

venous return through the ascending lumbar veins. The bronchial and intercostal arteries were normal on a thoracic aortogram. Echocardiography was normal. Computed tomography of the abdomen and chest showed no evidence of thrombosis in the inferior vena cava. The patient was followed up for 18 months and had no more episodes of haemoptysis.

Discussion

Although anomalies of the inferior vena cava are commonly discovered during imaging for other diseases,¹⁻³ it seems that the anomaly in this patient directly contributed to the pathogenesis of the haemoptysis.

The bronchial venous system communicates freely with the pulmonary veins and alveolar capillaries on one side, and with the azygos vein on the other.⁴⁻⁶ A direct communication between the systemic venous circulation and the pulmonary circulation is therefore present. This makes the bronchial veins vulnerable to pressure changes in either the systemic venous or pulmonary circulations. These bronchial venous channels are thin walled and non-distensible.⁵ Physiologically about one third of the blood accumulated in the bronchial venous plexuses is thought to return to the azygos vein, while the remaining blood flow returns to the pulmonary veins.⁷

Although we did not measure pressure in the azygos vein, we believe that the congenital interruption of the inferior vena cava caused azygos venous hypertension due to the massive

increase in the azygos venous flow. As a result of this haemodynamic change the bronchial venous drainage to the azygos vein could become impaired and reversal of bronchial venous flow might occur. Engorgement of the bronchial veins would therefore take place, similar to oesophageal varices in portal hypertension. These engorged, thin walled, relatively non-distensible, submucosal bronchial veins may undergo rupture with manoeuvres associated with increased intrathoracic pressure and this could lead to haemoptysis.

On the basis of our experience with this case we suggest that an inferior vena cavogram should be considered as one of the investigations when dealing with massive or recurrent haemoptysis of unknown origin.

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- 1 Todisco T, Dottorini M, Parise P, Boschetti E, Lupattelli L. Inferior vena caval defects and the venous circulation. *Chest* 1987;92:768-9.
- 2 Hawass ND, Kolawole TM, Badawi MG. Concomitant pulmonary arteriovenous and inferior vena cava malformations: a case report. *Eur J Radiol* 1988;8:102-5.
- 3 Brem AS, O'Shea PA, Wesselhoeft CA. Absence of inferior vena cava associated with an atrophic right kidney and hypertension. *J Urol* 1981;126:539-41.
- 4 Tobin CE. The bronchial arteries and their connections with other vessels in the human lung. *Surg Gynecol Obstet* 1952;95:741-50.
- 5 Murata K, Itoh H, Todo G, Kanaoka M, Furata M, Torizuka K. Bronchial venous plexus and its communication with pulmonary circulation. *Invest Radiol* 1986;21:24-30.
- 6 Ohmichi M, Tagaki S, Nomura N, Tsunematsu K, Suzuki A. Endobronchial changes in chronic pulmonary venous hypertension. *Chest* 1988;94:1127-32.
- 7 Fraser RG, Pare JA. *Diagnosis of diseases of chest*. 2nd ed. Philadelphia: Saunders, 1978:83-5.

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Comparison of nebulised aerosol deposition in the lungs of healthy adults following oral and nasal inhalation

Mark L Everard, John G Hardy, Anthony D Milner

Department of Child Health

M L Everard
A D Milner

Department of Medical Physics

J G Hardy

Queens Medical Centre, Nottingham NG7 2UH

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Abstract

A standard jet nebuliser was used to generate a radiolabelled aerosol and the pattern of deposition within the airways of eight healthy adults was studied with a gamma camera. Penetration of aerosol to the lung was greatly reduced when breathing through the nose compared with mouth breathing.

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Although the nose acts as a filtration system it

has been argued that patient preference should determine whether a facemask or a mouthpiece is used when inhaling aerosols from jet nebulisers.^{1,2} This argument is based on clinical studies which failed to show any significant difference in clinical response when salbutamol was inhaled through these two routes.^{1,3} However, bronchodilators are generally used in supramaximal doses^{4,5} and hence the observed clinical response need not directly reflect the total dose reaching the lungs.

The dose of aerosol deposited in the lungs is determined by the total dose of drug inhaled and the pattern of deposition of that dose within the airways. The factors influencing the total dose of drug inhaled when using a jet nebuliser are complex and have previously been discussed.⁶ The purpose of this study was to determine what effect inhaling a wet, heterodispersed aerosol by the nasal rather than the oral route might have on the pattern of deposition within the airways. A standard technique^{5,7} was used in which the deposition of a radiolabelled aerosol was assessed with a gamma camera.

Methods

Eight men aged 21-32 years were studied. All were in good health, were non-smokers, and gave no history of lower respiratory tract dis-

ease or current rhinitis. Ethical committee approval was obtained for this study.

The subjects attended on two separate occasions separated by at least 48 hours. During each visit they inhaled a radiolabelled aerosol for 75 seconds. This was generated by a Cirrus nebuliser (Intersurgical) which had been filled with 2 ml normal saline radiolabelled with approximately 40 MBq ^{99m}Tc-labelled diethylenetriamine pentaacetate (DTPA). A driving gas flow of 8 l/min was used. Relaxed tidal breathing was used to mimic the clinical setting and subjects inhaled from a facemask in a random order either through their nose, or through their mouth while using a nose clip. The subjects used their own allocated nebuliser and, apart from the route of inhalation, the conditions were the same for both visits. The nebuliser was housed in a lead case and aerosol generated during the expiratory phase or exhaled was collected on a filter to avoid environmental contamination. Immediately after administration of the ^{99m}Tc-labelled aerosol a gamma camera was used to record anterior and posterior images of the chest and stomach together with a lateral image of the head and neck. These images were displayed on a television screen and areas of interest were defined. Count rates were determined for the lungs, stomach, lower oesophagus, nose, and oropharynx. Each count rate was corrected for background counts and the geometric means of the corresponding anterior and posterior count rates were calculated. The outlines of the lungs were delineated during one visit by obtaining a posterior image of the lungs while the subject inhaled 81m-labelled krypton gas.

The dose deposited in the lungs was then expressed as a percentage of the total dose deposited in the body. Deposition within the lungs was subdivided into three regions; central, mid, and peripheral. From the krypton images the dimensions of each lung were considered in terms of a matrix 8 × 5 units wide.⁸ A block of six cells defined the central region of the lung, and this was surrounded by a mid lung region one cell wide. The remaining cells defined the peripheral region.

A Malvern 2600 laser particle sizer with the Fraunhofer diffraction model was used to obtain the mass median diameter of the aerosol generated by the nebuliser under these conditions.⁹ This diameter is such that 50% of the droplet mass within the aerosol is contained in smaller droplets and 50% in larger droplets.

Results

The quantity of aerosol deposited within the lungs as a percentage of the total dose deposited in the body is shown in the table. The mean improvement in lung deposition when breathing through the mouth was 37% (p < 0.01, Wilcoxon signed rank test). The mean deposition within the central, mid, and peripheral regions when expressed as a percentage of the total dose deposited in the lungs was 27%, 32%, and 41% after nasal breathing, and 28%, 32%, and 40% after inhalation through the mouth.

A mean mass median diameter of 4.4 µm

Aerosol deposition within the lungs as a percentage of total deposition within the body

Subjects	Proportion of inhaled dose in lungs (%)	
	Nasal breathing	Mouth breathing
1	53	82
2	39	78
3	28	59
4	30	78
5	38	86
6	36	79
7	37	70
8	45	70
Mean (SD)	38 (8.0)	75 (8.5)

(range 3.8–5.1 µm) was obtained for the nebulisers used in this study when a driving gas flow of 8 l/min was used.

Discussion

This study with a radiolabelled wet aerosol from a jet nebuliser shows that there is considerable intersubject variation in the ability of the upper airway to filter out droplets when inhaled by either the oral or nasal route even in fit healthy volunteers. Despite using a high driving gas flow, the proportion of the dose deposited in the upper airway was substantially greater for all subjects when inhaling through the nose than through the mouth. This is not entirely surprising since workers in the field of industrial hygiene, using monodispersed aerosols, have shown that nasal deposition increases with increasing inspiratory flow rates and increasing particle size. It has been estimated that at an inspiratory flow rate of 30 l/min, nasal trapping increases from 10% for particles of 1 µm diameter to more than 90% for 10 µm particles.¹⁰ They have also shown that a mouthpiece can further reduce upper airways deposition by reducing deposition within the oral cavity.¹⁰ For many drugs delivered via jet nebulisers such as antibiotics, steroids or, indeed, those used in bronchial challenges such as histamine, the clinical response is likely to correlate closely with the dose reaching the lungs. In these situations oral breathing, preferably via a mouthpiece, is to be recommended.

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1 Stevenon RD, Wilson RSE. Facemask or mouthpiece for delivery of nebulised bronchodilator aerosols? *Br J Dis Chest* 1981;75:88–90.

2 Newman SP. *Nebuliser therapy: scientific and technical aspects*. Lund: AB Draco, 1989:2.

3 Wood DO, Chandler D, Dugdale AE. Two methods of administering nebulised salbutamol, a controlled study. *Aust Paediatr J* 1978;14:150–2.

4 Ruffin RE, Kenworth MC, Newhouse MT. Response of asthmatic patients to fenoterol inhalation: a method of quantifying the airway bronchodilator dose. *Clin Pharmacol Ther* 1978;23:338–45.

5 Johnson MA, Newman SD, Bloom R, Talaee N, Clarke SW. Delivery of albuterol and ipratropium bromide from two nebulizer systems in chronic stable asthma. *Chest* 1989;96:1–10.

6 Everard ML, Clark AR, Milner AD. Drug delivery from jet nebulisers. *Arch Dis Child* 1992;67:586–91.

7 Newman SP, Woodman G, Clarke SW. Deposition of carbenicillin aerosols in cystic fibrosis: effect of nebuliser system and breathing pattern. *Thorax* 1988;43:318–22.

8 Agnew JE, Francis RA, Pavia D, Clarke SW. Quantitative comparison of ^{99m}Tc aerosol and ⁸¹Kr ventilation images. *Clin Phys Physiol Meas* 1982;3:21–30.

9 Newman SP, Pellow PGD, Clarke SW. Droplet size distributions of nebulised aerosols for inhalation therapy. *Clin Phys Physiol Meas* 1986;7:139–46.

10 Hatch TF, Gross P. *Pulmonary deposition and retention of inhaled aerosols*. New York: Academic, 1964:45–60.