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Neuro 430
Kids Judge Neuroscience Fair 2006 Exhibit
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Why Does My Mouth Feel Numb?

Abstract

Local anesthetics are used in many routine procedures in many settings, such as doctor's and dentist's offices. They are important in both minor and invasive operations in that they aid in inhibiting pain pathways. Local anesthetics bind to sodium channels, thus blocking current flow through the channel. While these channels are blocked pain is inhibited, unless a larger than normal action potential removes the block. In this way, we are better able to get through an operation. The actions of local anesthetics are complex, but because of their frequent usage, it is important to portray this concept to the kids at the Kids Judge! Neuroscience Fair. We communicated the concept of local anesthetics through a poster which helped the kids understand where exactly anesthetics work and a wooden model of the cell membrane. We also had an interactive activity that emphasized the sodium channel on the wooden model. The evaluations from the kids showed that our presentation was interesting, understandable and imparted a desire to learn more about the topic.

Introduction

A common bodily sensation, that nearly everyone has encountered at some point in their lives, is the feeling of numbness, usually by use of a local anesthetic. But how does this numb feeling actually happen and how does it inhibit the feeling of painful stimuli? We addressed this question at the Kid's Judge Neuroscience Fair.

Pain perception is crucial to life, in that, without this sensory modality, we could leave injuries untreated which could then lead to permanent damage of our bodies. The intensity of pain is coded in the frequency of action potentials, which, in turn, is coded by the intensity of the stimulus. For example, a hard hit to the arm will generate more action potentials (and more pain), than will a slight touch to the arm. Different types of nociceptors, classified as either thermal, mechanical or polymodal, recognize varying types of painful stimuli and transmit the signal to the brain through A β , A δ , a C fibers via the spinothalamic, spinoreticular and spinomesencephalic tracts where they are received by their corresponding parts of the brain. Unmyelinated C fibers associated with dorsal root ganglion (DRG) neurons are nociceptive, thinly myelinated A δ fibers mediate fast pain and A β fibers are nociceptive as well (Wood,

2004). Unfortunately, pain perception is highly subjective and highly complex, and must take into account not only the physiological happenings at the microscopic level, but also the emotional and behavioral reactions of the individual, thus making pain more or less “painful” from person to person.

Pain is caused by activities in Na⁺ channel subtypes, which play a role in nerve injury, inflammation and pain pathways (Baker, 2001). The Na⁺ channel is a structure composed of an α subunit with four domains of six-transmembrane segments. The S5-S6 linker of the channel is vitally important in the role of sensitivity to tetrodotoxin (TTX) (Baker, 2001). TTX, a toxin isolated from the puffer fish, has been noted to inhibit Na⁺ channels. Furthermore, these Na⁺ channels are separated into two components; TTX-s and TTX-r components which are significant in that different local anesthetic drugs have actions on either one or both of these types of currents, depending on concentrations (Baker, 2001). TTX-r Na⁺ channels are primarily found in neurons of the dorsal root ganglia and are called Nav 1.8 and Nav 1.9. These channels are approximately 100 times less sensitive to TTX than are TTX-s channels and have much slower kinetics (Scholz, 2002). TTX-r channels are mainly distributed in small to medium sized DRG neurons connected to A δ and C fibers, suggesting they play a role in the conduction of pain (Scholz, 2002). In addition, experiments have shown that TTX-r Na⁺ channels are important for the signal transduction of pain in extremely small nerve endings (Scholz, 2002). On the other hand, TTX-s Na⁺ channels have much faster kinetics and are much more sensitive to TTX currents.

Local anesthetics exert their actions on voltage gated Na⁺ channels, thus inhibiting pain. One of the most common times to get a local anesthetic is at the dentist during a cavity fill or while having a tooth pulled. Since this is such a common occurrence for people, it is the example we used for the fifth graders during the neuroscience fair. Anesthetics selectively block specific types of nerve fibers, termed “differential nerve block” (Scholz, 2002). This means that there is a sequence of nerve block in a specific nerve fiber order (related to nerve fiber size). The sequence for this block is: sharp pain, cold, warmth, touch and conduction in motor fibers. Seeing this sequence, we can see why when a local anesthetic is given to numb your mouth in a dentist’s office, we lack the feeling of pain, yet still have the ability to control motor movements of our mouth. In this way, the sensory modalities that are inhibited can be controlled by controlling the amount or concentration of anesthetic that is given to a patient.

Local anesthetics bind to the sodium channel by binding to one of two hydrophobic pore sites that interact with the anesthetic (Scholz, 2002). Drug binding may have other interactions with the sodium channel, such as amino acid interactions or pore mutations via an allosteric mechanism. As mentioned earlier, the S5-S6 linker region of the channel, seems to be imperative for the binding of the anesthetic. Since we know there to be two types of Na⁺ channel currents, TTX-r and TTX-s, how are they affected by local anesthetics? Studies have shown that the blockage of these currents is largely dependent upon the type of local anesthetic used. For example, local anesthetics such as lidocaine and bupivacaine suppress TTX-r action potentials

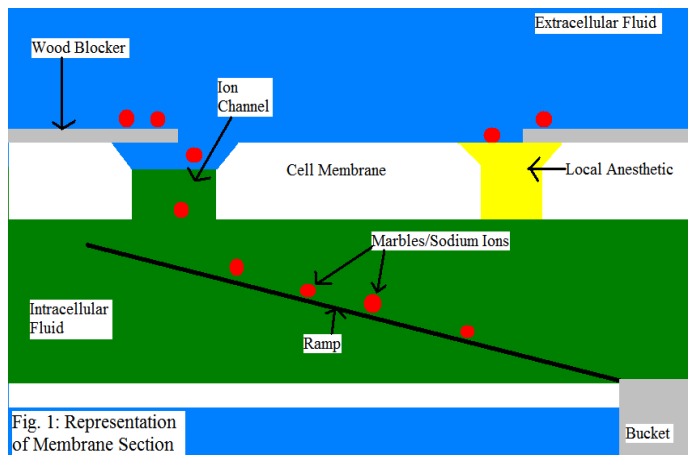
located in small sensory neurons when used in a concentration-dependent manner (Scholz, 2002). However, TTX-s Na⁺ currents can be blocked with a 3-4 times lower dose than is required for TTX-r Na⁺ currents (Scholz, 2002).

Na⁺ channels are not, however, the only channel type blocked by local anesthetics. Voltage-dependent K⁺ channels are also blocked by these drugs. The difference is that there is a lower binding affinity for anesthetics to K⁺ channels. Calcium channels are also blocked by local anesthetics, due to its close structural resemblance to the Na⁺ channel. Neuropathic pain, caused by an ectopic discharge, is an aberrant action potential along an injured nerve (Mao, 2000). These discharges are a result of abnormal sodium channel inactivation (Mao, 2000). Local anesthetics, such as lidocaine, work to suppress ectopic discharges by blocking the sodium channel so that abnormal action potentials will not continue. In this way, we are able to suppress pain during an operation such a drilling a tooth.

The mechanism of local anesthetics and their actions on pain pathways has been heavily researched, but is still complex and not fully understood. We attempted to teach the children the basics of local anesthetics by taking a step by step approach. By starting with a poster that continually zoomed in on the body, we helped them understand where exactly those sodium channels are. Subsequently, by having an interactive model illustrating the sodium channels and action potentials, the children began to understand about the channel's normal functioning. Lastly, by facilitating an activity to involve all the children, we were able to show them how local anesthetics work to block sodium channels, and thus, how that affected our bodies on a macroscopic level.

Materials and Methods

The setup for our project included four major components; a poster, a wooden model of the cell membrane, a lemon battery and an interactive component. Our poster began by zooming in on the mouth of Mr. Bean, a famous British comedian, then subsequently zoomed in on a neuron, a cell membrane and lastly, a sodium channel. The beginning of our presentation began with explaining this component. The next component of our presentation involved the wooden model of the cell membrane (see Figure 1 at right). This component was vital in being able to help the children understand the cell membrane. We took a piece of plywood and cut it into a 1.5x2 foot square. Onto the superior one third of the wood, we glued three wooden blocks with spaces in between them to represent the cell membrane. The spaces in between the blocks represent the sodium channel. Directly underneath



these blocks at a downward angle we glued another strip of wood to act as the runway for the ions to run down. Resting on top of the wooden blocks were two thin strips of wood that act as the gate for the sodium channel. To represent the local anesthetic, we designed pieces of wood that would perfectly fit into the two “sodium channels.” Finally, we painted the model to help distinguish the different parts of the membrane (i.e. extracellular and intracellular space) as seen in Figure 1. When the model was in action, marbles, representing sodium ions, were placed on top of the wooden strips representing the channel gate. When pulled apart, the marbles were allowed to fall through the sodium channel and roll down the ramp into a bucket at the end to illustrate sodium ions flowing into a cell and generating an action potential. After this, we placed the “local anesthetic” into the sodium channel and allowed for the marbles to attempt to fall through the channel again. This time, the marbles stayed on top, or in the extracellular fluid, showing to the children that a local anesthetic stops the flow of sodium into the cell, thus inhibiting the feelings of pain (due to lack of the action potential). At this time we also showed the kids our lemon battery. This was designed as a battery in series. We took a lemon and cut it into slices. Each slice had wires in it and were hooked up together with clip leads and attached to a voltmeter in order to show that the lemon acts as a battery. This was yet another useful tool in which to show the kids that many types of organisms have cell membranes and ion channels.

The last component to our project involved an interactive activity to further illustrate the sodium channel. We had four kids stand in a circle while holding hands. The kids on the outside of the circle threw wiffle balls into the center of the circle. This illustrated sodium (wiffle balls) freely flowing through the channel (the circle). Lastly, we had a student hold an umbrella in the center of the circle, acting as the local anesthetic. That way, when the wiffle balls were thrown back into the “channel”, they bounced back out.

Results

Our group came in second place in our division (Group B) with a total of nine votes for being the best presentation. The students ranked us on a series of four questions (see table one). Question one asked how well the student’s understood the presentation for which we received an average of 4.56 ± 0.58 . Question two asked how friendly the presenters were, for which we received a 4.9 ± 0.58 . Question three asked how fun the presentation was, for which we received an average score of 4.52 ± 0.71 . The fourth question asked the student’s to rank how much they had an interest in learning more about the topic for which we received a 3.84 ± 1.11 , which was the highest in Group B. Figure 2 compares our results for these four questions with the other projects in Group B.

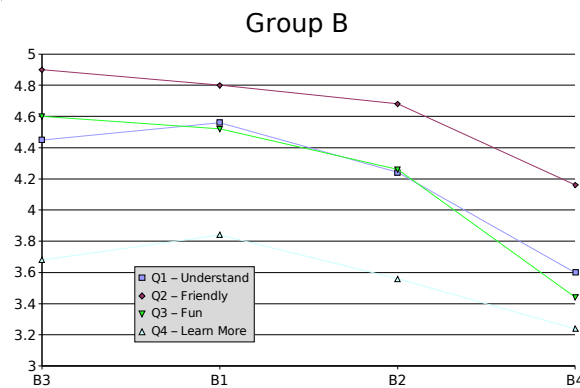
At the end of our presentation we asked the students if they had any questions and each group usually had many. After our official presentation, the kids usually wanted to play with the model and see how the ions flowed through the ion channel. We asked the kids questions as we presented to see if they could recall what we had talked about, for which many usually had answers. The kids stated on their evaluation sheets that they learned “why the mouth felt numb”,

that “anesthetics can block pain” and that “the cell membrane separates the inside and outside of the cell,” amongst many other comments.

	(Ranking) 1	(Ranking) 2	(Ranking) 3	(Ranking) 4	(Ranking) 5	Average	Std. Dev.
Question 1	0	0	1	9	15	4.56	0.58
Question 2	0	0	2	1	22	4.8	0.58
Question 3	0	0	3	6	16	4.52	0.71
Question 4	0	4	5	7	9	3.84	1.11

Table 1

Figure 2



Discussion

Our project for the Kid’s Judge! Neuroscience Fair sought to teach the kids how local anesthetics affect our perceptions of pain. We did this through the means of a poster, a wooden model of the cell membrane, a lemon battery and an interactive activity in which the students represented an individual sodium channel. We decided to have multiple components to explain the effects of local anesthetics so that we could accommodate the kids’ different learning styles. This seemed to work effectively, as seen by the comments made by the kids as well as by their rankings of our presentation. Our group received the highest score in the area on how much the student’s wanted to learn more, indicating that we were able to interest the student’s in how pain works. We also received the highest ranking in the area of the kid’s understanding of the project. This is further supported by their comments on what they learned.

I believe that our group did well at communicating the actions of local anesthetics and their effects on pain well by relating it to a topic in which most people have had some experience. By starting the presentation with an example of a visit to the dentist’s office to have a cavity drilled, we were able to help the kids recall that time and make them think about why they did not feel pain. This familiarization was a large aide in getting the presentation off to a good start. Subsequently, by allowing ample time for discussion and questions, the students were

able to revisit the different components of the presentation for further discussion and comprehension. In this way, a large amount of the kids seemed to leave our presentation with a good, basic understanding of local anesthetics' actions.

Some of the comments the kids made on their evaluations made it evident that perhaps we did not communicate to them clearly enough on how local anesthetics work. For example, one statement was "I learned that when sodium gets into your body you get hurt." This shows that we did not accurately describe the role of sodium. Furthermore, because our presentation only focused on local anesthetics, the kids might be a little confused as to the differences between that and laughing gas. Despite our attempts to make the project appealing to all the students there were some who were very interested and others who seemed to be staring off into space. I think having even more interaction that involves all the kids would allow the concept to be better understood and seem more interesting. Additionally, by zooming in on one sodium channel, the problem arose in the student's believing that this one channel is responsible for all sodium channel flow. For improvement, it would be necessary to stress how numerous sodium channels and cell membranes are in the body.

Overall, I believe that our presentation on local anesthetics was well received. The students were interested to learn more and they seemed to comprehend the concept well. I believe that in the chaoticness of the fair, and the overwhelming amount of information the kids were quickly receiving, we did a good job in communicating to them as accurately as possible, the role of local anesthetics.

Works Cited

Baker, Mark D. and Wood, John N. "Involvement of Na⁺ channels in pain pathways." *TRENDS in Pharmacological Sciences* Vol. 22 No. 1 (2001): 27-31.

Mao, Jianren and Chen, Lucy L. "Systemic lidocaine for neuropathic pain relief." *International Association for the Study of Pain* 87 (1999): 7-17.

Scholz, A. "Mechanisms of (local) anaesthetics on voltage-gated sodium and other ion channels." *British Journal of Anaesthesia* 89.1 (2002): 52-61.