**Short Report**

**Optimizing nebulization practice within a large teaching hospital: easier said than done**

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**Introduction**

The quantity and quality of drug delivered to the distal airways by nebulization is operator dependent (1). We have previously reported a variety of techniques practised for administering drugs via nebulizer (2) and deficiencies in the method of nebulizer operation have been highlighted (3). In the following study we examined the impact of issuing guidelines for nebulization (see Appendix), on the many variables involved. In addition we investigated whether reinforcement of the guidelines by pharmacist-led tutorials improved compliance with the guidelines.

**Methods**

Thirty-five wards within Glasgow Royal Infirmary were sampled using an open questionnaire. Prior to the study information was collected on: drugs nebulized, diluent and final fill volume, driving gas and flow-rate, sequence of drug administration, and nebulizer care and cleanliness.

Group 1 wards received guidelines plus pharmacist-led tutorials. Group 2 wards received guidelines alone. A second survey was carried out 6–8 weeks later.

For both surveys the nurse-in-charge was interviewed.

Statistical analysis was performed using non-parametric chi-squared ($\chi^2$) analysis.

**Results**

Group 1 comprised 14 wards, (A) prior to guideline circulation, and (B) after guidelines were reinforced by ward pharmacists. Group 2 comprised 21 wards, (A) prior to guideline circulation, and (B) after the guidelines.

**DRUGS NEBULIZED**

Drugs nebulized were similar between groups with salbutamol used in all wards, ipratropium bromide and normal saline less commonly used. Terbutaline and pentamidine isethionate were rarely used.

**DILUENT AND FINAL VOLUME**

All respondents diluted nebulizer solution before administration. The diluent favoured was normal saline (12, 13, 16, 20 in groups 1A, 1B, 2A, 2B, respectively). More respondents used a final fill volume of 4 ml or greater after guideline circulation (2, 11, 5, 14 in groups 1A, 1B, 2A, 2B, respectively).

**DRIVING GAS AND FLOW-RATE**

Choice of driving gas did not differ significantly (Table 1). Before guidelines most respondents (69%) used a flow-rate less than 6 l min$^{-1}$ (Table 1). After guidelines alone the use of a flow-rate greater than 6 l min$^{-1}$ did not change significantly. However, those receiving tutorial reinforcement showed significant improvement ($\chi^2$ 3.89, $P<0.05$) with the percentage using a flow-rate greater than 6 l min$^{-1}$ rising from 7% to 50%.

**SEQUENCE OF DRUG ADMINISTRATION**

Following guideline circulation those willing to administer both salbutamol and ipratropium bromide in the same nebulizer increased significantly in both groups [6 (1A)–11 (1B), $\chi^2$ 8.03, $P<0.05$; 4 (2A)–14 (2B), $\chi^2$ 7.26, $P<0.01$].

**RE-USE AND CARE OF THE NEBULIZER**

All wards except casualty re-used nebulizers for the same individuals. Cleansing procedures varied greatly. No significant difference in practice followed circulation of guidelines with or without tutorials.
Table 1 Driving gas selected and flow rate expressed as frequency (% wards in group)

<table>
<thead>
<tr>
<th></th>
<th>Group 1A Pre-guidelines</th>
<th>Group 1B After guidelines and tutorials</th>
<th>Group 2A Pre-guidelines</th>
<th>Group 2B After guidelines alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving gas:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Oxygen</td>
<td>1 (7)</td>
<td>3 (21)</td>
<td>6 (29)</td>
<td>5 (25)</td>
</tr>
<tr>
<td>Air</td>
<td>8 (57)</td>
<td>6 (43)</td>
<td>8 (38)</td>
<td>6 (29)</td>
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<tr>
<td>Air unless oxygen</td>
<td>2 (14)</td>
<td></td>
<td>1 (5)</td>
<td>3 (14)</td>
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<tr>
<td>prescribed</td>
<td></td>
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<tr>
<td>Oxygen unless air</td>
<td>1 (7)</td>
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<td>prescribed</td>
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<tr>
<td>Both</td>
<td>1 (7)</td>
<td>3 (21)</td>
<td>5 (24)</td>
<td>3 (14)</td>
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<tr>
<td>As prescribed</td>
<td></td>
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<tr>
<td>Oxygen asthmatics, air</td>
<td>1 (7)</td>
<td>2 (14)</td>
<td></td>
<td>3 (14)</td>
</tr>
<tr>
<td>COAD</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Flow-rate:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;61 min$^{-1}$</td>
<td>9 (64)</td>
<td>7 (50)</td>
<td>15 (71)</td>
<td>19 (90)</td>
</tr>
<tr>
<td>≥61 min$^{-1}$</td>
<td>1 (7)</td>
<td>7 (50)*</td>
<td>5 (24)</td>
<td>2 (10)</td>
</tr>
<tr>
<td>unspecified</td>
<td>4 (29)</td>
<td></td>
<td>1 (5)</td>
<td></td>
</tr>
</tbody>
</table>

*P<0.05. COAD, Chronic Obstructive Airways Disease.

Discussion

The data presented highlight the wide range of techniques used in administering drugs by nebulizer. Guidelines on optimal procedure only occasionally improved technique and the contribution of tutorial reinforcement was disappointingly limited.

Many aspects of this study require further comment. Where a patient was prescribed both salbutamol and ipratropium bromide those willing to mix the two solutions increased significantly after the guidelines were circulated. Such practice is appropriate since unnecessarily prolonged nebulization may decrease patient compliance. The mixing of nebulized drugs is widespread (4) and in limited experimental studies, there has been no evidence of hazardous interactions (5,6).

The diluent favoured by the majority was normal saline. However following the circulation of guidelines, two respondents still favoured water. Since water produces a hypotonic solution which may induce bronchospasm (7), this practice is potentially hazardous.

Our guidelines recommended an optimal fill volume of 4 ml, balancing residual volume with time to nebulize. Before the guidelines were circulated most respondents used a volume less than 4 ml (71%). After guidelines 71% used a fill volume of 4 ml or greater. This change was not significant but may go some way toward standardizing the fractional dose of drug delivered.

The driving gas used varied greatly and was not influenced by guidelines. This remains an area of concern. Although it is safe to drive nebulizers with oxygen in patients with obstructive airways disease with a normal blood gas picture, caution should be exercised in those with type 2 respiratory failure with carbon dioxide retention (8). Air as a driving gas in severe asthmatics with type 1 respiratory failure is inappropriate given their hypoxia. The failure of both guidelines and tutorials to improve practice is disappointing.

A flow-rate of 61 min$^{-1}$ is required to ensure satisfactory particle size distribution for distal airways deposition (9). Flow-rate was not significantly altered following guideline circulation alone. However, the tutorials significantly increased the number who used an appropriate flow-rate.

Nebulizer cleansing was not significantly altered by guideline circulation. In retrospect the practicality of our guidelines is questionable as only one respondent described the recommended practice after guideline circulation. A practical and acceptable procedure for nebulizer care and cleanliness therefore still needs to be defined, to minimize the risk of bacterial colonization of equipment (10–12).

It is disappointing that the implementation of nebulization guidelines with or without reinforcement by pharmacist tutorial was not more successful in improving technique.

Given the increasingly widespread use of nebulizers, the education of those involved in prescribing, supplying and supervising nebulized therapy is essential. This study highlights the difficulties of ensuring that good practice follows guidelines.

Acknowledgement

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advice, and staff within the Department of Pharmacy, Glasgow Royal Infirmary for assistance with the ward tutorials and data collection.

References
5. O’Driscoll BRC, King M, Cochrane GM. Should nebulised salbutamol and ipratropium bromide be administered sequentially or as a mixture? Thorax 1986; 41: 247.

Appendix

GUIDELINES FOR THE NEBULIZATION OF RESPIRATORY SOLUTIONS

1. **Sit the patient up, either in bed or in a chair. Make him/her comfortable.** Advise the patient to breathe gently through the mouth and encourage relaxation. The face mask should fit comfortably.

2. **Check the expiry date on the respirator solution.** If a multidose bottle is being used it must be discarded one month after opening. Record date opened on container.

3. **Use sterile normal saline as diluent.** Water will result in hypotonic solutions which may cause broncho-constriction. The most economic form of sodium chloride 0.9% for this purpose is Normasol sachets. The sachet may be used for more than one patient during the drug administration round but must be discarded immediately thereafter.

4. **Draw up all solutions with sterile needle and syringe.** For a drug administration round there is no need to change the needle and syringe when drawing up the same drug for use in a number of patients.

5. **A final volume of 4 ml is recommended.** The diluent may be poured in up to the 4-ml mark. Given that all nebulizers have a residual volume, this quantity allows an average 80% of the drugs to be delivered in a time acceptable to the patient. (approx. 10 min).

6. **Use a flow rate of 6 litres per minute.** This will deliver at least 65% of the droplets of a size below 5 μm. This size is required for adequate drug penetration into distal airways.

7. **Use oxygen as the driving gas in patients who are young and who have asthma. Use air as the driving gas in patients who have chronic bronchitis and evidence of carbon dioxide retention.** \((\text{PCO}_2 > 40 \text{ mmHg} \ (5.3 \text{ kPa}))\). If patients with CO₂ retention are receiving controlled oxygen this should be discontinued for the duration of the nebulization only and restarted immediately at the end of the 10 minute nebulization.

8. **Tap the nebulizer during nebulization.** This shakes down large droplets and ensures maximum delivery of the drug.

9. **Rinse the nebulizer with sterile water, wipe dry with a paper towel and dry the inner tube using compressed air or oxygen.** Cleansing is important to reduce the risk of bacterial contamination and prevent build up of crystallized drug in the nebulizer. Store the nebulizer in a bag with the patients’ name on it.

10. In patients receiving a combination of salbutamol and ipratropium the drugs may be mixed immediately before use and administered as one nebulization. **Do not mix other combinations before checking with pharmacy.**