INHALATION
DEVICES

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MD, PhD
FAAAAII, FACAAAI, SLAAAI 2010-2012

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University Hospital, "Dr. Jose Eleuterio Gonzalez"
Monterrey, N.L., Mexico
You Are Invited to Attend

WAO INTERNATIONAL SCIENTIFIC CONFERENCE

Asthma and Co-morbid Conditions: Expanding the Practice of Allergy for Optimal Patient Care

6–8 DECEMBER 2010
DUBAI, UAE

www.worldallergy.org/2010dubai
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- Internal Medicine Specialty, University Hospital U.A.N.L. 1986-1988, Monterrey, N.L.
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- Director of the Department of Funds Raising of the University Hospital, January 2007 - up to date
- President of UNASMA (International Asthma Foundation) 2007 – 2011
- Director of the Institute of Clinical Immunology, Asthma and Allergy A.C. (NPO)
- President elect of the Latin-American Society of Asthma, Allergy and Clinical Immunology (SLAAI) 2010-2012
- Past President of the Mesoamerica Chapter of the Latin-American Society of Asthma, Allergy and Clinical Immunology (SLAAI), 1997-1999
OBJECTIVES

- Acquire an in-depth understanding of how the most commonly prescribed inhalation devices function
- Identify the device most appropriate to the individual’s needs
- Know correct and effective techniques for the most commonly available devices
- Teach and assess patient’s techniques effectively
- When necessary, refer to appropriate professionals from the health care team
RESPIRATORY THERAPY

- Inhaled administration of drugs in patients with respiratory diseases
  - ASTHMA
  - CRUP
  - COPD
  - PNEUMONIA
  - CYSTIC FIBROSIS

This technique enables the drugs to act directly on the airways

J Allergy Clin Immunol 2009;124:S88-93
DRUGS AVAILABLES FOR RESPIRATORY THEPAYS

- Corticosteroids
- Bronchodilators
- Antiviral
- Antibiotics
- Antifungal
- Mucolytics

Inhaled corticosteroids form an integral part of asthma management and are the most effective long-term therapy.

ADVANTAGES

- Best local effect of the product that optimizes the desired effects
- Lower doses
- Rapid onset of action
- Low systemic bioavailability
- Minimal side effect than drugs delivered orally or intravenously

American Association for Respiratory Care. Aerosol consensus statement. Respir Care 1991;36:916–21
THE DEPOSIT OF THE PARTICLE DEPENDS:

- Particle size
- Speed inspiration
- Integrity of airway
- Proper technique
The effectiveness of an aerosol is largely dependent on how much of the medication actually reaches the small peripheral airways of the lungs.

Deposit of particles by size

**Particles > 8 um are deposited in the oropharynx (90% absorbed)**

- **5-8 um are deposited in the large airways**
- **2-5 um are deposited in the tracheobronchial region**
- **1-2 um are deposited in the alveolar region**
- **<1 um are deposited in diameter are passed expiration**
The physical mechanisms governing the movement and deposition of aerosol particles in the air are:

- Impacted
- Sedimentation
- Diffusion
Particle deposition

Speed of inspiration: the ideal flow is between 30 and 60 L / min

*High flow* facilitates central impaction

*Low flow* helps the sedimentation of particles

**Sedimentation**
- 0.5-5 micras
- Flujo aereo bajo
- La apnea post inhalacion favorece la sedimentación

**Impacted**
- >5 microns
- Upper airway
- High flow rate

< 0.5 microns
- High-speed movement short haul are exhaled
INHALATION DEVICES

Several different types of inhalation devices are available, but not all medications are available in each device.

The choice of inhalation device will depend on:

- Medication prescribed
- The needs and capabilities of the individual patient

DEFINITIONS

- **Aerosol**: A suspension of small solid or liquid particles in a gas.
- **Nebulizers**: The devices are used to generate aerosols of liquid particles in a gas cloud.
- **Inhalers**: Are the devices used to generate aerosols of solid particles.

USING INHALATION DEVICES
Danielle Beaucage and Suzanne Nesbitt
INHALATION DEVICES

- **Metered-dose inhaler (MDIs)**
  - Conventional pressurized inhaler
  - Activated by pressurized inhaler inspiration

- **Dry-powder inhaler (DPIs)**
  - Dose
  - Multidose

- **Nebulizers**
  - Jet
  - Ultrasonic
<table>
<thead>
<tr>
<th>Year</th>
<th>Inhaler Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Novolizer® (DPI)</td>
</tr>
<tr>
<td>1995</td>
<td>Diskus® (DPI)</td>
</tr>
<tr>
<td>1989</td>
<td>Autohaler® (breath-actuated MDI)</td>
</tr>
<tr>
<td>1988</td>
<td>Turbuhaler® (DPI)</td>
</tr>
<tr>
<td>1980</td>
<td>Diskhaler® / Rotadisk® (DPI)</td>
</tr>
<tr>
<td>1971</td>
<td>Breath-actuated MDI</td>
</tr>
<tr>
<td>1959</td>
<td>Spinhaler® (first DPI)</td>
</tr>
<tr>
<td>1960s</td>
<td>Ultrasonic nebulizers</td>
</tr>
<tr>
<td>1956</td>
<td>Medihaler® (first pMDI)</td>
</tr>
<tr>
<td>1930s</td>
<td>Compressed-air nebulizers</td>
</tr>
</tbody>
</table>

pMDI = pressurized metered dose inhaler  
DPI = dry powder inhaler
The most common device for inhaled drug delivery

Consists of a pressurized canister and a chamber outfitted with a mouthpiece and protective cover

The canister contains a medication, a surfactant and/or a solvent, and a liquid propellant

- Chlorofluorocarbons (CFCs)
- Hydrofluoroalkanes (HFAs)

The inhaler itself is designed to deliver exact doses of medication
Diagram of the pressurized metered-dose inhaler

Adapted with permission from GlaxoSmithKline, Canada
METERED-DOSE INHALER (MDIS)

- A **suspension** MDI is one in which the drug is physically ground down into solid particles and then the particles are suspended in the liquid propellant.

- That is why suspension inhalers need to be shaken.

- A **solution** MDI means that the drug is actually dissolved in the propellant/cosolvent formulation.

- The drug solution can produce aerosolized droplets in a size range when the propellant evaporates, would result in smaller, solid drug particles.
Chlorofluorocarbon (CFC) propellants
Recognition that CFC propellants deplete the ozone layer has led to their production being gradually phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer

To meet the need to find a replacement for CFCs in pressurized ("press and breathe") metered-dose inhalers (pMDIs)

Hydrofluoroalkane (HFA)
Environmentally friendly propellants rapidly replacing CFCs in pMDIs

## Feature Differences Between CFC and HFA MDIs

<table>
<thead>
<tr>
<th>Feature</th>
<th>CFC</th>
<th>HFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output speed</td>
<td>High (150km/h)</td>
<td>Much lower (3 time less)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Cold spray</td>
<td>Releases a warm spray</td>
</tr>
<tr>
<td></td>
<td>Release lower dose</td>
<td>Consistent dose even at -20°C</td>
</tr>
<tr>
<td>Volume</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Mass Median aerodynamic diameter</td>
<td>3.5 -4.0um</td>
<td>1.0 -1.2um</td>
</tr>
</tbody>
</table>
HFA-BDP

Deposition of radiolabeled steroid after inhalation of QVAR, CFC-FP, and CFC-BDP.26

Vanden Burgt. Efficacy and safety overview of a new inhaled corticosteroid, QVAR (hydrofluoroalkane beclomethasone extrafine inhalation aerosol), in asthma. J Allergy Clin Immunol 2000;106:1209-26
Lung deposition and particle size comparison of steroid inhalers

<table>
<thead>
<tr>
<th>Inhaled steroid</th>
<th>MMAD (μm)</th>
<th>Lung deposition value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluticasone DPI</td>
<td>~4.0</td>
<td>15%</td>
</tr>
<tr>
<td>Triamcinolone</td>
<td>4.5</td>
<td>14%</td>
</tr>
<tr>
<td>CFC-flunisolide</td>
<td>3.8</td>
<td>19%</td>
</tr>
<tr>
<td>CFC-beclomethasone</td>
<td>3.5</td>
<td>8%</td>
</tr>
<tr>
<td>CFC-fluticasone</td>
<td>2.6</td>
<td>13%</td>
</tr>
<tr>
<td>HFA-flunisolide solution</td>
<td>1.2</td>
<td>68%</td>
</tr>
<tr>
<td>HFA-beclomethasone solution</td>
<td>1.1</td>
<td>56%</td>
</tr>
<tr>
<td>HFA-ciclesonide solution</td>
<td>1.0</td>
<td>52%</td>
</tr>
</tbody>
</table>

*MMAD*, Median mass aerodynamic diameter.

HFA-BDP (ultrafine particle) provided greater improvement in FEV1 than CFC-BDP (large-particle inhaled steroid)

*Used with permission from Busse et al.

Dose-comparison calculation shows that it would take 2.6 times the dose of a large-particle inhaled steroid (CFC-BDP) to achieve the same improvement in FEV1 compared with an ultrafine-particle inhaled steroid (HFA-BDP)

*Used with permission from Busse et al.30

Pressurized metered-dose Inhaler: illustration of technique

1. Remove the cap
2. Shake device
3. Exhale to FRC
4a. Closed-mouth technique
4b. Open-mouth technique

- Begin inhaling and actuate canister once
- Inhale slowly until TLC
- Hold breath for 10 seconds
- If another dose is required, repeat steps
CARE AND MAINTENANCE OF THE PRESSURIZED METERED-DOSE INHALER

- Avoid temperature extremes
  - Heat and cold

- The canister should be kept warm

- Cold temperatures will reduce the efficacy of a CFC-driven pMDI

- Replace the inhaler’s protective cap between uses to avoid aspiration of foreign objects
  - Dust, paperclips, coins, etc
The inhaler should be replaced when the medication has expired (see date printed on canister) or when the inhaler is nearing empty.

EVALUATION OF CONTENTS
Advantages:
- It has been proven that pMDIs are a reliable and effective method of delivering inhaled medication.
- When used properly, their efficacy is at least equal to that of other inhalation devices.

Disadvantages:
- They are relatively complicated to use effectively.
- Several studies have revealed that a large number of patients are unable to master the technique.

Ergonomic grip builds a positive user experience
Sportier look and feel appeals to younger users
Strong color use increases brand recognition
Improved hygiene with attached cap
Tougher package for lots of abuse
BREATH ACTIVATED INHALERS

Inhalation device inspiroactivado dispenser by the patient

EASY BREATH

Require low flows
(18-30 L / min)
Require no patient coordination
SALBUTAMOL-Budesonide

AUTOHALER
**RESPIMAT**
*SPIRIVA (TIOTROPIUM BROMIDE)*

- **Soft inhaler dispersion**
  Use the mechanical strength of a spring instead of a propellant to deliver the drug dose
Spacing devices were designed to overcome the difficulties experienced when using a pMDI.

Spacing devices are available in varying forms and sizes.

Spacing devices also improve the deposition of medication in the lower airways.

Ahrens R, Lux C, Bahl T, Han SH. Choosing the metered dose inhaler spacer or holding chamber that matches the patient’s need: evidence that the specific drug being delivered is an important consideration. J Allergy Clin Immunol 1995;96:288–94.
The most efficient spacing devices have a **holding chamber** and a **one-way valve** that opens during inspiration and closes during expiration.

Preventing drug loss caused by poor coordination between actuation of the pMDI and inspiration.

SPACING DEVICES ARE THEREFORE INDICATED AS FOLLOWS

- To overcome difficulties of patients who are unable to use pMDIs correctly (ie, because of coordination problems, physical or mental handicaps, etc)

- To reduce the risk of adverse effects with inhaled respiratory medications (especially when using high doses of inhaled corticosteroids)

- To decrease or eliminate coughing or arrested inspiration experienced by some patients when using CFC-driven devices

- To administer inhaled medication during severe exacerbations as recommended by the American Thoracic Society
### EXAMPLES OF SPACING DEVICES

<table>
<thead>
<tr>
<th>Aerochamber Plus™</th>
<th>VentaHaler®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is a 145-mL rigid cylinder made of polyester</td>
<td>Is an elliptical-shaped device made of rigid, transparent plastic</td>
</tr>
<tr>
<td>• (Trudell Medical, London, ON)</td>
<td></td>
</tr>
<tr>
<td>Adapter that makes it compatible with most pMDIs</td>
<td></td>
</tr>
<tr>
<td>Is available with a mouthpiece or a mask</td>
<td>Not fit all pMDIs.</td>
</tr>
</tbody>
</table>
Diagram of the **AeroChamber Plus™** VHC with adult mouthpiece

(Adapted with permission from Trudell Medical International. London ON.)
AEROCHAMBER

His allows time for some of the propellant surrounding the particles of medication to evaporate. They slow down and suspend small droplets of aerosolized medication for approximately 1 to 2 seconds. The inhaled aerosol is made up of a greater proportion of particles small enough to reach the lower airways. The larger particles remain within the spacing device, thus significantly reducing the deposition of medication in the oropharynx and thereby reducing adverse effects.
AEROCHAMBER

- **PEDIATRICS**
  - Mask
  - Least resistance in valves
  - Lower volume

- **ADULTS**
  - Mask or mouthpiece
  - Mask size
  - High Volume
Plastic chambers
- Electrostatic charge inside that makes the drug is retained in its walls

Chambers of metallic material
- Avoid this problem by making better use of medication
SPACER WITH A MASK ATTACHMENT

Aerochamber 144ml
one way valve
3 model

Babyhaler 260ml
two valves
unidirectional
GLAXO

Nebuchamber 250ml
Two valves
unidirectional
ASTRA

Optichamber 350ml
Sound valve
VENTAHALER
SPACER WITH NOZZLE

Fisionair® (Fisons)
Volume of 800 cc
Way valve
Compatible with all cartridges

Volumatic® (Glaxo)
Volume of 800 cc
Way valve
Ventolín®, Serevent®

Nebuhaler® (Astra)
Volume 750cc
Way valve
Atrovent®, Berodual®, Pulmicort®
Spacing device: illustration of technique

Remove caps from spacing device and pMDI

Shake inhaler and connect it to the spacing device, keeping the pMDI upright

Insert mouthpiece between lips

Exhale to FRC

1

2–3

4a

4b

5

7 a) Hold breath for 5 to 10 seconds

Or

7b) Breath slowly in and out of the spacing device, 3 or 4 times in a row

Place the mask over the face, making sure that the mouth and nose are covered

Spray one dose of medication into the chamber

Inhale slowly until TLC* (total lung capacity) 3-5 s

Adapted from the self-management program “Living well with COPD, Inhalation Technique Card, Spacing Device.”
The **Aero Chamber Plus™ VHC** with mask: Caregivers and teachers can observe the flexible area around the mask compressing as the patient inhales.

**Espaciador**

**Inhalador**

The **AeroChamber Plus™ VHC** has a special sound feature that indicates when inspiration is too rapid, namely, a flow greater than 45 L/min.
Children using a pressurized metered dose inhaler
STORAGE OF MEDICINES WITHOUT THE USE OF SPACER AND SPACER USE
The general procedure for cleaning most spacing devices is as follows:

Take the device apart following the manufacturer’s instructions. Spacing devices should be washed prior to their first use.

Soak the pieces in a basin of warm, soapy water.

Do not rub the interior surfaces with sponges or brushes because this will cause the walls to be roughened and thus increase the amount of medication that will adhere to them.

Air-dry on a clean surface.
**DRY POWDER INHALERS (DPIS)**

- Portable inspiratory flow-driven devices that deliver dry powder formulations of inhaled drugs to the lungs

Alternative methods of aerosol delivery that are effective and easy to use are increasingly in demand.
DRY POWDER INHALERS (DPIS)

SINGLE-DOSE DEVICE

Aerolizer®

Handihaler®

MULTIPLE-DOSE DEVICES

Turbuhaler®

Twisthaler®

Diskus®
Main factors that determine drug delivery to the lungs
- Inspiratory volume
- Flows generated by the patient

- Particles of 1-2 mm
- 30-60lts/min ideal inspiratory flow

Some devices contain additives such as lactose or glucose to improve the perception of inhalation

They do not require coordination because the force of the patient’s inspiration activates the aerosol. They do not require propellants and are not affected by the cold, and are environmentally friendly. Are small, lightweight and easy to handle.

Some devices may not be effective, however, for individuals with severe airflow limitations or in acute situations. Require a degree of manual dexterity and a basic understanding of how they work.
DPI SINGLE-DOSE DEVICE

• Drugs available:
  Budesonide
  Cromolyn sodium
  Formoterol
  Ipratropium bromide

Capsules containing a single dose of drug and are perforated to power a device

Requires high inspiratory flow, higher than the multiple dose devices
TURBUHALER

- Budesonide
- Terbutaline
- Formoterol
- Combination Symbicort 80-160-320mcg

The medication in the Turbuhaler® is in the form of a fine, additive free dry powder.

The Turbuhaler® uses the force of inspiration to lift particles that are deposited onto a dosing disc within the container into the respiratory system.

With the exception of formoterol and abudesonide combination which also contains lactose powder.
Diagram of the Turbuhaler®

Adapted with permission from AstraZeneca, Canada
Remove plastic cover

Turbuhaler®: illustration of technique

1. Remove plastic cover

2-3. Hold the Turbuhaler® upright (mouthpiece up)
   - Turn the colored handle in one direction as far as possible. Then turn it back until you hear a click

4. Exhale to FRC: breathe out normally

5. Inhale forcefully and deeply through mouth

If another dose is required, repeat steps

Put the protective cap back on
### TABLE 6–3 Relationship between Inspiratory Flow Rate and Drug Deposition Site*

<table>
<thead>
<tr>
<th>Necessary Inspiratory Flow Rate</th>
<th>Drug Deposition in Lungs (%)</th>
<th>Drug Deposition in Oropharynx</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 L/min</td>
<td>14.8 ± 3.3</td>
<td>66.6 ± 8.0</td>
</tr>
<tr>
<td>60 L/min</td>
<td>27.7 ± 9.5</td>
<td>57.9 ± 13.0</td>
</tr>
</tbody>
</table>

*These results were obtained during a trial using Turbuhaler® to deliver budesonide. Similar results were obtained using terbutaline sulfate.48

Preparing the Twisthaler® for Use

Hold the Twisthaler® straight up with the pink portion on the bottom

Remove the cap from the Twisthaler® by twisting off the cap

As you lift off the cap the dose counter on the pink portion will count down by one. This action gets the medicine ready for you to inhale
• Hold the Twisthaler® away from your mouth and gently breathe out.

• Seal your lips around the mouthpiece.

• Inhale rapidly and deeply. Continue to take a full, deep breath.

• Take the Twisthaler® out of your mouth. Hold your breath for 10 seconds.

• Resume normal breathing. Do not breathe out into the Twisthaler.

• Close the Twisthaler® by twisting on the cap.

Ann Mullen, RN, MS, AE-C (June 2009)
Identifying When the Twisthaler® Is Empty

1. The Twisthaler® has a dose counter on the pink base

2. The dose counter will show the doses of medicine left. When the dose counter shows 01, there is one dose left

3. When the Twisthaler® is empty the dose counter will show 00 and the pink base will not turn. Start using a new Twisthaler
ACCUHALER
DISKUS®

The Diskus ® is a new multidose DPI that contains 60 doses of medication in a lactose-based carrier.

Inhaled corticosteroids
Short- and long-acting β2 agonists and combination therapy

- Fluticasone
- Salmeterol
- Salmeterol/fluticasone

Seretide 25/50-25/125-25/250
Diagram of the Diskus®

Mouthpiece

Strip lid peeled from pockets

Index wheel

Body

Lever

Contracting wheel

Dose indicator wheel

Empty strip

Thumb grip

Base wheel

Pockets containing drug

Adapted with permission from GlaxoSmithKline, Canada
Diskus®: illustration of technique

1. **Open the cover**
2. **Remove the Diskus® from the mouth and hold breath for 10 seconds**
3. **Exhale to FRC, away from the Diskus®**
4. **Inhale a dose**
5-6. **Slide the lever back**
6. **Close the Diskus® cover**

If another dose is required, follow steps 1 to 6.
FEATURES TO CONSIDER

- The individual wrapping protects the powder from humidity and other environmental conditions.
- The Diskus® provides a relatively consistent dose over a wider range of flow rates than the other DPIs.
FEATURES TO CONSIDER

- Inspiratory flow between 30 and 90 L/min ensures delivery of 90% of the dose

- The mouthpiece of the Diskus® should be wiped with a clean, dry cloth to prevent moisture from entering the system after each use
THE MAJOR DISADVANTAGES OF THE DISKHALER®

- It carries very few doses

- Requires the highest flows for adequate peripheral deposition

- Lactose, the drug carrier used in some DPIs, may be irritating to the upper airways (mouth, throat), thus inducing cough, and

- Also has a taste that some patients find unpleasant

- This can, however, be reassuring to many because it signals that they have received their dose
Nebulizers break down measured doses of medication in liquid form into a mist of small droplets, called an aerosol.

**Wet nebulization requires the following:**

An energy source such as a compressor

Compressed air or oxygen

A mask or a mouthpiece

A nebulizer
NEBULIZERS

- Ability to administer drugs at high doses and in combination
- Supports different forms of oxygen therapy and assisted ventilation
- It provides humidification of the airways
  - Pneumatic nebulizers (Jet ®)
  - Ultrasonic Nebulizer

Diagram of a nebulizer
1. Set up the compressor
2. Connect the nebulizer to the compressor outlet with the tubing
3. Turn on the compressor and verify output
4. Prepare medication, place it in the nebulizer cup, and connect the mask or mouthpiece
5a. Place mask over face or mouthpiece into mouth
PNEUMATIC NEBULIZERS (Jet ®)

Optimal flow for most currently used nebulizers is between 6 and 10 L/min.

It takes approximately 5 to 10 minutes to administer 2.5 mL of solution at this flow rate.

Breathing should be slow and regular, with an occasional deep breath.
ULTRASONIC NEBULIZERS

More rapids and quiet

An oscillator generates high frequency vibrations that causes the particles of medicine is gradually detached from the fluid mass and suspended in the air, forming the aerosol.
CARE AND MAINTENANCE OF NEBULIZERS

Following each use....
The nebulizer cup should be disassembled, rinsed, and air dried to prevent the crystallization of the medication.

Mask or mouthpiece and nebulizer cup
Washed in lukewarm, soapy water, rinsed thoroughly, and air-dried.

The nebulizer should be turned on for a few minutes after cleaning to clear the system of water.

Disinfected using a solution of water and vinegar.
NEBULIZERS
DISADVANTAGES

- No additional advantages over conventional systems
- The cost is higher
- High maintenance requirements
- Time consuming
- Dependent on outside power sources, electricity
- Noisy
- Less portable

Only 1 to 5% of the output from most compressed air nebulizers is delivered to the lower branches of the bronchial tree.
NEBULIZERS

It has been recommended ... that pMDIs with spacers replace wet nebulizers for bronchodilator administration in the acute care setting

Will probably result in cost savings

TREATMENT SUCCESS IS THE RESULT OF A GOOD TEAM WORK