Effect of sweet solutions on pain tolerance threshold in pediatric oral mucosa

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Abstract

PURPOSE: We examined the effects of sweet taste stimulation on pain tolerance threshold (PTT) of oral mucosa in children. SUBJECTS AND METHODS: Subjects comprised 10 children (mean age, 7.3 ± 1.2 years) for whom PTT of oral mucosa was measured 2 min after oral administrations of sucrose or xylitol and water. Sine wave current stimulation (2 kHz, 250 Hz and 5 Hz, SWCS) which can stimulate sensory nerve fiber selectively (Aβ, Aδ and C) was used to measure PTT. RESULTS: Sweet taste stimulation with sucrose or xylitol increased oral mucosa PTT in children, but not in adults. No difference in the increased PTT was seen between sucrose and xylitol. CONCLUSIONS: Oral administration of sucrose and xylitol may potentially relieve pain associated with local anesthetic injections in children.

Introduction

Interventions in dental treatment frequently involve some degree of pain. Injections of local anesthetic for analgesia present a dilemma, as they are in themselves painful. In particular, the pain from injection of local anesthetic must be reduced as much as possible when given to children to ensure smooth performance of subsequent treatments. In clinical practice, oral administration of sucrose has been reported to suppress pain in neonates receiving vaccinations in the heel and having blood samples taken1-3). In animal experiments, oral administration of sucrose has also been reported to reduce pain after injection of formalin, a pain-producing substance, into the rat hind paw4). Other studies have disputed the pain-inhibiting effects of sucrose5,6). Sweet taste stimulation may possibly be applicable in the field of dentistry, and to relieve pain during injection of local anesthetic, but no studies have examined the effects of sweet taste stimulation on pain tolerance threshold (PTT) in the oral mucosa. The present study used sine wave current stimulation (SWCS) to test the effect of sweet taste stimulation by oral administration of sucrose and xylitol on PTT in the oral mucosa of children. We obtained similar measurements from adults in order to compare PTT of the oral mucosa with that of children.

Subjects and Methods

Subjects comprised 10 children between 6 and 9 years old (3 boys, 7 girls; mean age, 7.3 ± 1.2 years) who provided consent and whose parent/guardian provided consent after receiving a sufficient explanation of the study purposes and 10 healthy adults (5 men, 5 women; mean age, 35.6 ± 8.2 years) who gave similar consent. Subjects were orally administered three types of liquids: 0.5 ml of 24% sucrose solution (SS group) as the sweet taste stimulation substance; 0.5 ml of xylitol solution (XS group) at the same concentration as the S solution; and 0.5 ml of water (W group). PTT measurements were taken...
4 times: at the beginning, without any administration (C group) as control values; and once each after administration of sucrose, xylitol and water within a 5- to 10-day interval. The order for administering stimulants sucrose, xylitol and water was randomized. Each measurement was started after 2 min, when the pain-inhibiting effect of sucrose is reportedly maximal\(^5\). PTT was measured with 2 kHz, 250 Hz, and 5 Hz SWCS using a Neurometer CPT/C\(^\circledR\) (Neurotron Inc., Baltimore, USA) that is capable of selective stimulation of sensory nerve fibers at different frequencies. When the measurer turned on the switch, stimulation increased in a stepwise manner (2 kHz: Step 20 Max 500 CPT; 250 Hz: Step 20 Max 500 CPT; 5 Hz: Step 29 Max 500 CPT, 1 CPT = 10\(\mu\)A) at fixed intervals (2 kHz: 0.5 sec.; 250 Hz: 1.5 sec.; 5 Hz: 1.75 sec.). SWCS was continued until subjects raised their hand to signal they felt pain. The measured value was the stimulus step number at which the switch was turned off. Mann-Whitney U tests were used to statistically compare PTT of children versus adults. Kruskal-Wallis tests were used to compare PTT between the administered solutions. When significant differences were found between administered solutions, Scheffé’s method was used to compare each groups. Comparisons with a hazard ratio of less than 5% were considered statistically significant. This research was approved under the experimental policies and ethical standards of the Kyushu Dental College Experimentation Committee.

Results

Oral mucosa PTT was significantly lower in children than in adults at all frequencies (2 kHz, 250 Hz, and 5 Hz) (Fig. 1). This demonstrates that children have a lower pain threshold than adults. Among children, PPT was significantly higher in the SS and XS groups than in the W group, at 250 Hz and 5 Hz current stimulation, but no differences were found at 2 kHz. Furthermore, no significant differences were found between the SS and XS groups at any frequencies (Figs. 2–4). This shows that pain threshold in children increases with sweet taste stimulation, and that there is an equal increase in pain threshold with SS group and with XS group. Sweet taste stimulation did not influence PTT in adults, demonstrating that sweet taste stimulation does not influence pain threshold in adults.

Discussion

We used a Neurometer CPT/C\(^\circledR\) to test the changes in oral mucosa PTT in children when sweet taste stimulation was added orally. The Neurometer CPT/\(^\circledR\) can selectively stimulate sensory nerve fibers by changing the frequency of SWCS\(^7,8\). This method is therefore widely used in measuring perception and pain threshold\(^9,10\). The available frequencies of SWCS are 2 kHz, 250 Hz, and 5 Hz, which are said to be associated with A\(\beta\), A\(\delta\), and C fibers, respectively. The free nerve endings of A\(\delta\) and C fibers react to noxious stimulation, causing the
perception of pain. The free nerve endings of A\(\delta\) fibers react specifically to mechanical high-threshold noxious stimulation. Most C fibers are polymodal neurons with free nerve endings that react to all types of stimulation, and contribute to deep sensation in various parts, including bones, muscles, and connective tissue. A\(\beta\) fiber stimulation normally does not trigger pain, but rather is used in diagnosing neuropathic pain such as allodynia that develops after nerve damage. In other words, A\(\delta\) fibers can be said to contribute to the sensation of pain when the oral mucosa is punctured with a injection needle, and C fibers contribute to pain from pressure in the submucosa during injection of local anesthetic.

Oral mucosa PTT in children was shown to be significantly lower than that in adults for all frequencies of current stimulation. This means that children have higher sensitivity to pain, and perceive strong pain even during mild invasion. Pain stimulation during injection of local anesthetic should therefore be avoided as much as possible. In the present study, PPT at 250 Hz and 5 Hz was significantly higher in the W group than the S group. Oral administration of sucrose may potentially relieve the pain of local anesthetic injections in the oral mucosa. Pain relief during injection of local anesthetic using sucrose is easy and safe, but application in clinical practice is difficult because of the historical background of dental practice being dedicated to prevention of dental caries and dental treatment. Actual eating behaviors such as swallowing and mastication have been reported to inhibit pain\(^{11}\). According to this report, chewing, eating and swallowing cause a great increase in pain threshold. However, no changes were seen in PTT at any frequency of current stimulation with water stimulation. No increase in PTT was achieved with water in children, suggesting the importance of sweet taste stimulation. Recently, xylitol, a sugar alcohol synthesized from xylose as a new artificial sweetener, has been receiving attention in dental practice. X does not cause dental caries, as dental caries-causing bacteria cannot produce acid from xylitol. X also appears effective in preventing dental caries\(^{12}\). In the present study, PTT at 250 Hz and 5 Hz was also significantly higher with xylitol than with water, and was not significantly
different from PTT with sucrose. Xylitol can thus be considered as effective as sucrose in inhibiting pain from oral procedures. Oral administration of xylitol should be actively used during injection of local anesthetic into the oral cavity in dental practice. However, great care should be taken with use in clinical practice, as high doses can lead to diarrhea or hyperalgesia.

Sweet taste stimulation from sucrose raised the pain threshold, but the suggestion has been made that sweet taste stimulation may simply distract children from pain, as they like the taste. Administering sucrose water to the oral cavity of rats causes beta-endorphins, which are endogenous opioids, to be secreted from the hypothalamus into cerebrospinal fluid in large volumes, thereby inhibiting pain. The pain-inhibiting effect achieved with sweet taste stimulation is countered by naloxone, an opioid antagonist. Both first-order neuron terminals that transmit pain in the dorsal horn of the spinal cord and second-order neurons that receive pain sensory information have opioid receptors. When opioid receptors at the presynaptic terminal in first-order neuron terminals are stimulated, voltage-gated Ca++ channels are inhibited and the volume of Ca++ flowing into the presynaptic terminal is decreased, in turn inhibiting the release of glutamate and other excitatory neurotransmitters. When opioid receptors in cell bodies and dendrites of second-order neurons are stimulated, the K-channel opens, and the second-order neurons become hyperpolarized due to the outflow of K+ from the cell. Inhibition of excitatory neurotransmitter discharge from the presynaptic terminal and hyperpolarization of the postsynaptic cell both act to suppress the action potential in the dorsal horn of the spinal cord, so that pain information is not sent from the spinal cord to the upper neurons. Moreover, secretion of endogenous opioids in the midbrain and medulla oblongata enhances activity in the descending pain modulatory system (DPMS). The descending pain inhibitory system is a pain relief mechanism through which serotonergic neurons from the raphe nuclei and noradrenergic neurons from the nucleus ceruleus in the brainstem that is in a higher position than the spinal cord descend into the dorsal horn of the spinal cord, thus inhibiting synaptic transmission from first-order neurons to second-order neurons in the area. In other words, the increase in pain threshold from S is caused by enhanced secretion of endogenous opioids and activation of the descending pain inhibitory system. In the present study, no increase in pain threshold was seen for the Aβ fibers associated with 2 kHz current stimulation. The distribution in the dorsal horn of the spinal cord of Aδ and C fibers that react to noxious stimulation and Aβ nerve endings that react only to innocuous stimulation is clearly separated. Many endogenous opioid receptors in the shallow layer of the trigeminal subnucleus caudalis in which Aδ and C fibers are distributed, but few such receptors in the layer where Aβ fibers are distributed. Furthermore, serotonergic neurons and noradrenergic neurons in DPMS are also only distributed in the shallow layer of the trigeminal subnucleus caudalis. The lack of an increase in pain threshold at 2 kHz is evidence that endogenous opioids in the superficial layer of the trigeminal subnucleus caudalis and DPMS both contribute to the pain-inhibiting effects of sweet taste stimulation. In the present study, XS group also showed a pain-relieving effect. Xylitol and sucrose may use the same mechanisms to increase pain threshold.

In the present study, sweet taste stimulation did not cause an overall increase in PTT in the adult group. However, some adults did show a clear increase in pain threshold with sweet taste stimulation. Sweet taste is always preferred by children, but not always by adults. This may be a result of individual changes in taste preferences that develop as children mature into adulthood. Experiments on animals have shown that drinking water can increase pain threshold, and that sweet taste stimulation does not cause an increase in pain threshold when the animal is ill. It is important to add not just sweet taste stimulation, but stimulation that is preferred by the individual. Saccharin also causes an increase in pain threshold, even though it does not contain any sugar. The lack of difference in the pain threshold increase in children between SS group and XS group is attributable to the fact that they are equally preferred as sweet taste stimuli. Further research is needed, as few reports have examined the effects of taste stimulation on pain threshold in the orofacial region.

Conclusion

We examined the effect of sweet taste stimulation on pain threshold in the oral mucosa in children. We found that children showed a lower pain threshold than adults in the oral mucosa. Oral administration of S and X were shown to increase the oral mucosa
pain threshold in children, but not in adults. Sweet taste stimulation may potentially inhibit pain from injection of local anesthetic to the oral mucosa.

References


