Lung deposition of aerosol—a comparison of different spacers

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Abstract

Aims—To investigate (1) aerosol lung deposition obtained from two small volume conventional spacers (Babyhaler and Aerochamber) and a home made spacer (modified 500 ml plastic cold drink bottle); (2) the effect of using a face mask or mouthpiece; and (3) the relation between age and pulmonary deposition.

Methods—Lung deposition of aerosolised technetium-99m DTPA inhaled via spacer was measured in 40 children aged 3–7 years with stable asthma. Each patient performed sequential randomly assigned inhalations using two spacers. Three studies were performed: Babyhaler compared to Aerochamber (with facemasks); Babyhaler with facemask compared to Babyhaler with mouthpiece; and Babyhaler with mouthpiece compared to a 500 ml bottle.

Results—Median lung aerosol deposition from a Babyhaler and Aerochamber with masks were similar (25% v 21%, p = 0.9). Aerosol lung deposition from a Babyhaler with mask compared to a Babyhaler with mouthpiece was equivalent (26% v 26%, p = 0.5). Lung deposition was higher from a 500 ml bottle compared to a Babyhaler in both young (25% v 12.5%, p = 0.005) and older children (42% v 22.5%, p = 0.003). A notable reduction in pulmonary deposition occurred at 50 months of age.

Conclusion—A Babyhaler or Aerochamber produce equivalent lung deposition of aerosol. There is no difference in lung deposition when a mask or mouthpiece is used. A modified 500 ml plastic bottle produces greater pulmonary aerosol deposition than a conventional small volume spacer.

Keywords: spacer; pulmonary aerosol deposition

A metered dose inhaler (MDI) with spacer provides the optimal system for delivery of maintenance therapy for childhood asthma. A spacer, used in conjunction with an MDI improves drug delivery to the lungs and significantly reduces local and systemic side effects from drugs, especially inhaled corticosteroids. Recent studies suggest that an MDI with spacer is also the preferred delivery system for children with acute asthma. Equivalent or better bronchodilatation is obtained when β agonists are delivered via MDI with spacer compared to nebulisation in children with acute asthma, even when the degree of airways obstruction is severe. Young children with asthma are unable to use an MDI effectively without the addition of a spacer. Small volume spacers such as the Babyhaler (GlaxoWellcome) and Aerochamber (Trudell Medical, Canada) have been developed for this purpose. These spacers consist of a facemask connected to a cylindrical extension device via a one way valve. The facemask can be replaced by a mouthpiece. Home made spacers, principally a 500 ml plastic cold drink bottle have been adapted for use in developing countries. Although these spacers are widely used there is little data on their comparative efficacy or on the effect of a mouthpiece compared to a facemask for delivery of aerosolised medication.

We have previously developed a system to measure aerosol lung deposition from different spacers in older children. This technology was adapted in order to: (1) compare lung deposition of aerosol from the Babyhaler and Aerochamber; (2) investigate the effect of a facemask or mouthpiece on lung deposition of aerosol; (3) compare pulmonary aerosol deposition obtained from the Babyhaler and modified 500 ml plastic bottle; and (4) examine the relation between age and pulmonary deposition.

Methods

Patients

Forty patients with moderate asthma who regularly attend the asthma clinic at Red Cross Children’s Hospital, participated in the study. Inclusion criteria were a requirement for regular inhalation therapy for control of asthma, absence of an acute asthma exacerbation within the preceding six weeks, and age 3–5 years (studies 1–3) or 5–7 years (study 3 only). Patients were excluded if they had clinical signs or symptoms of airways obstruction on the day of the test. In addition, children older than 5 years had a peak expiratory flow rate of greater than 85% of the predicted normal value on the day of the study. Informed consent was obtained from a parent or legal guardian. The study was approved by the Ethics Review Committee, UCT Medical School.

Delivery and Measurement of Aerosol

Technetium-99m DTPA (code N108, Amersham International plc, Amersham, UK) aerosol was used to measure deposition in the lungs. The delivery system consisted of a 2 litre anaesthetic rebreathing bag, which could be sealed. A two way tap (isolation valve) of the type used in medical gas lines was attached to
the proximal end of the bag and a gas flow controller from a Baumanometer to the distal end. The bag was filled with aerosol by connecting it to a micro Cirrus nebuliser (Amersham Health Care code N 1430, Amersham International plc, Amersham, UK) with a 1 m length of corrugated respirator tubing and passing oxygen vertically up through the nebuliser, corrugated tubing, and bag at a flow rate of 6 l/min for a minimum of 10 minutes. A plastic tube on the flow valve on the distal end of the bag carried all aerosol passing through the bag to a trapping system. The bag was sealed by closing the Baumanometer flow valve and then the two way tap before being removed from the circuit and attached by this tap to the particular spacer device being tested.

The activity available for inhalation was calculated from static one minute images of the bag recorded before and after the patient breathed from the delivery system and spacer combination. Deposition of aerosol in the lungs was calculated from a dynamic series of posterior images recorded at one second per frame for two minutes while the patient breathed deeply from the spacer and attached bag. In all children activity in the lungs had reached plateau within 40 seconds and total counts in the lung in the second minute of the study were taken as total pulmonary activity.

Each patient performed two separate inhalations in order to compare the efficacy of different spacers. The spacers were tested in two sequential inhalations. Immediately before beginning the second inhalation, the residual activity in the patient’s lungs was measured and later subtracted from the total pulmonary activity measured in the second study. Subtraction of residual activity was necessary to obtain an accurate measurement for aerosol lung deposition from the second spacer.

Table 1 summarises the results of lung deposition from different spacers in children

<table>
<thead>
<tr>
<th>Spacer</th>
<th>Median</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babyhaler with mask</td>
<td>25</td>
<td>15.2–28.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Aerochamber with mask</td>
<td>21</td>
<td>18.1–27.3</td>
<td></td>
</tr>
<tr>
<td><strong>Study 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babyhaler with mask</td>
<td>26</td>
<td>21.4–36.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Babyhaler with mouthpiece</td>
<td>26</td>
<td>22.0–31.4</td>
<td></td>
</tr>
<tr>
<td><strong>Study 3</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Age 3–5 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babyhaler with mouthpiece</td>
<td>12.5</td>
<td>6.5–19.5</td>
<td>0.005</td>
</tr>
<tr>
<td>500 ml bottle</td>
<td>25</td>
<td>19.7–31.5</td>
<td></td>
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<tr>
<td>Age 5–7 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babyhaler with mouthpiece</td>
<td>22.5</td>
<td>15.9–27.7</td>
<td>0.003</td>
</tr>
<tr>
<td>500 ml bottle</td>
<td>42</td>
<td>36.0–44.0</td>
<td></td>
</tr>
</tbody>
</table>

Values expressed as percentage aerosol deposition.
Lung deposition of aerosol

497

conventional spacer, the Babyhaler. This e
terior aerosol lung deposition than a small volume
produced greater pulmonary
study; this probably accounts for the lower
months had deposition of more than 19%,
Babyhaler, only one child younger than 55
was seen in children of various ages. Two
Babyhaler and Aerochamber produced equival-
children in the 3–5 year age group of the third
 seasoning the ability of the child to cooperate as well as age dependent
tidal volumes and inspiratory flow rates gener-
from an MDI might di

diameter).8 Furthermore, a 500 ml bottle
were exposed to is far less than that obtained
estimated dose of radiation that children
were exposed to is far less than that obtained
from a single abdominal x ray and may be
similar to the amount of naturally occurring
radiation that is acquired daily.

Exposure of children to radiation raises ethi-
concern. However, the total radiation dose
for each child in this study was extremely small.
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The method of aerosol delivery in our study
differs from that of an MDI. We have
previously developed and tested this delivery
system in older children.5 The aerosol used
was generated via a jet nebuliser that produces par-
ticles with a mass median aerodynamic diam-
er of 2–4 µm. Lung deposition of aerosol
from an MDI might differ from that attained

Discussion
This study showed that a modified 500 ml
plastic bottle produced greater pulmonary
aerosol lung deposition than a small volume
conventional spacer, the Babyhaler. This effect
was seen in children of various ages. Two
widely available small volume spacers, the
Babyhaler and Aerochamber produced equiv-
alent aerosol lung deposition in young chil-
ren. Furthermore, aerosol deposition did not
differ whether a mask or mouthpiece was used.

Many properties of a spacer may affect pul-
monary deposition of aerosol, including the
volume and shape of the device, the electro-
static charge of the side walls, volume of dead
space, and presence or type of valves.8–10 The
efficiency of a 500 ml bottle may be partly a
result of its physical characteristics. A 500 ml
bottle was selected in preference to a larger
volume bottle as it more closely approximates
the optimum chamber dimensions for a spacer
for children (experimentally found to be a cy-
linder approximately 11 cm in length by 3.5 cm
in diameter).8 Furthermore, a 500 ml bottle
has been previously reported to be an effective
spacer, producing equivalent aerosol deposi-
tion and bronchodilation to that obtained from
a conventional spacer in older children.5 11 Our
results suggest that the absence of a one way
valve (as occurs with a bottle) does not
adversely affect aerosol deposition but may in
fact increase the amount of aerosol delivered.
Valveless spacers have been reported to en-
hance the delivery of aerosol to the lungs in
infants with chronic lung disease.12 Similarly,
absence of a valve may prove beneficial for
children as the need to overcome the resistance
of the valve on inspiration is obviated.

Although the Aerochamber is less than half
the volume of the Babyhaler, equivalent aerosol
deposition was obtained from both devices.

Discussion

Although the Babyhaler, equivalent aerosol
deposition was obtained from both devices.

The choice of spacer size must balance the
need for a small volume with the loss of aerosol
because of impaction on the side walls which
increases as the volume diminishes.13 Previous
studies have reported that larger doses of aero-
sol are obtainable from the Babyhaler than the
Aerochamber.13 14 However, these studies
measured the drug collected on filter paper
interposed after the inspiratory valve of the
spacer; thus they reflect the dose of aerosol
delivered at the child’s mouth and not the
amount deposited in the lungs. The reduction
in lung aerosol deposition because of the
smaller volume of the Aerochamber may be
countered by the large dead space in the Baby-
haler, thus explaining the equivalence of these
spacers.

Characteristics of the child such as their tidal
volume, breathing pattern, and technique of
spacer usage may further affect drug
deposition.5 15 As evidence of this, reduced
deposition of aerosol occurred at approxi-
ately 50 months of age with all spacers.

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Figure 1  Pulmonary aerosol deposition from a bottle used
as a spacer by age.

deposition obtained when the bottle was used
as a spacer (fig 1). Of the children younger than
50 months of age, one had pulmonary deposi-
tion of more than 30%, while only a single child
older than 50 months had deposition less than
30%. This pattern of deposition was similar for
the Babyhaler but at a lower level. For the
Babyhaler, only one child younger than 55
months had deposition of more than 19%,
while seven of 10 children older than 55
months had deposition of more than 19%.
Children in the 3–5 year age group of the third
study were younger than those in the second
study; this probably accounts for the lower
aerosol deposition obtained from a Babyhaler
in the former study.
using our delivery system. However, the percentage deposition obtained is not important, but rather the relative deposition from different spacers. As the delivery system was kept constant and the particular spacer varied, a valid comparison of the efficacy of different spacers could be made.

In conclusion, a modified 500 ml plastic bottle produced superior aerosol deposition to that obtained from a conventional small volume valved spacer. The Aerocam and Babyhaler were equivalent in the amount of pulmonary aerosol deposition produced. Use of a mouthpiece rather than a facemask did not increase the amount of aerosol deposited in the respiratory tract in children older than 3 years. The choice of spacer and use of mask or mouthpiece should be made based on consideration of factors such as patient preference, cost of the device, ability of the care giver or patient to use the spacer correctly, and type of MDI used. Use of a 500 ml modified bottle as a spacer for children requiring inhaled therapy for asthma should be encouraged.

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