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Effect of Storage Condition in a Conex Box on the Properties of Dental Local Anesthesia for Field Use in the Army

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Statement of the Problem

Storage and transportation of dental supplies in the Army often does not meet the manufacturer's recommendation, especially during field exercises or deployments. Conex box is a type of cargo container that is utilized to transport and store supplies. Temperature and humidity are typically elevated in these type of storage containers. Often, dental materials are stored in the Conex box for a prolonged period before its usage and possibly affect the desired outcomes for the materials' use. Non-compliance of the storage recommendation from the manufacturers may arise a concern of changes to the physical/chemical property of the anesthetic such as pH of its contents. Wasted dental supplies due to improper storage can have a negative impact on dental readiness and represent a financial loss to the Army.

Significance

Achievement of profound anesthesia is essential to provide quality dental care to patients. Incomplete anesthesia results in increased pain and anxiety. Furthermore, the outcomes of insufficient anesthetics can lead to traumatic dental experiences which are preventable. Proper storage of these materials can be one of many ways to prevent incomplete anesthesia. There have been studies in the past that focused on the effects of storage conditions on the anesthetic cartridge,[5] specifically the plunger becoming defective, but of the effects on local anesthetic agents remains unclear.

Background

Local anesthetics generally work by blocking the conduction of the peripheral nerve or suppressing the excitation of the nerve endings. This is achieved by the reversible binding of anesthetics to sodium channels resulting in their deactivation. Sodium inflow through these channels is necessary for depolarization of nerve cell membranes and propagation of stimuli from the receptor to the central nervous system. When the nerve loses its ability to depolarize and transmit impulses, the individual loses sensation in the area innervated by that nerve. Properties of a local anesthetic that may influence its pharmacokinetic activity includes lipid solubility, diffusibility, affinity for protein binding, vasodilating properties, and pH values. These properties may be altered by not meeting the manufacturers' storage recommendations which could result in insufficient efficacy of anesthetics. Purpose of this study is to evaluate the possible effects of inadequate storage condition on the pH of the local anesthetics, which can potentially have negative effects of gaining profound anesthesia.

Local anesthetics exist in two states: ionized and non-ionized. The proportion of each state varies according to the pH at the injection site, such as soft tissue. The pH will decrease when the equilibrium is towards the ionized state whereas increase in pH will be examined with equilibrium towards the non-ionized state. Temperature plays a significant role on change in pH values. The molecular vibrations increase as the temperature rises, which results in shift of equilibrium towards ionized states of the solution leading to decrease in pH value. The non-ionized state of local anesthetic carries capacity to diffuse across the nerve membranes and block the sodium channels. The higher the concentration of an anesthetic in the non-ionized state, the faster the onset of the anesthetic. At lower pH more ionized form of the drug leads to a delay in the anesthetic action.

The manufacturer recommends storage and handling of the local anesthetics at controlled room temperature 25°C (77°F) with brief excursions permitted between 15°C and 30°C (59°F-86°F). Storage of the dental supplies often may not meet this recommendation in the Army where it may be stored in a much more aggravated environment, in which the Conex box is a prime example. This study aims to evaluate the side effects of improper storage and handling of the local anesthetics as the manufacturers' information document does not specify.

Objective

To evaluate the effect of variable storage conditions on the pH value of dental local anesthesia commonly used in the Army with comparison to the recommended storage settings.

Hypothesis

There is a significant difference between the pH value of dental local anesthesia stored at humid and hot/cold temperature compared to those stored at room temperature.

Materials and Methods

This is an experimental study. The materials considered will be local anesthetics commonly used in the Army: Lidocaine (Lidocaine HCl 2% and Epinephrine 1:100,000, Novocol Pharmaceutical of Canada, Inc.), Septocaine (Articaine HCl 4% and Epinephrine 1:100,000, Septodont Inc.), and Marcaine (Bupivacaine HCl 0.5% and Epinephrine 1:200,000, Novocol Pharmaceutical of Canada, Inc.).

A sample set of ten cartridges of each material will be set aside and serve as the control group. The control group will be stored at room temperature to accommodate the manufacturer's recommended storage temperature, 25°C (77°F).

A sample set of 20 cartridges from each material will stored in a Conex box for a period of nine months to mimic the storage for the field use in the Army and for comparison. The Conex will be located at Fort Bragg, NC, and the study will be conducted from June 2022 through February 2023 to expose the samples to expected hottest/coldest temperature.

An Onset HOBO MX2301A Temperature/RH Data Logger will be placed inside the Conex box with the sample sets to record the storage temperature and humidity on an hourly basis. At the end of the exposure to the storage time in Conex box, each cartridge will be evaluated for any visible physical changes such as damages to the carpules, colors, and consistency as well as the changes in the value of pH to compare to the control group.

Data will be collected be tested utilizing Apera WS200 pH meter. The manufacturer specifies technical parameters of the meter as following:

Measuring range	(-2.00 - 19.99) pH
Resolution	0.1/0.01 pH
Accuracy	± 0.01 pH ± 1 digit
Temperature Compensation Range	(0 - 100) ℃ (Automatic)

The meter will be calibrated per manufacturer recommendation utilizing specified buffer solutions before data collection to increase accuracy. After each pH reading, the probe will be wiped clean before switching to testing a different local anesthetic solution. Collected data will be compared to the control sample set and evaluated for significance.

Statistical Analysis

Measures of central tendency and dispersion are reported as means with associated standard deviations. Data were screened for normality and homogeneity of variance using the Shapiro–Wilk statistic and Levene's test, respectively. The assumption of data sphericity was assessed using Mauchly's test. To evaluate the effect of storage on the pH of three types of local anethetic (Lidocaine, Septocaine, and Marcaine), a repeated measures analysis of variance (ANOVA) was used. A value of $P < 0.05$ was considered significant for all tests. All data were analyzed with the IBM SPSS version 25 (IBM Corporation, Armonk NY, USA).

Results

The pH values of 90 samples, including 30 control samples and 60 experimental are presented in Table 1. While the room temperature samples were stored under static conditions, the variable conditions were not. Under the variable condition storage,

temperature varied from a minimum of 15.53◦F to a maximum of 128.21◦F and a minimum dewpoint of 1.50◦F to a maximum of 102.43◦F.
The highest pH values were recorded for the Lidocaine samples (M = 4.2, SD = 0.1), P<0.001. Samples of Septocaine were found to have the lowest pH (M = 3.1, SD = 0.1), P<0.001. Results of the repeated measures ANOVA indicated no significant main effect of storage on the mean pH values of samples, P = 0.13.

Table 1. Sample pH values by condition, M (SD)

	Storage Condition	
Sample	Room Temperature	Variable Temperature
Lidocaine	4.2 (0.1)	4.2 (0.0)
Septocaine	3.1 (0.1)	3.1 (0.1)
Marcaine	4.0 (0.0)	4.0 (0.0)

Discussion

The purpose of this study was to evaluate the effect of variable storage conditions on the pH value changes of dental local anesthesia commonly used in the Army. In this study, the improper storage of dental local anesthesia did not have a significant impact on its pH value which rejects the hypothesis and the assumption that it can affect the drug efficacy in achieving profound anesthesia due to the changes to the pH value.

An assumption was made that temperature will play a significant role on change in pH values, as temperature levels increase, the pH value decreases changing its acidity. However, this does not mean that the sample becomes more acidic at higher temperatures. A solution is considered acidic only if there are more hydrogen ions than hydroxide ions. Therefore, storage temperature may not permanently change the pH value of the sample anesthetics and perhaps only at the time of storage and not at the time of injection.

This study has several limitations. First, it is a single case design experimental study with small number of sample size that are tested, which limits the generalizability of the results. Second, the study was conducted only to evaluate for the pH values and therefore, the results may not be sufficient to truly evaluate for its drug efficacy. Possibility of changes in other properties of the anesthetics, i.e., toxicity, preservatives, or shelf-life, that may have potential influence on the pharmaceutical effects remains unclear.

Conclusion

In conclusion, in this study the improper storage of dental local anesthesia did not have a significant impact on its pH value. It is unreasonable to relate the variance in storage temperature and its effects on the drug efficacy of the local anesthetics and therefore the safest practice is to comply with the manufacturer’s recommended storage conditions to ensure the most predictable and desirable outcomes in achieving profound anesthesia. Further research is needed to investigate the effects of improper storage conditions on other physical and chemical properties that can have impact on the drug efficacy of local anesthetics and its clinical outcomes.

Disclaimer

The views expressed herein are those of the author(s) and do not necessarily reflect the official policy of the Department of the Army, Defense Health Agency, Department of Defense, or the US Government.

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