulation were 3.32 ± 0.82 V ($\sim 6\times T_{\text{visual}}$) and 9.5 ± 0.5 V ($\sim 3\times T_{\text{visual}}$), respectively. The triggered response by 3-/0+ stimulation solely occurred in zone P (Figures 1B and 1D). The 0-/1+ stimulation frequently evoked response outside zone P, e.g. in zone G in anesthetized condition when sheep were laying on the side (Figure 1B) and at all zones in conscious test when animals were standing up (Figure 1D).

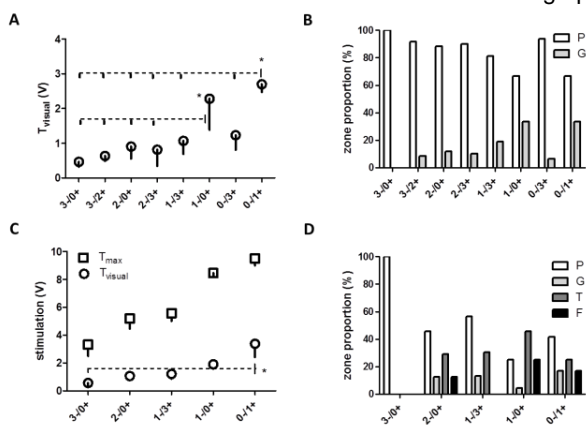


Figure 1. Visual motor responses in anesthetized condition (A, B) and conscious condition (C, D). A and C. Summary of the visual threshold to trigger motor responses (T_{visual}). The significance of differences between tests was demonstrated by repeated test. $n=6$, * $p<0.05$, ANOVA, Bonferroni post test. B and D. Histogram of myotome zone distribution to different configurations of nerve stimulation.

The EMGs from the anus were sensitive to low intensities of stimulation on electrode 3 (e.g. 3-/0+, 3-/2+, Figures 2A and 2D). Threshold of 3-/0+ stimulation was 0.49 ± 0.06 V in anesthetized condition. 0-/1+ stimulation at the most distal end of the lead had the highest threshold (2.28 ± 0.89 V). These differences were observed from EAS, or/and the anus.

Comparison of opposite cathode and anode configurations (3-/0+ vs 0-/3+, 1-/0+ vs 0-/1+, 3-/2+ vs 2-/3+) demonstrated that when proximal electrodes were negative and distal electrodes were positive, stimulation was more effective. In addition, the electrode combinations with non-adjacent (wide) space tended to be more effective than that of non-spaced (tight) combinations (e.g. 0-/3+ vs 0-/1+, 1-/3+ vs 1-/0+), though such differences were not statistically significant. The rank order of response thresholds were 3-/0+ < 0-/3+ ~ 2-/0+ ~ 3-/2+ ~ 2-/3+ ~ 1-/3+ < 1-/0+ < 0-/1. Two-way ANOVA analysis demonstrates a statistically significant

difference on stimulus-response functions between 3-/0+ and 0-/1+ stimulation (Figure 2).

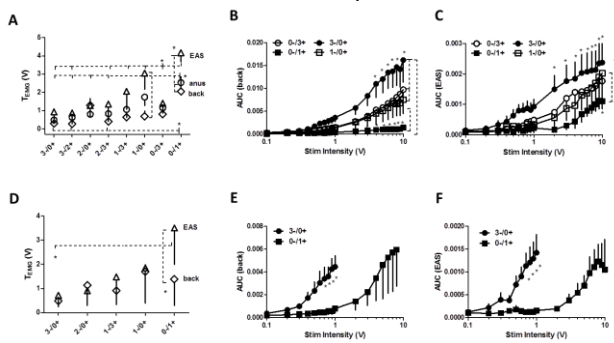


Figure 2. EMG activities sensed from contralateral tined quadripolar (back), ipsilateral external sphincter (EAS), and/or the anus using anal sensor in anesthetized condition (A, B, C) and conscious condition (D, E, F). A and D. Summary of the threshold to trigger EMG signals (T_{EMG}). $n=6$, * $p<0.05$, ANOVA, Bonferroni post test. B, C, E, and F. Summary data of stimulus-response functions of increased EMG activities (area under the curve, AUC) from contralateral tined quadripolar (back, B, E) and ipsilateral external sphincter (EAS, C, F) to different configurations of electrical stimulation (10 Hz) to graded intensity of the sacral neuromodulation. $n=6$, * $p<0.05$, ANOVA, Bonferroni post test.

Interpretation of results

As expected, the sensitivity of motor responses (threshold or amplitude of response) varied among stimulation configurations regarding the negative electrode or the distance between negative and positive electrodes. The order according to threshold of EMG response from low to high was $3<2<1<0$. Significantly lower voltage required to evoke EMG response to 3-/0+ stimulation compared to the 0-/1+ stimulation likely reflects that the electrode 3 was placed most proximal to the foramina and thus to the nerve innervating the EAS. We also report that nonadjacent or spaced pairs seemed favourable as the stimulation in comparison with adjacent pairs. This may be due to the stimulation field shape is broader by spaced pair stimulation (1).

The accuracy of “on-target” response to electrode 3 stimulation was confirmed by observed motor responses at perineal areas. In contrast, “off-target” responses to other myotomes were most likely obtained to stimulation via electrode 1 or 0. The slight discrepancy of the myotome zone mappings between anesthetized and conscious sheep may be due to inability to visually identify the motor response zones when sheep were placed on their side. The off-target response may be caused by distal electrodes stimulating other nerves in this position. Responses from undesired response areas are believed to cause insufficient clinical response to SNM therapy (2).

Concluding message

Comparing motor response threshold and myotome recruitment to SNM with different pairs of stimulating electrodes, there was significantly lower voltage required to evoke an EMG response when stimulating with 3-/0+ versus 0-/1+ and electrode 3 always triggered contractions at perineal area, an “on-target” response. In contrast, electrode 1 or 0 stimulations most likely trigger “off-target” responses. Future studies are needed, however, to determine if the therapeutic efficacy of SNM is associated with electrode pair combinations.

References

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2. Deng DY, Gulati M, Rutman M, Raz S, Rodríguez LV. Failure of sacral nerve stimulation due to migration of tined lead. J Urol 175:2182-5, 2006.

Disclosures

Funding: Medtronic Research & Core Technology **Clinical Trial:** No **Subjects:** ANIMAL **Species:** sheep **Ethics Committee:** the Institutional Animal Care and Use Committee of Medtronic