CollapsAir: The Convenient Inhaler Spacer

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INTRODUCTION

Asthma is a chronic disease that causes airways in the lungs to narrow and inflame, making breathing difficult. More than 27 million people in the United States suffer from asthma (Goff, 2022). Luckily, there are many treatments available to those with asthma including inhalers and steroids. The most popular treatments, such as albuterol, typically involve an inhaler. Inhalers aerosolize medication, therefore making delivery to the lungs more effective. These medications are bronchodilators which relax lung muscles and widen bronchi. Inhalers alone are not the most effective at delivering medication, but using a spacer can help increase the effectiveness.

Spacers are tube-like attachments that ensure the maximum amount of medication reaches the lungs by preventing it from settling in the throat or mouth. In Newman et. al. (1984) about 10-15% of the dose reached the lungs and 80% of the dose settled in the oropharynx when participants used an inhaler alone, while 21% of the dose reached the lungs and 16% of the dose settled in the oropharynx when participants used the inhaler with a spacer. Unfortunately, asthmatics do not seem to use spacers with their inhalers. This claim is supported by the results of a survey conducted by the Asthma Society of Ireland (2018) where 41% of people with asthma claimed that they do not use spacers with their inhalers.

One reason spacers may not be commonly used is because they take up quite a bit of space, making it difficult to travel with daily. For spacers to be effective, there needs to be a volume of at least 100-700 mL with a distance of at least 10 cm between the inhaler and the patient's mouth (Vincken, 2018).

PURPOSE STATEMENT

The inhaler spacer is important for ensuring medication delivery to the lungs of asthma patients. However, only 41% of people with asthma use these devices. A possible issue with current spacers is their size, making them inconvenient to carry around. A collapsible spacer design would take up significantly less space when traveling. Such a device would also maintain the effectiveness of delivering medication despite the changes in shape. This project aims to design, construct, and test a collapsible inhaler spacer to increase its usage by making it more convenient.

MY INNOVATION

The CollapsAir spacer is a collapsible inhaler spacer designed for easier travel while maintaining the effectiveness of medication delivery. The collapsible feature will ensure more convenience, which aims to increase the usage of this important device.
CollapsAir's accordion-like design allows it to collapse to 80mm, but expand to 164mm, keeping it in the appropriate range to maintain effectiveness. Two materials were used to create the prototypes: TPU and flexible resin.

To test the effectiveness, a litmus paper test was conducted using ammonia (NH3). Additionally, a comparison study was done to observe the difference in the size of the CollapsAir spacer versus a normal spacer (AeroChamber).

LITERATURE CITED

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MATERIALS & METHODS

Litmus Paper Test. The end of the inhaler spacer was sealed with Parafilm. The nozzle of a vapor-venting wash bottle filled with a small sample of concentrated ammonia gas (NH3) was then inserted through the parafilm. A piece of litmus paper was taped to the mouthpiece of the spacer. The vapor venting bottle was squeezed; after squeezing the bottle, any color changes to the litmus paper were noted. A total of ten trials were conducted, with the litmus paper being replaced for each trial.

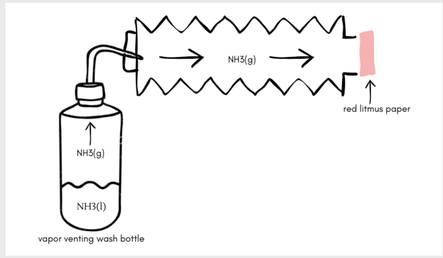


Figure 1. The experimental set up of the materials used to conduct the litmus paper test, showing the flow of NH3 substance through the mechanism.

Size Comparison Study. Calipers were used to take measurements of the lengths and diameters, in millimeters, of the spacers (including the mouthpiece attachment). The first measurement determined the length and diameter of the CollapsAir spacer while it was extended. The next measurement determined the length and diameter of the CollapsAir spacer while it was collapsed. The Calipers were then used to determine the length and diameter of the AeroChamber spacer, which is not collapsible. All values were recorded. The volumes were also determined using water and the formula for cylinder volumes. The CollapsAir spacer was filled with water and then emptied into a beaker. The amount of water in mL was observed and recorded, then the beaker was emptied. Next, the CollapsAir spacer was collapsed, filled with water, and emptied into the beaker. The amount of water in mL was observed and recorded. Finally, the volume of the AeroChamber was determined using the length and diameter, which were plugged into the formula for cylinder volume. The volume was recorded in mL.

RESULTS

Litmus Paper Test. 100% of the NH3 trials resulted in a color change of the red litmus paper. After NH3 exposure, the litmus paper displayed a blue tint (See Figure 2).

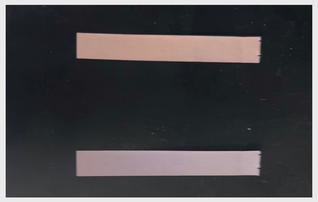


Figure 2. Two pieces of litmus paper, one not exposed to NH3 (top) and one after exposure to NH3 (bottom)

Size Comparison Study. Collapsed, the CollapsAir spacer is 80mm in length, 73mm in diameter, and 92 mL in volume. When the CollapsAir is not collapsed it has a length of 164mm, a diameter of 73mm, and a volume of 291 mL. The AeroChamber is 147mm in length, 41.275mm in diameter, and has a volume of 197 cubic mL. All length measurements included the mouthpiece attachment. (See Figure 3).

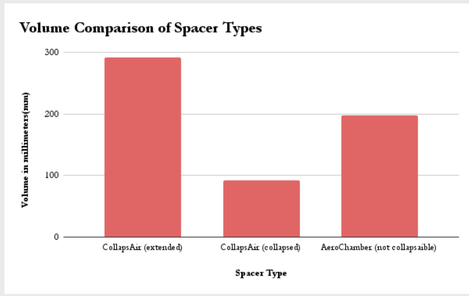


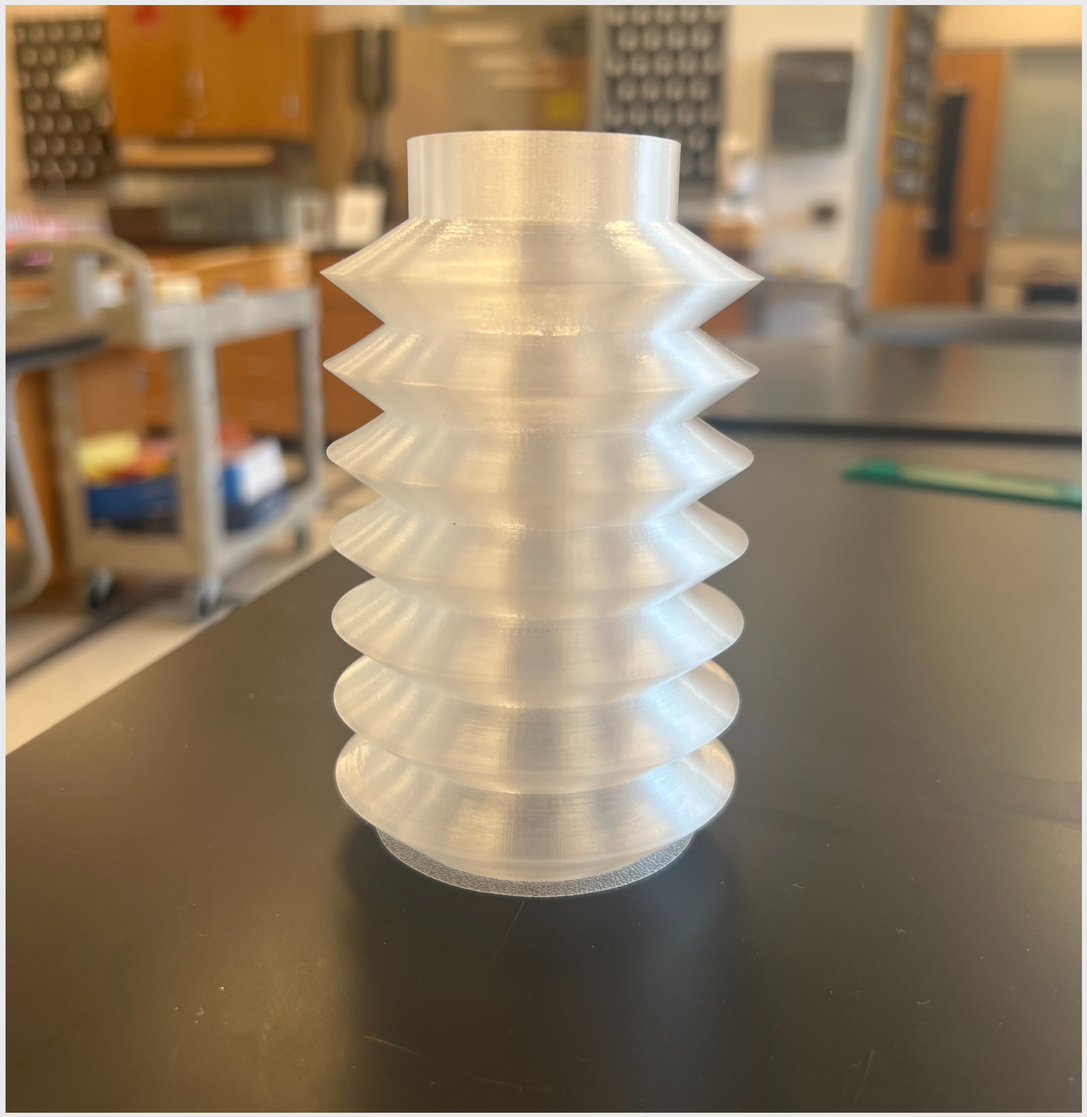
Figure 3. The difference in volume between the inhaler spacer innovation, CollapsAir, versus AeroChamber

CONCLUSION

The CollapsAir spacer lessens the amount of space taken up compared to the AeroChamber while also maintaining the effectiveness of delivering medication. The litmus paper test results provided evidence that medication would have the ability to move freely throughout the CollapsAir spacer. Also, the size comparison study indicates that the spacer is the appropriate volume and length to function properly when extended. The study also indicates that the CollapsAir spacer collapses to a size that is smaller than the typical AeroChamber spacer.
To further test the effectiveness of the CollabsAir spacer, follow-up testing would be beneficial to determine how much medication would make it to the lungs when the user inhales through the spacer. This could give further data about the effectiveness of the spacer.
It is possible that errors were made during the testing process of the spacer. Errors may include water escaping during the volume calculation, the spacer may not be airtight, or the spacer was not equally collapsed for each trial of the water volume test. These errors may be avoided if the prototype is improved. Making a CollapsAir spacer out of low-density polyethylene may be a better alternative to TPU in terms of accuracy of design and air-tightness. Low-density polyethylene (LDPE) is often used in products like squeeze bottles since it is a flexible plastic, indicating it can be altered to form a collapsible shape. LDPE can also be shaped by a process called injection molding, where the material is melted and inserted into a mold in which it dries into a specific shape. LDPE can be treated with additives such as UV resistance and can even act as an anti-static barrier. Coating the inside with an anti-static substance would be beneficial because it will ensure medication does not get stuck to the sides of the spacer and instead is able to be inhaled by the user.
The CollapsAir spacer can benefit society due to its ability to be compacted down, allowing for easier travel and convenience. Since it is smaller than a normal inhaler, more people are likely to carry it for everyday use without having to wonder if it will fit in their handbag. Carrying a smaller device is a better alternative to not using a spacer at all.

ANALYSIS

Inhalers release both the fine mist medication and an aerosol propellant called hydrofluoroalkane gas. The innovation would be effective if it allowed these substances to travel into the spacer to be inhaled. The litmus paper results suggest that the CollapsAir Spacer can allow gas to be pushed through it. Red litmus paper only turns blue when it has come into contact with a base, such as NH3. Since all the trials resulted in a red-to-blue color change of the litmus paper, it is reasonable to suggest that the NH3 gas traveled from the inhaler end of the spacer to the mouthpiece end in 100% of the trials. If NH3 gas made its way through the spacer, it is likely that a hydrofluoroalkane gas with medication could also travel through the spacer. Given the litmus paper test results, it is reasonable to suggest that the CollapsAir spacer will hold a mist and a gas within the chamber, allowing the patient to receive medication when inhaling. The effectiveness of delivering medication will be successfully maintained using a CollapsAir spacer.
In addition to needing to be able to push gas through the chamber, the CollapsAir spacer must also be a certain length for proper function. In Vincken et. al (2018), it was found that for an inhaler to function properly, it must be greater than 100mm in length from the inhaler opening to the mouthpiece. The comparison study found that the CollapsAir was 164mm long, which meets the standard set by Vincken et. al. (2018). Furthermore, the volume of a spacer needs to be 100-700mL to be effective (Vincken, 2018). Our water retention technique found the volume of the CollapsAir to be 291mL. This suggests that the CollapsAir spacer is the appropriate volume to deliver medication effectively.
The main purpose of the CollapsAir spacer is to be more convenient by taking up less space when collapsed. In Figure 3, the volumes(mL) of the CollapsAir spacer while extended and collapsed are recorded, as well as the volume(mL) of the AeroChamber. Since the CollapsAir spacer has a volume of 92mL when collapsed, and the AeroChamber has a volume of 197mL, it is reasonable to suggest that the CollapsAir spacer accomplishes the goal of taking up less space than the AeroChamber. The CollapsAir spacer has a longer length (164mm) than the AeroChamber (147mm), but the collapsible feature of CollapsAir ensures its ability to decrease the amount of space it takes up. When collapsed the CollapsAir spacer is 67mm shorter than the AeroChamer spacer.



TPU SPACER PROTOTYPE SIDE

TPU SPACER PROTOTYPE TOP

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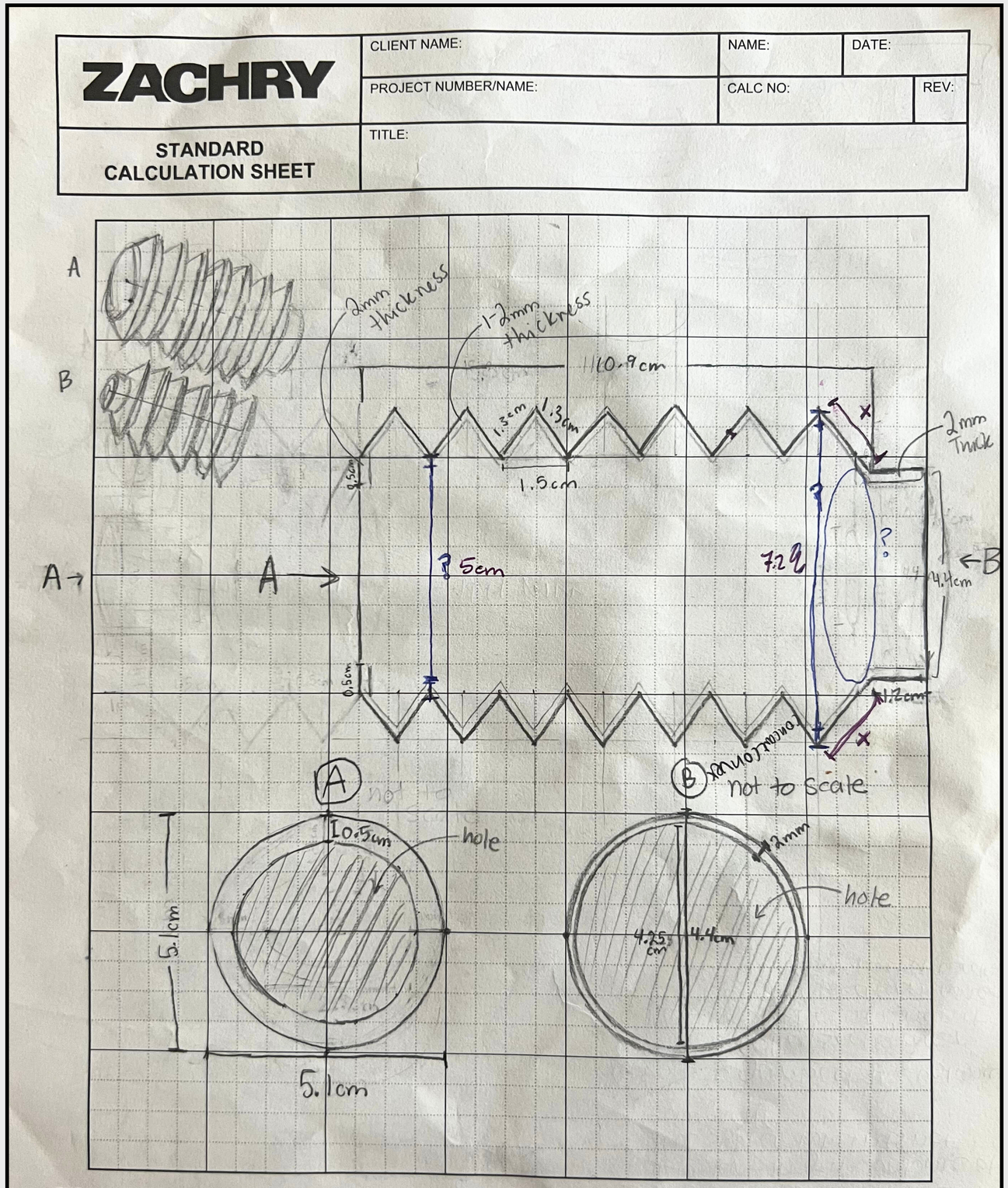

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