Effect of Injection Pressure of Infiltration Anesthesia to the Jawbone

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To obtain effective infiltration anesthesia in the jawbone, high concentrations of local anesthetic are needed. However, to reduce pain experienced by patients during local anesthetic administration, low-pressure injection is recommended for subperiosteal infiltration anesthesia. Currently, there are no studies regarding the effect of injection pressure on infiltration anesthesia, and a standard injection pressure has not been clearly determined. Hence, the effect of injection pressure of subperiosteal infiltration anesthesia on local anesthetic infiltration to the jawbone was considered by directly measuring lidocaine concentration in the jawbone. Japanese white male rabbits were used as test animals. After inducing general anesthesia with oxygen and sevoflurane, cannulation to the femoral artery was performed and arterial pressure was continuously recorded. Subperiosteal infiltration anesthesia was performed by injecting 0.5 mL of 2% lidocaine containing 1/80,000 adrenaline, and injection pressure was monitored by a pressure transducer for 40 seconds. After specified time intervals (10, 20, 30, 40, 50, and 60 minutes), jawbone and blood samples were collected, and the concentration of lidocaine at each time interval was measured. The mean injection pressure was divided into 4 groups (100 ± 50 mm Hg, 200 ± 50 mm Hg, 300 ± 50 mm Hg, and 400 ± 50 mm Hg), and comparison statistical analysis between these 4 groups was performed. No significant change in blood pressure during infiltration anesthesia was observed in any of the 4 groups. Lidocaine concentration in the blood and jawbone were highest 10 minutes after the infiltration anesthesia in all 4 groups and decreased thereafter. Lidocaine concentration in the jawbone increased as injection pressure increased, while serum lidocaine concentration was significantly lower. This suggests that when injection pressure of subperiosteal infiltration anesthesia is low, infiltration of local anesthetic to the jawbone may be reduced, while transfer to oral mucosa and blood may be increased.

Key Words: Infiltration anesthesia; Local anesthesia; Jawbone; Injection pressure; Lidocaine concentration.

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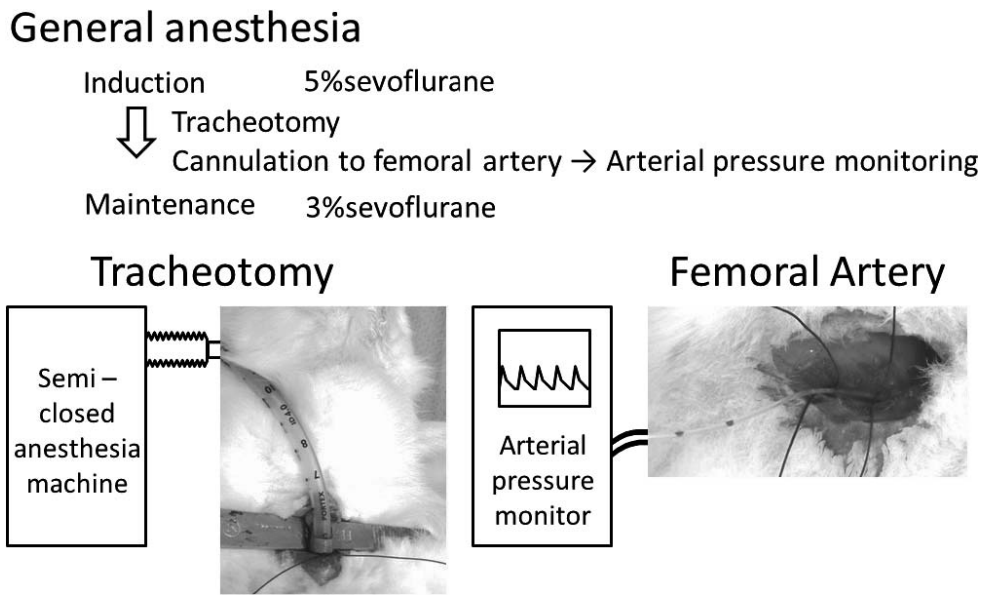

Figure 1. Method of general anesthesia. General anesthesia was induced by oxygen 5 L/min and 5% sevoflurane, and then a tracheotomy was performed, after which general anesthesia was maintained at oxygen 3 L/min and 3% sevoflurane. A cannula was inserted into the femoral artery, and arterial pressure was continuously recorded throughout the experiment using a polygraph and a pressure transducer.

MATERIALS AND METHODS

Animals

Japanese white rabbits ($n = 144$, body weight: 2.66 ± 0.3 kg, 16 weeks of age, male; Nippon Bio-Supp. Center, Tokyo, Japan) were used. Animals were kept in a controlled animal room at 23°C and 60% humidity and given free access to pellets (MF, Oriental Yeast, Tokyo, Japan) and drinking tap water until the experiment day. This study was performed in accordance with the Animal Experiment Regulations of Ohu University (permit No. 2013-52, 2014-28).

General Anesthesia and Experimental Model

General anesthesia was induced by oxygen 5 L/min and 5% sevoflurane using anesthesia equipment for small animals (Soft Lander, Shin-Ei Industries, Tokyo, Japan). Next, tracheotomy was performed, after which general anesthesia was maintained at oxygen 3 L/min and 3% sevoflurane. A cannula was inserted into the femoral artery, and arterial pressure was continuously recorded throughout the experiment using a polygraph (Sanei Sokki, Tokyo, Japan) and a pressure transducer (Nihon Kohden, Tokyo, Japan; Figure 1).

Infiltration Anesthetic Injection and Excision of Jawbone

Under general anesthesia, using quantitative electric injector (Cartri-Ace, Dentronics, Tokyo, Japan) with an injection needle (27G, 0.40 × 19; TERUMO NEEDLE, TERUMO, Tokyo, Japan), 0.5 mL of 2% of lidocaine containing 1/80,000 adrenaline (dental xylocaine cartridge containing 1/80,000 adrenaline, Dentsply Sankin, Tokyo, Japan) was injected into the right lower jawbone for 40 seconds. The injection pressure was determined for 4 groups (100 ± 50 mm Hg, 200 ± 50 mm Hg, 300 ± 50 mm Hg, and 400 ± 50 mm Hg). The injection pressure was measured using a pressure transducer by connecting Terufusion, a T-shaped stopcock (TERUMO) between Cartri-Ace, an electric injector for dental anesthesia, and the injection needle. For the subperiosteal infiltration anesthesia, the needle tip was inserted into the gingivobuccal fold of the molar mesial buccal region side of the right lower jawbone. Then, the local anesthetic solution was injected by attaching the needle tip to the alveolar bone (Figure 2). Next, after a specified time interval (10, 20, 30, 40, 50, and 60 minutes), the periosteum was elevated, and approximately 0.12 g of jawbone was removed using bone-cutting forceps. Sample size (height × weight × depth) was 5 mm × 5 mm × 5 mm. The sample was collected within 1 minute to avoid the influence due to the

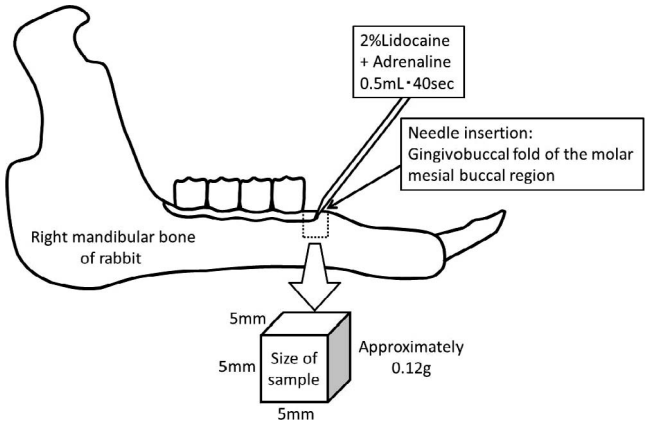

Figure 2. Method of subperiosteal infiltration anesthesia. The needle tip was inserted into the gingivobuccal fold of the molar mesial buccal region of the right mandible. The local anesthetic was injected by attaching the needle tip to the alveolar bone. After a specified time interval, the periosteum was elevated, and approximately 0.12 g of jawbone was removed using bone-cutting forceps. Sample size (height × weight × depth) was 5 mm × 5 mm × 5 mm. The sample was collected within 1 minute to avoid the influence of the bleeding.

bleeding. The collected bone was cryopreserved at –80°C.

Measurement of the Mean Arterial Pressure Before and After Injection of Local Anesthesia

Since arterial blood pressure changes due to pain and adrenaline contained in local anesthesia, even while under general anesthesia,[1] the change in blood pressure during infiltration anesthesia was measured. Arterial blood pressure was recorded by polygraph, through cannulation of femoral artery via pressure transducer. From the polygraphic arterial pressure data, one-third pulse pressure added diastolic arterial pressure was calculated as the mean arterial pressure (MAP), and changes in arterial pressure were assessed 10 and 20 seconds after infiltration anesthesia of 2% lidocaine with 1:80,000 adrenaline.

Measurement of the Serum Lidocaine Concentration

Subperiosteal infiltration anesthesia was performed, and a 3-mL blood sample was collected after the specified time interval (10, 20, 30, 40, 50, and 60 minutes). The sample was separated into individual plasma components by centrifuge, and serum lidocaine concentration was measured by the enzyme multiplied immunoassay technique method.[2–4]

Measurement of Lidocaine Concentration in the Jawbone

Frozen bone and mucosa samples were ground using a bone mill (TK-CM20S, Tokken, Tokyo, Japan), suspended in 0.01 M boric acid solution with a pH of 9.18, and homogenized for 2 minutes using a homogenizer (POLYTRON PT2100, Kinematica, Switzerland). The supernatant (0.5 mL) was combined with 100 μL mexiletine (10 μg/mL) and then 5 mL of chloroform:-methanol (8:2). After mixing, the solution was centrifuged at 3000 rpm (1000*g*) for 10 minutes, and 3 mL of the organic layer was collected and dried under a reduced pressure at 40°C for 60 minutes using a rotary evaporator (EYELA, Tokyo Rikakikai, Tokyo, Japan). The sample was then dissolved in 250 μL of the mobile phase (50 mM KH_2PO_4 : $CH_3CN = 4 : 1$), stirred using a mixer, filtered, and applied to high-performance liquid chromatography (Jasco PU-2080 Plus, JASCO, Tokyo, Japan) to measure the jawbone lidocaine level.[5] Detailed high-performance liquid chromatography conditions are shown in the report by Morota et al.[6] Tissue lidocaine data were converted to lidocaine level per gram (g) of jawbone. MAP and the lidocaine concentration in the jawbone were measured by the double-blind method.

Comparison Statistics of Data

Comparison statistical analysis of MAP, serum lidocaine, and lidocaine concentration in the jawbone was performed on the 4 groups (100 ± 50 mm Hg, 200 ± 50 mm Hg, 300 ± 50 mm Hg, and 400 ± 50 mm Hg). Kruskal-Wallis H-test was used for the statistical analysis, and Mann-Whitney *U* test with Bonferroni correction was performed for multiple comparisons. The statistical significance level of all cases was determined to be $P < .05$.

RESULTS

Fluctuation in MAP due to Infiltration Anesthesia

The MAP of the 4 groups is shown before injection, after 10 seconds, and after 20 seconds, respectively, as follows (Figure 3).

In the 100 ± 50 mm Hg group, the MAP was 97 ± 1.08, 94 ± 2.04, and 98 ± 0.86 mm Hg. In the 200 ± 50 mm Hg group, the MAP was 97 ± 1.29, 95 ± 1.87, and 99 ± 0.82 mm Hg. In the 300 ± 50 mmHg group, the MAP was 97 ± 0.82, 95 ± 0.43, and 98 ± 0.43 mm Hg. In the 400 ± 50 mm Hg group, MAP was 97

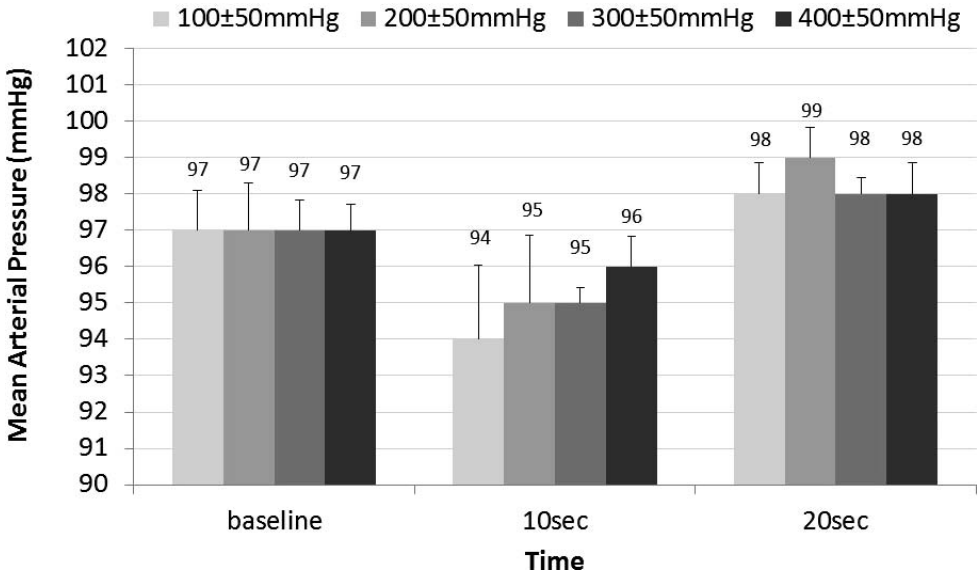

Figure 3. Change of mean arterial pressure before and after infiltration anesthesia. No significant fluctuation in blood pressure was observed in any group, and no significant difference between the 4 groups was detected.

± 0.70, 96 ± 0.82, and 98 ± 0.86 mm Hg, respectively.

No significant fluctuation in blood pressure was observed in any group, and no significant difference between the 4 groups was detected.

Serum Lidocaine Concentration

The serum lidocaine concentration of the 4 groups at 10-, 20-, 30-, 40-, 50-, and 60-minute intervals after the infiltration anesthesia, is shown as follows (Figure 4).

In the 100 ± 50 mm Hg group, the serum lidocaine concentration was 1.38 ± 0.12, 1.13 ± 0.11, 0.97 ± 0.13, 0.87 ± 0.17, 0.69 ± 0.12, and 0.59 ± 0.09 μg/mL, respectively. In the 200 ± 50 mm Hg group, it was 1.09 ± 0.06, 0.95 ± 0.09, 0.79 ± 0.12, 0.67 ± 0.17, 0.60 ± 0.16, and 0.53 ± 0.15 μg/mL, respectively. In the 300 ± 50 mm Hg group, the serum lidocaine concentration was 0.88 ± 0.06, 0.72 ± 0.03, 0.60 ± 0.03, 0.55 ± 0.03, 0.50 ± 0.04, and 0.41 ± 0.03, respectively. In the 400 ± 50 mm Hg group, the concentration was 0.79 ± 0.03, 0.69 ± 0.04, 0.59 ± 0.05, 0.53 ± 0.04, 0.49 ± 0.06, and 0.40 ± 0.04, respectively.

For all groups, the highest value was obtained 10 minutes after infiltration anesthesia, and concentration decreased thereafter. For all time intervals, cases of lower injection pressure had significantly higher serum lidocaine concentrations. Moreover, the serum lidocaine concentration for the 400 ± 50 mm Hg group at all time intervals was significantly lower than that for the 100 ± 50 mm Hg group. In the 200 ± 50 mm Hg group, a significant difference was no longer observed after 30 minutes. In the 300 ± 50 mm Hg group, a significant difference was no longer observed after 50 minutes.

Lidocaine Concentration in the Jawbone

The lidocaine concentration in the jawbone of the 4 groups at 10-, 20-, 30-, 40-, 50-, and 60-minurte intervals after infiltration anesthesia is shown as follows (Figure 5).

In the 100 ± 50 mm Hg group, the lidocaine concentration in the jawbone was 130 ± 4, 86 ± 7, 71 ± 4, 46 ± 6, 21 ± 4, and 19 ± 5 μg/g. In the 200 ± 50 mm Hg group, the concentration was 298 ± 15, 269 ± 14, 252 ± 7, 171 ± 13, 120 ± 10, and 50 ± 8 μg/g. In the 300 ± 50 mm Hg group, the concentration was 355 ± 23, 319 ± 14, 289 ± 10, 201 ± 9, 139 ± 11, and 91 ± 6 μg/g. In the 400 ± 50 mm Hg group, the lidocaine concentration was 494 ± 68, 406 ± 8, 344 ± 12, 236 ± 19, 143 ± 6, and 120 ± 7 μg/g, respectively.

The highest value was obtained at 10 minutes after infiltration anesthesia for all groups, and concentration decreased thereafter. Groups with a higher injection pressure had significantly higher lidocaine concentration in the jawbone at all time intervals.

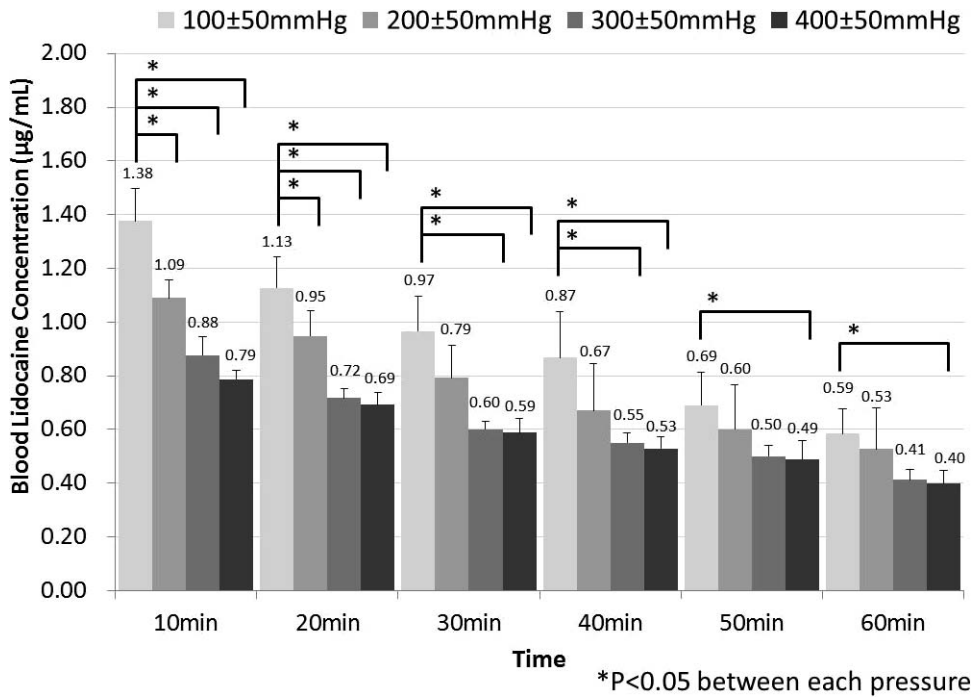

Figure 4. Change of blood lidocaine concentration after infiltration anesthesia. All 4 groups are compared with each other (6 comparisons). However, only comparisons with significant differences are displayed. For all groups, the highest value was obtained at 10 minutes after infiltration anesthesia, and concentration decreased thereafter. For all time intervals, cases of lower injection pressure had significantly higher blood lidocaine concentrations. Moreover, blood lidocaine concentration for the 400 ± 50 mm Hg group at all time intervals was significantly lower than that for the 100 ± 50 mm Hg group and the 200 ± 50 mm Hg group, but the significant difference was no longer observed after 30 minutes. In the 300 ± 50 mm Hg group, significant difference was no longer observed after 50 minutes.

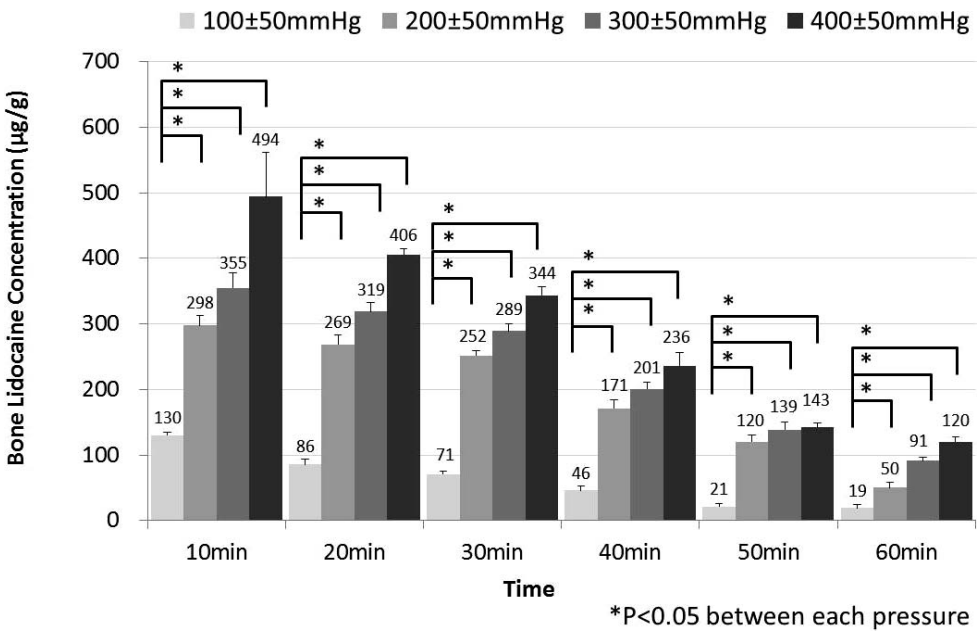

Figure 5. Change of jawbone lidocaine concentration after infiltration anesthesia. All 4 groups are compared with each other (6 comparisons). However, only comparisons with significant differences are displayed. The highest value was obtained at 10 minutes after infiltration anesthesia for all groups, and concentration decreased thereafter. Groups with a higher injection pressure had a significantly higher lidocaine concentration in the jawbone at all time intervals.

DISCUSSION

Appropriate Pressure and Effect in Infiltration Anesthesia

To obtain effective infiltration anesthesia effect in the jawbone, high concentrations of local anesthetic are needed.[7] However, to reduce pain experienced by a patient during dental surgery, low-pressure injection is recommended for subperiosteal infiltration anesthesia.[8] In clinically performed dental and oral surgical treatments, including the removal of impacted teeth and oral implant surgery, the periosteum is often lifted and washed with saline. The effective clinical infiltration anesthesia time for such surgery is reported to be short.[9] Even in experiments on rabbits, the effect of infiltration anesthesia and local anesthetic concentration in the jawbone has been reported to be significantly impaired when the periosteum is lifted and washed with saline in comparison with cases in which the periosteum is not lifted.[10] Consequently, a higher infiltration anesthesia effect is needed during surgery on the jawbone.

Regarding studies on infiltration of local anesthesia to the jawbone, experiments on rabbits in which infiltration anesthesia is applied to the attached gingiva rather than alveolar mucosa have been reported, and greater infiltration of local anesthesia to jawbone, higher analgesic effect, and a longer effective duration have been observed.[6] For oral implant placement surgery commonly performed on older patients with a higher likelihood of cardiovascular disease such as hypertension, coronary artery disease, and so forth, a stronger local anesthetic effect and longer effective duration would likely be safer and more advantageous.[11,12] Some studies on the injection pressure of subperiosteal infiltration anesthesia to the jawbone focus on injection pain, and low-pressure injection is reportedly recommended to reduce pain perception by the patient.[8] On the other hand, studies on infiltration injection pressure and quality of surgical anesthesia have not been made. As a result, a standard injection pressure for infiltration anesthesia has not been clearly determined. Hence, this study considered the effect of injection pressure via subperiosteal infiltration anesthesia on lidocaine concentration in the jawbone.

Fluctuation in MAP due to Infiltration Anesthesia

Although no significant differences were observed in the fluctuation in MAP before and after infiltration anesthesia, a tendency toward a temporary decrease was observed in all groups after infiltration anesthesia. A decrease in MAP due to a temporary reduction in vascular resistance of skeletal muscle caused by adrenaline's β_2 effect, and a return to levels before injection due to peripheral vasoconstriction by the α_1 effect, have been reported.[13,14] Furthermore, cardiac output is increased by adrenaline, and total peripheral resistance is reduced. However, it is reported that blood pressure does not increase significantly by just 1 or 2 cartridges of 2% lidocaine with 1/80,000 adrenaline in a healthy adult.[13] Hence, the amount of lidocaine and adrenaline used on rabbits in this study is considered to be within the range of clinical use dosage.

Pain of injection may also cause an increase in endogenous catecholamine release and affect blood pressure. There are some reports that anxiety and pain at the beginning of injection can be minimized with a lower injection pressure. However, other reports on injection pressure and pain show that in cases of a higher injection pressure of 500 mm Hg, pain does not significantly increase, presumably because of pain blocking by local anesthetic infiltration as well as transient nerve ischemia by pressure.[7,15,16] Moreover, greater fluctuation of MAP with the increase of pain has also been reported, showing a positive correlation in an experiment of general anesthesia in rabbits.[1] For injection pressures of 100 to 400 mm Hg during general anesthesia on rabbits, this result may suggest that a significant difference in pain may not be observed with increasing injection pressure, since no significant difference between groups was observed in the fluctuation of MAP during infiltration anesthesia. However, whether a similar result will be obtained in conscious patients requires further study.

Serum Lidocaine Concentration

Serum lidocaine concentration increased as injection pressure decreased at each time interval. Generally, local anesthesia is injected under the periosteum and diffuses through cortical bone, reaching the bone marrow, where it is absorbed via the blood capillaries.[17] Although lidocaine has high tissue permeability, infiltration into bone tissue is considered more difficult than that into soft tissue.[18,19] In addition,, oral soft tissue has a denser blood vessel supply and greater blood flow volume than bone.[9] Consequently, local anesthesia uptake into the systemic circulation occurs more quickly than absorption into jawbone. Since these findings showed a faster increase in serum lidocaine concentration at a lower injection pressure, the possibility that local anesthesia did not infiltrate as well into jawbone but migrated to oral soft tissues and surrounding capillaries was indicated.

Injection Pressure and Lidocaine Concentration in the Jawbone

Since lidocaine concentration in the jawbone significantly increased as injection pressure increased, greater infiltration of local anesthesia into the jawbone due to the increased injection pressure of subperiosteal infiltration anesthesia was demonstrated. Moreover, the results of serum lidocaine concentration in this study strongly support this conclusion.

As reported by Morota et al,[6] in experiments comparing injection to attached gingiva versus to alveolar mucosa, infiltration anesthesia to attached gingiva was performed at a higher injection pressure, with increased lidocaine concentration in the jawbone. Hochman et al[18] also has reported that greater infiltration to tissue at a higher injection pressure could be achieved for attached gingiva than for alveolar mucosa. Results obtained by Tateno et al[19] using rats showed that local anesthesia injected into alveolar mucosa spread widely to soft tissue. These reports also support the results of this study, namely, that as injection pressure increases, infiltration of local anesthesia into the jawbone is improved. However, in these reports, the possibility that differences in injection sites influence the degree of infiltration of local anesthesia was not considered. In this regard, subperiosteal infiltration anesthesia was applied to the same site under the same conditions and then classified into 4 groups according to the mean injection pressure. As a result, only consideration of injection pressure, rather than differences in injection sites, was determined in this study. In surgeries clinically performed on the jawbone, obtaining a higher infiltration anesthetic effect for a longer period of time is considered likely by avoiding a lower injection pressure and determining the point of a higher injection pressure at which to perform injection. Furthermore, in subperiosteal infiltration anesthesia at a higher injection pressure, reducing injection volume of local anesthetic also may be possible.

CONCLUSION

The effect of injection pressure of subperiosteal infiltration on local anesthetic concentrations in rabbit jawbone was determined by directly measuring the lidocaine concentration in the jawbone. Our results indicate that as injection pressure increases, subperiosteal infiltration anesthesia increases the quantity of lidocaine concentration in rabbit jawbone while decreasing serum lidocaine concentration.

Disclosure

The authors have declared no conflicts of interest.

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