Improving Signal Analysis using a Novel Neural Blockade Monitor in Children: RMS Averaging Time

Jessica George M.D.[1], Wayne I. Sternberger Ph.D.[1,2], John Gearhart M.D.[3], Robert S. Greenberg M.D.[1]

[1]Pediatric Anesthesiology/Critical Care Medicine, [2]Applied Physics Laboratory, [3]Pediatric Urology

Johns Hopkins Medical Institutions, Baltimore, MD

Abstract

Background: Significant progress has been made in the use, efficacy, and safety of anesthesia. Though *clinical tools are not currently clinically available to specifically monitor or objectively evaluate the effectiveness of local anesthetics* in humans or animals, we *have previously demonstrated a technology that has the ability to monitor the effects of local anesthetics on the patient* and inform the clinician regarding patient condition from onset to termination of neural blockade. We further evaluate this technology with regard to optimal averaging and informative signal analysis.

The use of local anesthetics has greatly enhanced the safety and quality of anesthesia for more than a century. Improvements in techniques and devices (e.g., nerve stimulation and ultrasound guidance, specialized needles), and anesthetic agents have also been made. Nevertheless, no routinely used monitor has enabled the clinician to objectively characterize the effect of the block in the patient.

The ability to collect and interpret data to characterize the effect of blocking agents would give the clinician an unparalleled means to limit toxicity, improve dosing regimens to enable care to better approximate analgesic need (both in location and quality), manage uncooperative patients (adult asleep, adult uncooperative [psychological or defiant], pediatric uncooperative [developmental or communication barrier], pediatric asleep), and better refine techniques (e.g., to improve discrimination between motor/sensory blockade [differential blockade]) for patients.

We present ongoing analysis and study using a new monitor that objectively measures the effect of caudal epidural block in children. Using statistical methods, we evaluate varying time periods for derivation of a key measure of neural blockade.

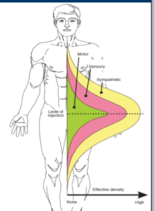
Methods: Twelve children (3 months to 2 years of age) undergoing circumcision were studied using a prospective, randomized, open treatment observational study after parental consent of this IRB approved protocol. After general anesthetic induction (sevoflurane, LMA, and IV placement) subjects were randomly assigned to receive either caudal (bupivacaine 0.25% w/ 1:200K epinephrine, 1ml/kg) or penile block (bupivacaine 0.25%, 0.5ml/kg). Surface electromyogram (EMG) was recorded at several levels, including T4, T6, & T10 at baseline and after local anesthetic injection during the operative procedure. Post-operative analysis of EMG (ratio of pre-/post- root mean squared averages, EMG_{RMS}) was used to assess the changes seen between groups. Evaluation of nominal logistic fit and calculation of sensitivity and specificity in predicting presence of block at the T10 level was analyzed using various time periods for derivation of EMG_{RMS}.

Results: All subjects had intra-operative courses consistent with effective block. Analysis of normalized EMG_{RMS} at T10 over 0.05, 0.1, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5 second time period revealed differences in both sensitivity/specificity and receiver operating characteristic (ROC) curves for prediction of caudal or penile block. (Table 1) Nominal logistic fit for block (caudal v. penile) demonstrated maximum discrimination using 0.5 seconds (χ^2=13.5, p=0.0002). Area under the curve for the ROC at this level was 1.0, which represents ideal performance.

Summary: Discrimination between caudal and penile block was found to be superior using a 0.5 second time frame for derivation of the EMG_{RMS} at T10. Of those studied, this demonstrates the optimal time period for determination of this signal for block assessment. Application of this is critical in future analysis of this novel monitoring modality.

Technology

- Local anesthetic effect will be seen as a change in the baseline non-stimulated surface electromyogram.
- Ascending block is expected from caudal but not penile block



Introduction

- Use of local anesthetics has greatly enhanced the safety and quality of anesthesia for more than a century.
- Though progress has been made in the use, efficacy, and safety of anesthesia, tools are not available to objectively monitor/evaluate block effectiveness.
- We studied a technology that measures and reports the effects of local anesthetics and report proof of principle in children using a new monitor that objectively measures and reports the effect of caudal epidural block in children.
- We measured changes over time in surface electromyogram (EMG) associated with administration of local anesthetic in the caudal epidural space, compared to penile block, in children undergoing circumcision.
- We then analyzed various time periods for the derivation of the optimal EMG_{RMS}

Methods & Procedures

- ✓ IRB **approval**, parental **consent** of prospective, randomized, open treatment observational intraoperative study
- ✓ Boys (3mos to 2yrs of age) having **circumcision**
- ✓ General **anesthetic induction** (sevoflurane, LMA, and IV placement), then random assignment (2:1):
  - **caudal block** (bupivacaine 0.25% w/ 1:200K epinephrine, 1ml/kg)
  - **penile block** (bupivacaine 0.25%, 0.5ml/kg)
- ✓ **Surface EMG** was recorded at T4, T6 , T10 (L&R) and L2 at **baseline** and **after injection** of local anesthetic during the operative procedure.
- ✓ **Post-op analysis of EMG_{RMS}** (normalized root mean squared averages,) to assess the changes seen between groups at T10
- ✓ Analysis of various time periods for the derivation of the optimal EMG_{RMS}

Signal Sampling, EMG_{RMS} & Analysis

Surface EMG signal data was analyzed as a quantitative/ continuous value by computing the associated power in the time domain. The root-mean-square (rms) estimator was selected as the power indication:

$$rms = \sqrt{\sum_{i=1}^{n}\left[x_i^2 / n \right]}$$

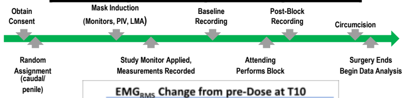
where n is the number of samples in the integration interval. We acquired data at a rate of 500 samples/sec. The reported results were analyzed using a varying integration interval of 0.05, 0.1, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5 seconds. The rms time history is generated over the full data segment of interest by sliding the integration window one data sample at a time. The mean of the rms time history is computed for a period of time (about 10 seconds) before the anesthetic dose ("pre-dose") and before the first incision ("post-dose").

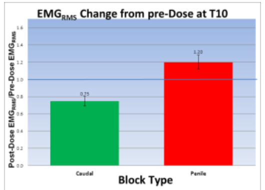
Results

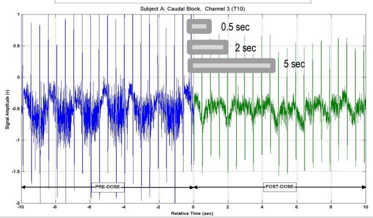
Subject Characteristics

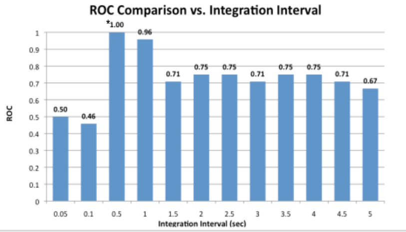
(mean ± SEM)

Block	Number of Subjects	Age (months)	Weight (Kg)
Caudal	7	19.9±2.0	11.9±0.6
Penile	5	14.1±1.3	11.2±1.3
All	**12**	**16.8±1.2**	**11.5±0.6**









*At an integration interval of 0.5 seconds, the p-value was 0.0002

Discussion

Compared to baseline, recognizable decreases in non-stimulated EMG_{RMS} were present in all subjects upon administration of local anesthetic in the caudal space at T10. In contrast, increases in EMG_{RMS} were noted at T10 in all subjects who received penile block. This effect makes discriminating between caudal and penile block sensitive and specific at T10.

Discrimination between caudal and penile block was found to be superior using a 0.5 second time frame for derivation of the EMG_{RMS} at T10. Of those studied, this demonstrates the optimal time period for determination of this signal for block assessment. Application of this is critical in future analysis of this novel monitoring modality.

Implications

The ability to characterize the effect of blocking agents would give the clinician an unparalleled means to limit toxicity, improve dosing regimens to enable care to better approximate analgesic need (both in location and quality), manage uncooperative patients (adult asleep, adult uncooperative [psychological or defiant], pediatric uncooperative [developmental or communication barrier], pediatric asleep), and better refine techniques (e.g., to improve discrimination between motor/sensory blockade [differential blockade]) for patients.

This study demonstrates not only the feasibility and promise of using passive surface EMG as an objective measure of the effectiveness of regional blockade in anesthetized children, but is also begins to optimize the post-block analysis phase. Ultimately, post-block analysis will be able to discern both the location and density of the block, guiding the clinician in future treatment or medication administration.

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