# Comparison of buffered and non-buffered lidocaine: pH and pain perception

VANDANA SADANANDA[1], JUBANA M K[1], MITHRA N. HEGDE[1], ADITYA SHETTY[1] and PRIYA GATTI[2]

[1]Department of Conservative Dentistry and Endodontics, A. B. Shetty Memorial Institute of Dental Sciences, Nitte (Deemed to be University), Deralakatte, Mangaluru, Karnataka 575018, India; [2]Department of Medical Biology, Université du Québec à Trois-Rivières, Trois-Rivières, Quebec G8Z 4M3, Canada

Received September 9, 2021; Accepted September 16, 2022

DOI: 10.3892/wasj.2022.172

**Abstract.** Commonly used local anaesthetic (LA) solutions in the field of dentistry are acidic, and have been known to cause pain and a burning sensation. The present study aimed to determine the pH levels of commercially available LA solutions with and without adrenaline and 8.4% sodium bicarbonate-buffered LA solution, and to evaluate the pain during the administration of buffered and non-buffered LA solutions. For this purpose, 20 patients with deep dentinal carious lesions with pulpal involvement affecting the bilateral posterior teeth and requiring the administration of a local nerve block were randomly selected to receive buffered and non-buffered LA agents on either side, respectively. The patients were instructed to score the pain perceived during LA administration with the aid of a visual analogue scale (VAS) score of 1-10. All the data obtained were subjected to statistical analysis. The results revealed that the LA solution of 2% lignocaine with 1:80,000 adrenaline buffered with sodium bicarbonate had a mean (± SD) pH level of 6.92±0.34 and non-buffered LA solution had a mean pH level of 3.49±0.26. As per the VAS, a greater level of pain was reported during the non-buffered LA administration (3.15±1.27) compared to the buffered LA administration (1.40±0.68). Buffered local anaesthetics were more likely than non-buffered solutions to achieve successful anaesthesia [95% confidence interval (CI), 1.09-2.41; P<0.001]. On the whole, the present study demonstrates that a significant reduction in the pain perceived in patients during the administration of LA agents buffered with sodium bicarbonate when used during pulpal involvement.

*Correspondence to:* Dr Vandana Sadananda, Department of Conservative Dentistry and Endodontics, A. B. Shetty Memorial Institute of Dental Sciences, Nitte (Deemed to be University), Deralakatte, Mangaluru, Karnataka 575018, India
E-mail: drvandanasadananda@nitte.edu.in

*Key words:* alkalinization, buffering, local anaesthetics, pH, sodium bicarbonate

## Introduction

The ability of dental professionals to perform routine endodontic procedures successfully relies primarily on the adequacy of the local anaesthetic (LA) administered. However, LAs tend to cause pain on mucosal infiltration, which adds to patient anxiety during procedures (1). More painful skin and subcutaneous infiltration has been reported with adrenaline containing lidocaine (2). The lower pH of an anaesthetic solution containing adrenaline is primarily responsible for the greater pain sensation. A weak basic amide, lidocaine being unstable at a pH of 7.9, is made in an acidic preparation to enhance its solubility and prolong its shelf life. Epinephrine is added to lidocaine to extend the duration of action of the aesthetic, decrease toxicity and achieve haemostasis. As adrenaline is stable for lengthy phases in an acidic environment, the pH of commercially available lidocaine with epinephrine (pH 3.3-5.5) is lower than that of plain lidocaine (pH 5.7-6.5). The acidity can give rise to tissue irritation, which may be felt by patients as a stinging or burning pain (3,4).

The most common method for buffering is by alkalinization of the lidocaine with sodium bicarbonate just prior to the injection. Buffering with sodium bicarbonate ($NaHCO_3$) 8.4% in a 10:1 or 9:1 ratio (10 or 9 parts lidocaine-epinephrine 1% containing 5 $\mu$g/ml to 1part sodium bicarbonate containing 8.4 g/l) more closely resembles the neutral pH (~7.4) in human tissues. Buffered solutions are known to cause less pain than unbuffered lidocaine (1,3-14).

The present study aimed to evaluate the pain profile of nerve blocks following the injection of the LA 2% lidocaine with adrenaline; with and without buffering using 8.4% sodium bicarbonate. The objectives of the present study were to compare the pH levels of anaesthetic solutions in buffered and non-buffered form, and to evaluate the perception of pain during LA administration, while using buffered and non-buffered forms.

## Materials and methods

*Patients and anaesthetics*. The University Research Ethics Board of Nitte (Deemed to be University), approved the study (Cert. no. ABSM/ECO5/2019). A total of 20 healthy adult volunteers with deep dentinal caries on either side, requiring

Table I. Comparison of pH levels between groups.

| Group | Mean | Standard deviation | P-value |
|---|---|---|---|
| Lidocaine with adrenaline | 3.4990 | 0.26 | <0.001 |
| Lidocaine with adrenaline + 8.4% sodium bicarbonate | 6.9250 | 0.34 | |
| Lidocaine without adrenaline | 6.5050 | 0.26 | |
| Lidocaine without adrenaline + 8.4% sodium bicarbonate | 7.2110 | 0.18 | |

The mean pH for all groups is presented. ANOVA revealed that there was a significant difference between all groups (P<0.001).

Table II. Comparison of pain perception between the groups based on the visual analogue scale score.

| Group | No. of patients | Mean | Standard deviation | Mean difference | 95% confidence interval of the difference | P-value |
|---|---|---|---|---|---|---|
| Lidocaine with adrenaline | 20 | 3.15 | 1.27 | 1.75 | 1.09-2.41 | 0.001 |
| Lidocaine with adrenaline + 8.4% sodium bicarbonate | 20 | 1.40 | 0.68 | | | |

the administration of a local nerve block were randomly selected. The study excluded subjects with a history of allergy to lidocaine or medically compromising conditions, such as abnormal pain sensation, a history of surgery, or trauma to the face. Informed consent was obtained from the all the patients enrolled.

Both the volunteer and injector were blinded to the type of the LA solution to be administered. The split-mouth design was used in the present study. The order of the side of face to be injected and the order of buffered and non-buffered LA solutions to be injected were randomized by an investigator not involved in the process and handed over to the injector.

The buffered solution was prepared by mixing commercially available 2% lidocaine with adrenaline 1:80,000 (Xylocaine, AstraZeneca) with 8.4% sodium bicarbonate in a 10:1 dilution (0.2 ml bicarbonate was added to 2 ml lidocaine with adrenaline). The pH level of 2% lidocaine with adrenaline was examined before and after mixing 8.4% sodium bicarbonate (at a 10:1 ratio, respectively) using a temperature compensating pH meter (Apera Instruments, pH 700 bench-top lab pH meter) in 20 samples. The mean pH level was derived from four groups as demonstrated in Table I.

Each subject received a freshly prepared buffered anaesthetic solution by mixing 8.4% sodium bicarbonate. The inferior nerve block was the route of choice for administration. Each subject received two injections, one with the non-buffered solution on one side and one with the buffered solution on the other side using a 25-gauge needle into the medial side of the mandibular ramus.

The penetration of the needle was continued until bony resistance was felt, and aspiration was performed before 1.5 ml of the local anaesthetic was deposited over a minimum of 60 sec. The subjects were instructed to ignore the pain of needle insertion and to focus on the discomfort during the injection of the anaesthetic agent. Immediately following the injection, the patients were asked to score the pain perceived during LA agent administration by marking on a previously validated visual analogue scale (VAS) with a score ranging from 0-10 (14). This was followed by the injection with a non-buffered solution similarly on the other side. All study procedures were performed during a single visit, which lasted no more than 30 min.

*Statistical analysis*. Data were statistically analysed using Microsoft Excel and SPSS software version 22 (IBM Corp.). The non-parametric VAS data were analysed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test. The data are presented as the mean ± standard deviation. A P-value <0.05 was considered to indicate a statistically significant difference.

## Results

The score obtained for the buffered and non-buffered LAs was compared using one-way ANOVA. The mean (± SD) pH value of the buffered solution was 6.9±0.34, while that without bicarbonate was 3.4±0.26 (Table I). 65 % of the 20 subjects felt that the non-buffered lidocaine was more painful than the buffered solution. Lidocaine with adrenaline had a very low pH; however, when buffered with sodium bicarbonate, the solution approached that of the normal body tissue pH. In addition, the adrenaline-containing solutions (approximate pH 3.5) were markedly more acidic than those without adrenaline (approximate pH 6) (Table I)

The pain scores obtained during the LA injection with and without sodium bicarbonate are presented in Table II. There was a trend towards lower pain scores when the LA contained sodium bicarbonate. The mean (± SD) pain scores (0-10) in the bicarbonate-containing groups were 1.4±0.68 compared to 3.15±1.27 in the groups not administered bicarbonate (P=0.001). The mean difference in pain perception with the

buffered solution was almost one-half compared with the non-buffered solution.

Hence, lidocaine with adrenaline buffered with sodium bicarbonate yielded statistically significant differences in terms of the pH achieved and the score of pain perception when compared with the non-buffered solution.

## Discussion

The buffering of LAs is well recognized and established in medicine. In a systematic review by Davies (14) on the buffering of LAs, a significant reduction in the pain of the injection was found with buffering with sodium bicarbonate, while not affecting efficacy. The use of pH-adjusted LA solutions (pH 7.4) in epidural analgesia, peripheral nerve blocks and regional anaesthesia was investigated by Galindo (15) and it was concluded that basic solutions established anaesthesia of better quality. The addition of 1 ml of 8.4% sodium bicarbonate to 10 ml LA is the most common method of buffering lidocaine. The 10:1 ratio of the LA to bicarbonate ratio raises the pH of the solution to a more physiological range (16).

Following the buffering of the anaesthetic with sodium bicarbonate, the LA injections have been shown to be associated with a decreased intensity of pain, and reduction of the stinging quality of pain (1,5). Immediately after the administration, the pH of the injected solution would rapidly approach the physiological pH of the tissue. Buffering raises the concentration of the non-ionized component of the anaesthetic solution, resulting in an enhanced diffusion through the neuronal membrane resulting in a more rapid onset of action (17).

Buffering with bicarbonate leads to the production of carbon dioxide ($CO_2$) and water as a by-product. It was previously confirmed by Catchlove (18) that the presence of $CO_2$ tends to lower the interstitial fluid pH within the nerve sheath. This further enhances the ionization of the LA that has diffused into this region. Moreover, $CO_2$ relative to lidocaine may cause an instant form of analgesia as it rapidly diffuses through the nerve sheath and reaches the axon before the LA (18). While this initial effect may be as beneficial as gas, however, buffered anaesthetics in a glass carpule may be considered unstable. As the excessive alkalinity can cause precipitation in the solution, the buffered mixture freshly prepared should be administered immediately following preparation. Tissue damage from an unstable mixture or precipitate could also be of clinical concern (18). Nerve conduction blockade being significantly more in the presence of $CO_2$ was also confirmed by Condouris and Shakalis (19) in an isolated rat sciatic nerve model. Momsen *et al* (20) established the stability of buffered lidocaine adrenaline solution for up to 24 h following preparation.

The difference in pain scores being statistically significant confirms the use of buffered lidocaine as a means of reducing pain on injection.

In conclusion, anxiety and phobia are perhaps the most frequently encountered issues in the clinical practice of dentistry and are associated with the painful stimulus of the LA injection. Ensuring adequate anaesthesia in patients with minimum discomfort is paramount, particularly in endodontic procedures, such as pulp extirpation, enlarging the canal in vital teeth and obturation. The present study demonstrates that this a simple, inexpensive method that can easily be performed by dentists shortly before the LA injection to deliver improved patient care.

## Acknowledgements

Not applicable.

## Funding

No funding was received.

## Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Authors' contributions

All authors (VS, JMK, MNH, AS and PG) made a substantial contribution to i) the conception, design, or the analysis and interpretation of the data; and ii) to drafting the article or revising it critically for important intellectual content. JMK and VS confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

## Ethics approval and consent to participate

The University Research Ethics Board of Nitte (Deemed to be University) approved the study (Cert. no. ABSM/ECO5/2019). Written informed consent was obtained from each individual participant involved in the study.

## Patient consent for publication

Not applicable.

## Competing interests

The authors declare that they have no competing interests.

## References

1. Burns CA, Ferris G, Feng C, Cooper JZ and Brown MD: Decreasing the pain of local anesthesia: A prospective, double-blind comparison of buffered, premixed 1% lidocaine with epinephrine versus 1% lidocaine freshly mixed with epinephrine. J Am Acad Dermatol 54: 128-131, 2006.
2. McKay W, Morris R and Mushlin P: Sodium bicarbonate attenuates pain on skin infiltration with lidocaine, with or without epinephrine. Anesth Analg 66: 572-574, 1987.
3. Christoph RA, Buchanan L, Begalla K and Schwartz S: Pain reduction in local anesthetic administration through pH buffering. Ann Emerg Med 17: 117-120, 1988.
4. Hruza GJ: Anesthesia. In: Dermatology. Bolognia JL, Jorizzo FL and Rapini RP (eds). Elsevier Science, New York, NY, pp 2233-2242, 2003.
5. Stewart JH, Cole GW and Klein JA: Neutralized lidocaine with epinephrine for local anesthesia. J Dermatol Surg Oncol 15: 1081-1088, 1989.
6. Orlinsky M, Hudson C, Chan L and Deslauriers R: Pain comparison of unbuffered versus buffered lidocaine in local wound infiltration. J Emerg Med 10: 411-415, 1992.

7. Bartfield JM, Crisafulli KM, Raccio-Robak N and Salluzzo RF: The effects of warming and buffering on pain of infiltration of lidocaine. Acad Emerg Med 2: 254-258, 1995.
8. Brogan Jr GX, Giarrusso E, Hollander JE, Cassara G, Maranga MC and Thode HC: Comparison of plain, warmed, and buffered lidocaine for anesthesia of traumatic wounds. Ann Emerg Med 26: 121-125, 1995.
9. Colaric KB, Overton DT and Moore K: Pain reduction in lidocaine administration through buffering and warming. Am J Emerg Med 16: 353-356, 1998.
10. Xia Y, Chen E, Tibbits DL, Reilley TE and McSweeney TD: Comparison of effects of lidocaine hydrochloride, buffered lidocaine, diphenhydramine, and normal saline after intradermal injection. J Clin Anesth 14: 339-343, 2002.
11. Larson PO, Ragi G, Swandby M, Darcey B, Polzin G and Carey P: Stability of buffered lidocaine and epinephrine used for local anesthesia. J Dermatol Surg Oncol 17: 411-414, 1991.
12. Bartfield JM, Gennis P, Barbera J, Breuer B and Gallagher EJ: Buffered versus plain lidocaine as a local anesthetic for simple laceration repair. Ann Emerg Med 19: 1387-1389, 1990.
13. Scott J and Huskisson EC: Graphic representation of pain. Pain 2: 175-184, 1976.
14. Davies RJ: Buffering the pain of local anaesthetics: A systematic review. Emerg Med (Fremantle) 15: 81-88, 2003.
15. Galindo A: pH-adjusted local anesthetics: Clinical experience. Reg Anesth 8: 35-36, 1983.
16. Richtsmeier AJ and Hatcher JW: Buffered lidocaine for skin infiltration prior to hemodialysis. J Pain Symptom Manage 10: 198-203, 1995.
17. Gosteli P, Gessel EV and Gamulin Z: Effects of pH adjustment and carbonation of lidocaine during epidural anesthesia for foot or ankle surgery. Anesth Analg 81: 104-109, 1995.
18. Catchlove R: The influence of $CO_2$ and pH on local anesthetic action. Survey of Anesthesiology 17: 184-185, 1973. https://escholarship.mcgill.ca/downloads/tx31qm98v.
19. Condouris GA and Shakalis A: Potentiation of the nerve-depressant effect of local anaesthetics by carbon dioxide. Nature 204: 57-59, 1964.
20. Momsen OH, Roman CM, Mohammed BA and Andersen G. Neutralization of lidocaine-adrenaline. A simple method for less painful application of local anesthesia. Ugeskr Laeger 162: 4391-4394, 2000 (In Danish).