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Buffering Local Anesthetics in Dentistry

by Stanley F. Malamend, D.D.S.

Local anesthetics (LAs) form the backbone of pain control techniques in dentistry. LAs are the safest and the most effective drugs in medicine for the prevention and management of pain. LAs are the only drugs that prevent the nociceptive impulse from reaching the patient's brain.

With the introduction of the first amide LA, lidocaine HCl, in 1948 providing profound anesthesia of long duration became almost a certainty. Other amides introduced since 1948 include mepivacaine HCl, prilocaine HCl, bupivacaine HCl, etidocaine HCl and articaine HCl (the latter considered an amide though technically a hybrid drug, possessing both amide and ester-type characteristics).

Onset of pulpal anesthesia commonly occurs within 5 to 10 minutes, persisting for approximately 60 minutes for articaine HCl, lidocaine HCl, mepivacaine HCl and prilocaine HCl formulations containing a vasopressor (either epinephrine or levonordefrin).

Local anesthetics work. If deposited in close proximity to a nerve they will block nerve conduction.

However, LAs suffer a number of drawbacks:

- LAs containing a vasopressor sting on injection
- LAs are associated with a degree of post-injection tissue injury
- LAs have relatively slow onset
- LAs do not work as reliably in the presence of infection and inflammation

All of these drawbacks can be addressed by anesthetic buffering which:

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- Eliminates the sting
- Reduces tissue injury
- Reduces latency
- Introduces the independent anesthetic effect of carbon dioxide
- Introduces the catalytic effect of carbon dioxide

Reducing Stinging and Post-Injection Tissue Injury. The burning and stinging of acidic injections represent one of the most common complaints in dentistry.

LAs containing a vasopressor have a pH of approximately 3.5 while 'plain' solutions have a pH of approximately 5.9. LA injections containing epinephrine typically have a very low pH, which may produce a more significant degree of soft tissue injury from the injection, leading to increased post-injection soreness.

Chemistry and Anesthetic Latency. To achieve pulpal anesthesia two things must happen: (a) the practitioner must deposit LA in close proximity to a nerve; and (b) the LA must cross the nerve membrane to block sodium channels. At present the first requirement is met through the injection technique. However, without modification, the

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anesthetic's ability to cross the nerve membrane is dependent on biochemical processes that are out of the practitioner's control.

Two ionic forms of the LA exist in equilibrium within an anesthetic cartridge: RN (the uncharged, de-ionized, 'active' free base form of the drug which is lipid soluble) and RNH+ (the 'charged' or ionized cationic form, which is not lipid soluble); only the lipid soluble de-ionized form can cross the nerve membrane.

The equilibrium between de-ionized (RN) and the ionized (RNH+) is illustrated as: RN + H ⇔ RNH+. The relative amounts of de-ionized and ionized forms of LA in a dental cartridge are dependent upon the pH of the solution, in accordance with the Henderson-Hasselbalch equation. For instance, at a pH of 3.5, 99.996% of the lidocaine HCl is in the non-lipid-soluble ionized (RNH+) form, while only 0.004% will be in the lipid soluble de-ionized (RN) form. Recall that only the lipid soluble de-ionized form can cross the nerve membrane. Once within the nerve, the RN picks up a H+ with the resultant RNH+ entering a Na+ channel to block nerve conduction. Only after the body buffers the pH of the anesthetic solution closer toward the physiologic range (7.35 - 7.45) does the anesthetic begin to take effect. The time that this transformation requires is a key factor in anesthetic latency.

Figure 1

Local Anesthetic in the Presence of Infection

Infection represents an additional factor in anesthetic performance. Lower tissue pH at the site of infection makes it extremely difficult for the typical LA injection to provide adequate pulpal anesthesia. Infected tissue is more acidic, which makes it more difficult for the RN conversion to occur.

Buffering Local Anesthetic Immediately Prior to Injection

Increasing the pH of a cartridge of lidocaine HCl with epinephrine immediately before administering the injection significantly increases the amount of the active anesthetic form (RN) available: for example, raising the pH from 3.5 to 7.4 produces a 6000-fold increase. This 'anesthetic buffering' process results in a number of clinical advantages, including: (1) greater patient comfort during injection; (2) more rapid onset of anesthesia; and (3) decreased post-injection tissue injury.

Introducing Carbon Dioxide via the Buffering Process

When sodium bicarbonate (NaHCO3) solution is mixed with an LA, it interacts with the hydrochloric acid in the LA to create water and carbon dioxide (CO2). The CO2 begins to diffuse out of solution immediately and continues to do so even after the solution has been injected. Catchlove[1]

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concluded that CO2 in combination with lidocaine HCl potentiates the action of lidocaine HCl by (1) a direct depressant effect of the CO2 on the axon; (2) concentrating the local anesthetic inside the nerve trunk through ion trapping; and (3) changing the charge of the local anesthetic inside the nerve axon. Condouris and Shakalis[2] demonstrated that CO2 possesses an independent anesthetic effect and caused a seven-fold potentiation in anesthetic action.

Figure 2

Buffering Local Anesthetic in Dentistry

LA buffering is well-known and accepted in medicine. The question in dentistry has been: "How can dental practitioners, who use sealed LA cartridges, take advantage of buffering?"

A dental company (Onpharma Inc., Los Gatos, California) (See figures 1 & 2) has introduced a simple way to consistently buffer dental cartridges of LA.

The author participated in a prospective, randomized, double-blind, crossover trial (N=20) comparing 'standard' LA with epinephrine to LA with epinephrine buffered toward physiologic pH using the Onpharma products. The study, which is being prepared for publication, reached the following two conclusions on injection pain. First, 72% of the subjects rated the buffered LA injection more comfortable than unbuffered; 17% rated them the same; and 11% rated the unbuffered LA more comfortable (p=0.003). Second, 44% of the injections with buffered LA were reported to be painless (VAS=0), versus 6% of injections with traditional LA (p=0.004).

The study also assessed onset of pulpal anesthesia. Patients served as their own control, receiving either the buffered or standard LA with epinephrine on two visits separated by at least 2 weeks. Average time to pulpal anesthesia was 7 minutes 29 seconds for the standard LA and 1 minute 51 seconds for the buffered LA ($p<0.05$). Eighty percent of the buffered subjects obtained pulpal anesthesia in less than 2 minutes.

Conclusion. Buffering lidocaine HCl with epinephrine using NaHCO3 has definite advantages to the practitioner and the patient: buffered LA is more comfortable and faster acting. Buffering dental anesthetic cartridges can now be accomplished relatively simply and consistently using recently introduced technology.

References

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[Ed. Note: Dr. Malamed's article was written at my request because I thought our members would be interested in this topic. The Pulse is not a "peer reviewed" journal. WAM]