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Accuracy of Float Testing for Metered-Dose Inhaler Canisters

Tina Penick Brock, Andrea M. Wessell, Dennis M. Williams, and James F. Donohue

Objective: To characterize and evaluate canister floating patterns of three commercially available metered-dose inhalers (MDIs) with varying amounts of medication remaining. **Design:** Four canisters each of three asthma medications were studied. MDIs were actuated every 30 seconds to 60 seconds, and canisters were weighed and floated at 100%, 75%, 66%, 50%, 33%, 25%, 10%, and 0% of remaining labeled actuations. Position of the canisters and percentage submersion in water were recorded. **Setting:** Controlled laboratory. **Results:** We observed differences among the products with regard to canister floating behavior at varying levels of fullness. All canisters were completely submerged with the nozzle up at two-thirds full and greater. The canisters remained nozzle-up and were submerged to varying levels at the half-full point. When observed at less than half full, canisters inverted and floated nozzle down. Positions of the canisters varied among products at less than half full. No canister was fully tilted when all labeled actuations were used. **Conclusion:** Float characteristics are product-specific and a function of canister size, design, content, and method of testing. Clinicians and asthma educators should not advise patients to use a float test to assess the amount of medication remaining in an MDI. Recommendations from the National Asthma Education and Prevention Program of the National Heart, Lung, and Blood Institute suggest that the only reliable method for determining the number of doses remaining in a canister is to subtract the number of doses used from the number available.

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In the United States, metered-dose inhalers (MDIs) are the most commonly used devices for delivering inhaled medication to the lungs. Although the phaseout of chlorofluorocarbon (CFC) propellants has stimulated the development of alternative drug delivery devices, it is likely that MDIs with alternative propellants will continue to be used by patients with respiratory diseases.

Appropriate MDI use is limited by the patient's inability to determine the precise amount of medication remaining in the canister. Because canisters have no internal counter to determine the number of doses remaining, to be exact, patients must track the number of actuations used and subtract this number from the total

number of available actuations listed on the product's labeling. Although this strategy makes sense in theory for inhalers patients use on a scheduled basis (e.g., controller medications), in practice, such dose tracking is cumbersome, especially for patients who use multiple inhalers several times each day or those who increase their dosage intermittently according to their action plans. In a survey of patients designed to assess how patients determine when to replace their MDIs, only 8% of respondents reported counting the number of actuations used.¹

Often, patients simply shake their inhalers to check whether the canister feels empty. This method, however, is grossly inaccurate since canisters typically contain propellants and other inert ingredients in addition to the actual drug,¹ and a patient may be led to believe a canister contains medication when none is actually present. The inability to assess the amount of medication in an inhaler can leave patients uncertain about when to obtain refills and anxious about whether an appropriate dose of medication will be available to resolve an acute asthma attack.

The traditional method for assessing the amount of drug remaining in an MDI canister is the float test. This procedure involves separating the MDI canister from the mouthpiece of the inhaler and placing the canister in a glass of water. Based on the position of the canister in the water, the patient estimates the amount of medication remaining. However, concerns about prod-

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uct integrity following the canister's immersion in water have prompted some manufacturers to caution against using this technique.¹⁻⁴ Additional concerns have been raised about the accuracy of the float test.⁵ Previous investigators have reported varying results with float testing, and their conclusions about the utility of this method have differed.⁶⁻⁸

Further complicating the issue of whether to use the float test is the problem of exactly how to conduct and evaluate the test. Several asthma references describe the float test, but diagrams showing the expected positions of the canister in water vary widely.⁹⁻¹⁴ Despite these inconsistencies, some clinicians continue to advise patients to use the float test to estimate the amount of remaining drug. Clinicians may also use this method to assess patient adherence to therapy. Although the float test is most often suggested for patients using MDIs on an as needed basis (e.g., short-acting β_2 -agonists), patients who keep controller inhalers in multiple locations (e.g., work and home) and those who are receiving inconsistent advice from multiple health care providers also use this technique in some situations.

Objective

The objective of this study was to characterize and evaluate canister floating patterns of three commercially available MDIs with varying amounts of medication remaining.

Methods

The products evaluated in this study were Atrovent Inhalation Aerosol 18 mcg/inhalation (14 grams of ipratropium bromide—Boehringer Ingelheim), Flovent Inhalation Aerosol 44 mcg/inhalation (13 grams of fluticasone propionate—GlaxoSmithKline), and

Ventolin Inhalation Aerosol 90 mcg/inhalation (17 grams of albuterol—GlaxoSmithKline). All products tested contained CFC propellants and were prescription-sized canisters identical to those used by patients. Four canisters of each product (i.e., 12 inhalers total) were used to study the accuracy and reliability of the float test.

The same investigator (AMW) conducted the study over a 3-day period. All studies were conducted under room temperature conditions. A Fisher Scientific XA Analytical Balance (Hampton, N.H.) was used to measure canister weights. The balance was calibrated once daily and zeroed before each measurement.

Before being dropped into the water, each canister was marked at 1/8, 1/4, 1/2, 3/4, and 7/8 of the total canister length to assess the amount of submersion. For the data collection process, 600 mL and 1,000 mL clear Pyrex beakers were filled with 500 mL and 950 mL of distilled water, respectively. Atrovent and Flovent canisters were floated in the 600 mL beaker, whereas Ventolin was floated in the 1,000 mL beaker. The larger beaker was used for the latter product to ensure that the larger canister could float freely. The volume of water was constant throughout the study.

With the mouthpiece in place, each inhaler was primed until a consistent spray was released (two to three sprays). The inhalers were then actuated with the nozzle down once every 30 seconds to 60 seconds. With the mouthpiece removed, the canisters were weighed and floated at assigned measurement points of 100%, 90%, 75%, 66%, 50%, 33%, 25%, 10%, and 0% of labeled actuations remaining. The investigator manually recorded each actuation. Table 1 summarizes the points of measurement.

At designated intervals, canisters were dropped nozzle-up into the beakers from a height of 1 inch to 2 inches. Each canister was allowed to settle in the water, and its position was recorded based on where the nozzle pointed in reference to the hands of a clock and the percentage of the total canister submerged. These recordings were made based on visual observations by the investigator.

Table 1. Points of Measurement and Mean Canister Weights

% Medication Remaining	Atrovent ^a		Flovent ^b		Ventolin ^a	
	No. of Doses Remaining	Weight ^c Mean \pm SD	No. of Doses Remaining	Weight ^c Mean \pm SD	No. of Doses Remaining	Weight ^c Mean \pm SD
100	200	23.46 ^d	120	19.92 \pm 0.05	200	28.17 \pm 0.11
90	180	22.38 \pm 0.08	108	18.91 \pm 0.07	180	26.48 \pm 0.11
75	150	20.36 \pm 0.06	90	17.44 \pm 0.04	150	23.91 \pm 0.14
66	132	19.35 \pm 0.11	79	16.7 \pm 0.08	132	22.58 \pm 0.17
50	100	17.19 \pm 0.18	60	15.21 \pm 0.11	100	19.66 \pm 0.23
33	66	15.22 \pm 0.26	40	13.82 \pm 0.23	66	17.18 \pm 0.32
25	50	14.06 \pm 0.32	30	13.02 \pm 0.31	50	15.83 \pm 0.32
10	20	12.13 \pm 0.37	12	11.67 \pm 0.36	20	13.46 \pm 0.33
0	0	10.86 \pm 0.42	0	10.81 \pm 0.42	0	11.81 \pm 0.35

SD = standard deviation.

^a200 metered actuations.

^b120 metered actuations.

^cMean weight in grams.

^dOnly one canister weight available.

Statistical Analysis

Data were entered into a data set and verified for completeness and accuracy. Canister float test results were summarized, and mean canister weights \pm standard deviations (SDs) were calculated. All analyses were conducted using SPSS version 8.0.

Results

Float Characteristics

The float studies for the three products yielded varying results. Specifically, we noted differences among the products with regard to canister floating behavior at varying levels of fullness. At two-thirds full and greater, all canisters were completely submerged with the nozzle up. The canisters remained nozzle-up and submerged at varying amounts at the half-full point. When observed at less than half full, canisters inverted and floated nozzle-down. Positions of the canisters varied among the products at less than half full. Mean float characteristics (position and submersion) for each product are illustrated in Figure 1.

With each product, one canister was actuated beyond the labeled number of doses until the investigator subjectively felt it was empty (i.e., until repeated spraying resulted in expulsion of no gas). An additional 55 actuations were released from Atrovent (27.5% in excess of labeled actuations), 29 additional actuations from Flovent (24.2% in excess), and 19 additional actuations from Ventolin (9.5% in excess). In each instance, the empty canister floated fully tilted in the water (Figure 1). These data reflect the number of actuations released from the products studied and not necessarily the amount of actual drug released from the MDI.

Canister weights were obtained at each test point. Mean canister weights (in grams) and SDs are summarized in Table 1. A positive linear relationship was observed between the percentage of labeled actuations remaining and the mean canister weight for each product (see Figure 2).

Discussion

Our results suggest that the commonly used practice of floating MDI canisters to determine the remaining amount of medication may yield inaccurate and misleading information. We were unable to consistently differentiate the amount of drug remaining at the different stages, and we noted varying floating patterns among the products. Importantly, canisters continued to float as if medication remained even after the labeled numbers of actuations were used. Floating characteristics may be dependent on the product being tested and may vary widely among individual products. The lack of a convenient and accurate method for determining the amount of medication in an MDI is an important clinical problem for clinicians advising patients using MDIs.

Official pharmaceutical or medical compendia provide no standards or criteria for float testing MDIs. Several methods have been proposed to assess the amount of medication remaining in an MDI, including estimating the number of doses available in the product or using an external counting device. The a priori method of estimating doses remaining in a canister involves making a simple calculation using the original number of labeled doses and the number of doses expected to be taken each day. This method can be useful for a chronic medication that is used on a regularly

Figure 1. Float Characteristics for Atrovent, Flovent, and Ventolin



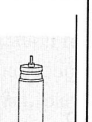
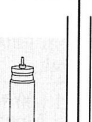
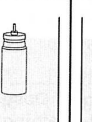
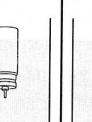
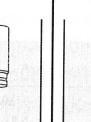
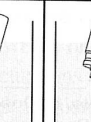
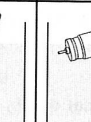


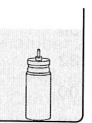
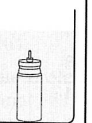
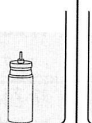
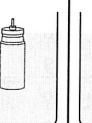
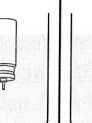
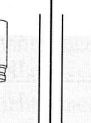
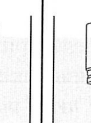
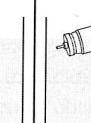
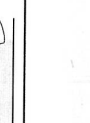

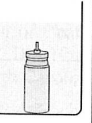
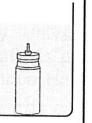
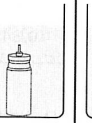
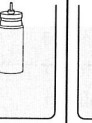
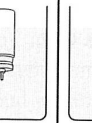
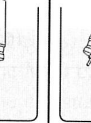

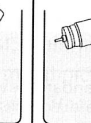

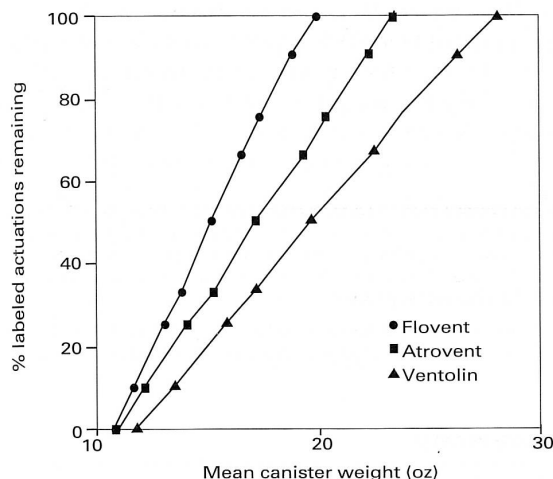
% labeled actuations remaining	100	90	75	66	50	33	25	10	0	Empty canister
Atrovent										 55 extra actuations
Flovent										 49 extra actuations
Ventolin										 19 extra actuations

Figure 2. Float Test Results: Relationship Between Mean Canister Weights and Actuations Remaining

scheduled basis, although it rests on the assumption that the patient is adhering to his or her regimen. For example, an inhaler containing 200 doses of medication prescribed for use as two inhalations four times daily (eight puffs daily) should last for 25 days.

An external counting device could solve the problem of estimating how much drug remains in the inhaler by recording how many times the MDI has been actuated. The Doser (MEDI-TRACK) is an example of such a counting device.¹⁵ It is pressure-activated and designed to attach to the top of an MDI canister. After calibration, the Doser displays the number of actuations remaining in the inhaler and the number of doses actuated per day. In addition, it records the number of doses actuated on preceding days for later recall. Accuracy of the Doser was established in a multicenter study that compared it with a diary system and the Nebulizer Chronolog (MEDITRACK), another micro-electronic monitoring device.¹⁶ However, the Doser is not recommended for use with ipratropium, cromolyn, or nedocromil inhalers because the inhalers cannot be actuated appropriately once the device is in place.¹⁶ In addition, it may be less convenient to use than an MDI alone.

According to most manufacturers, delivery of accurate medication doses from MDIs can only be ensured if a patient uses no more than the labeled number of inhalations. Furthermore, package information states that the canister should be "discarded when the labeled number of actuations (inhalations) have been used ... the correct amount of medication in each inhalation cannot be assured after this point." This statement appears in the patient information for Ventolin, Atrovent, and Flovent.^{2,17,18}

Newer MDI products were developed with alternatives to CFC propellants. None of the manufacturers of these products recommend the floating technique, and some specifically caution against

it because of concerns about reliability and product integrity. The manufacturers of Proventil HFA (albuterol sulfate—Schering) and QVAR (beclomethasone dipropionate—3M) report that the canisters for these products will float even when full and that immersion in water may result in "wicking" that can affect product integrity. GlaxoSmithKline, manufacturer of the newly approved Ventolin HFA (albuterol sulfate), cites similar concerns.

Despite inconsistencies regarding the accuracy of float testing, some patient and physician information sources continue to recommend this method as an accurate way to determine the amount of medication remaining. In fact, several Web sites recommend the float test.^{19,20} A search of the World Wide Web using the terms *metered-dose inhaler* and *float test* identified more than 20 references promoting the use of the float test.

Our findings are not consistent with published diagrams of MDI floating behavior.⁹⁻¹⁴ Variations were also noted among the published diagrams in their illustration of the float test. Each presents similar depictions of half-full, full, and empty containers.⁹⁻¹⁴ However, at one-quarter and three-quarters full, the depictions of canister behavior differ in position and amount of submersion.^{9,10,13,14}

None of the canisters we tested floated horizontally on the surface of the water when all labeled actuations were released. Canisters floated horizontally when the inhaler was actuated beyond the labeled number of doses until no additional spray was evident from the device. Our results for Atrovent and Ventolin at 10%, 25%, and 75% medication remaining do not match the angles depicted in the published diagrams. Even more divergence from the diagram was noted with Flovent canisters.

Our results also differ from those of Wolf and Cochran.⁷ In a study examining the floating patterns of prescription- and sample-sized MDIs, they concluded that prescription-sized inhalers follow a reliable floating pattern. They described two distinct floating patterns: the "sinker" and the "floater." In the sinker pattern, the canisters sunk initially, progressively rose to the surface as fewer doses remained, inverted at the surface, and tilted off the vertical axis until the base was out of the water. Almost all of the prescription-size canisters they studied, including Atrovent and Ventolin, followed this pattern. Most of the sample-size canisters followed the floater pattern, in which they floated initially and ended in the same manner as the sinker pattern. Although we evaluated only prescription-size MDI canisters, our findings diverged from those of Wolf and Cochran in that the Atrovent and Flovent canisters did not float fully tilted with 0% of actuations remaining.

Weinstein⁸ reported that Serevent (salmeterol xinafoate—Glaxo-SmithKline) and Vanceril (beclomethasone dipropionate—Schering) prescription canisters tilted off the vertical axis only after the product was actuated beyond the discard point. Our results were similar in that Atrovent and Flovent did not significantly tilt until we released more than the labeled number of actuations.

Our results suggest that Atrovent and Flovent canister floating behavior falls into three categories: full to two-thirds full, half

full, or one-third full to empty, with no accurate method to distinguish between specific measurement points. Ventolin canister behavior can be categorized in four ways: full to two-thirds full, half full, one-third to one-quarter full, and 10% full to empty.

As we were conducting this study, we encountered another potential source of confusion. In our methodology, the MDI canister was dropped into the water with the valve stem up. In reviewing the published illustrations, it was apparent that some experiments were performed by dropping the canister with the valve stem down. We repeated our experiment with one canister of each product by performing the float test with the valve stem down. The results differed from the previous experiments in the following ways:

- For each product, when the canister was more than half full, it laid on the bottom of the water vessel.
- When the canister was half full, it floated horizontally, partially immersed with the valve stem down.
- At less than half full, canister floating behavior was similar to the previous results in our own work. These variations may cause additional confusion for patients using this method.

In the current study, canister weights were obtained with various levels of drug remaining. Our results suggest a linear relationship between the canister weights and the amount of drug remaining. However, these results were obtained in a controlled research setting and may not be applicable to clinical use situations. Measuring canister weights may be a useful method of assessing adherence in certain clinical or research situations in which control conditions are similar to the conditions of the current study. The relationship between canister weight and amount of drug remaining is specific and unique to each individual product.

Limitations

Although these findings have significant clinical implications, our methodology has some limitations. We selected only three products to illustrate the problems with floating canisters; thus, our results may not apply to all MDI products on the market.

We did not study every potential situation related to the amount of medication remaining. Rather, we chose several breakpoints that appeared to be clinically relevant, including the point at which all labeled actuations were used.

Finally, our observations about float characteristics were made from visual inspection. Others may have interpreted floating positions differently, which supports our conclusion that the float test is neither an accurate nor a reliable method of determining the amount of drug remaining in an MDI canister.

Conclusion

The float test may be neither an accurate nor a reliable method for estimating the contents remaining in an MDI canister. Float

characteristics are a function of canister size, design, contents, and method of testing. Our results suggest that clinicians and asthma educators should not recommend this practice. The *Practical Guide for the Diagnosis and Management of Asthma*,²¹ which is a companion document to the NIH Expert Panel Guidelines (EPR-2), states that the only reliable method for determining the number of doses remaining in a canister is to count the number of doses used. Other methods, with the exception of external counting devices in some patient-specific cases, should not be recommended to patients.

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