THE MAGNITUDE OF AIR ADMIXTURE WITH A JET DEVICE IN PAEDIATRIC ANAESTHESIA

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SUMMARY

The admixture of air in inspired gas with a paediatric insufflation system based on a gas jet has been investigated. During anaesthesia with spontaneous ventilation 1% of air per kg body weight was found in tracheal gas samples. A venturi effect was virtually absent even at high jet flows, which suggests that artificial ventilation prevents air admixture.

A gas jet assembly for inhalation anaesthesia and artificial ventilation in infants has been described by Benveniste and Pedersen (1968). It operates by supplying anaesthetic gases at high pressure as a jet with high linear velocity. Thus directional valves are unnecessary and inflation pressures may be generated. This device, which is now commercially available (Dameca Inc., Islevdalvej 211, DK 2610, Redovre, Denmark), has proved very useful as it combines small dimensions and low weight with mechanical reliability. During inspiration, entrainment of atmospheric air occurs and the present study describes the magnitude of admixture.

METHODS

The jet assembly (fig. 1) has two small brass tubes, the nozzle (A) and the collecting tube (B) brazed coaxially to opposite points of a ring in such a way that a jet of gas from the nozzle will hit the inlet opening of the collecting tube. The latter can be connected to an endotracheal tube or a mask. Thus gas from the jet can be inspired or insufflated, while expired gas is vented to the surrounding atmosphere. For further details the original article should be consulted (Benveniste and Pedersen, 1968).

The extent of mixing of air and inspired gas was studied by measuring the nitrogen concentration produced in the tracheal tube when nitrogen-free gas was used in the jet. For the gas analysis we used a Pye Model 34 gas chromatograph with a Molecular Sieve 5A column at 50 °C and a gas-sampling valve. The nitrogen peak height was found to be proportional to the concentration in three test mixtures of nitrogen and oxygen measured with a calibrated Beckman E paramagnetic oxygen analyser. The chromatograph was calibrated daily with atmospheric air. Studies were carried out in an experimental model and in anaesthetized children.

The model was a 4-mm tracheal tube connected to the collecting tube of the jet device. Pure oxygen from a rotameter with a needle valve was passed through the jet while gas for analysis was drawn slowly from the lumen of the tube via a needle.

In the first set of measurements on the model the distal end of the tracheal tube was connected through another rotameter to an adjustable vacuum in order to simulate inspiration during spontaneous ventilation.
Jet flows ranged from 1 to 10 litre/min creating jet flow/tube flow ratios of 0.2–1.5.

In the second set of experiments the distal end of the tracheal tube was left open and the jet flow varied from 1 to 48 litre/min of oxygen, in order to estimate the possible air admixture resulting from the venturi effect.

The two rotameters used were calibrated by means of a bell spirometer.

The coefficient of variation by sampling and analysis was 5%.

In the clinical study 29 children weighing 4–21 kg, scheduled for minor operations, were anaesthetized with 0.7–2.0% halothane or enflurane in 50% nitrous oxide in oxygen. The mixture was administered via the jet assembly at a flow of 6 litre/min. Orotracheal intubation was performed without a muscle relaxant. The subjects breathed spontaneously throughout the duration of anaesthesia. After 20–40 min of anaesthesia a 5-ml gas sample was taken during the operation by means of a syringe with a needle which perforated the endotracheal tube 2 cm below the connection. The syringe was flushed and the gas was then aspirated slowly (during inspiration) and analysed for nitrogen within 10 min.

![Figure 2](https://academic.oup.com/bja/article-abstract/47/12/1335/333793)

**FIG. 2.** The effect of varying the ratio of jet flow to collecting tube flow in the model experiment. The line represents the function:

\[
\text{Air fraction} = 1 - \frac{\text{jet flow}}{\text{collecting tube flow}}
\]

for jet flow equal to or less than collecting tube flow, or

\[
\text{Air fraction} = 0
\]

for jet flow greater than collecting tube flow.

In five children, two samples were taken successively within 2 min. In this way, the standard deviation of a measurement was estimated at 1.3% of nitrogen, independent of the measured value.

The variation of air admixture during anaesthesia was studied similarly in five children, when an additional sample was taken 10 min or more after the first. In the remaining children only one measurement was made.

**RESULTS**

Figure 2 shows the relation between air fraction and jet flow/collecting tube flow ratio in the first part of the model experiment. At flow ratios lower than 1, the points of observation almost satisfied the equation:

\[
\text{air fraction} = 1 - \text{jet flow/collecting tube flow}
\]

Since the air fraction must be the ratio between the flow of admixed air and the total collecting tube flow, the observed relationship states that the flow of admixed air is the difference between the collecting tube flow and the jet flow. Thus the jet flow is inspired totally when it does not exceed the inspiratory flow. At jet flows exceeding the collecting tube flow the extent of air admixture was minimal. When the two flows were equal, or nearly so, the air fraction was found to be slightly higher than would be expected from these simple rules.

In the second part of the model experiment, where suction through the collecting tube was not applied, no air admixture occurred at jet flows of less than 15 litre/min, and the air fraction at higher flows did not exceed 0.02. Thus, there was practically no venturi effect even at flows of 48 litre/min.

![Figure 3](https://academic.oup.com/bja/article-abstract/47/12/1335/333793)

**FIG. 3.** Air fractions found in tracheal gas during anaesthesia with spontaneous ventilation. The regression line has the equation:

\[
y = 0.0128x - 0.024.
\]
The air fractions found in tracheal gas during anaesthesia have been plotted against body weight (fig. 3). The air fraction increased with body weight (r = 0.77; P < 0.001). The relationship can be described:

\[
\text{air fraction} = 0.0128(\text{body weight (kg)}) - 0.024
\]

That is, approximately 1% of air is admixed per kg.

The air fraction can vary considerably during anaesthesia and operation. In the five children where sampling was repeated at intervals, the variation was from 10 to 40% of the average value.

**DISCUSSION**

As shown in the first part of the model experiment, air admixture occurs when the inspiratory flow exceeds the jet flow, and the difference between these two flows determines the extent of air admixture. The air fraction in mixed inspired gas during spontaneous ventilation will therefore be a ratio, the denominator of which is the area below the inspiratory flow curve, while the numerator is the area between this curve and the line representing the jet flow (fig. 4).

The air admixture occurring during anaesthesia with spontaneous ventilation should pose no serious problem in an infant of less than 15 kg weight as the fraction is normally less than \(\frac{1}{2}\). The dilution can be compensated by increasing the concentration of anaesthetic, or reduced by controlling ventilation manually. According to our second model experiment, which showed that the Venturi effect was very small, the latter method will nearly prevent air admixture. The use of jet flows greater than 6 litre/min with spontaneous ventilation would also reduce the admixture but at the same time produce a positive expiratory pressure.

In larger children controlled ventilation is preferable. However, the jet assembly is not suitable for use in children older than 3 yr.

For the smallest infants a jet flow of less than 6 litre/min may be used with spontaneous ventilation. For artificial ventilation about 6 litre/min should flow into the anaesthetic reservoir bag as an intermittent flow of 17–24 litre/min must be produced in order to attain an inflating pressure of 10–20 cm H\(_2\)O. (Empirically, the inflating pressure produced is 0.017 \(\times \) flow\(^2\), using these units of measurement.)

**REFERENCE**


**IMPORTANCE DU MELANGE D'AIR A L'AIDE D'UN DISPOSITIF DE PULVERISATION POUR LES ANESTHESIES PEDIATRIQUES**

**RESUME**

On a effectué des recherches sur le mélange d’air dans les gaz inspirés pour un système d’insufflation pédiatrique basé sur un pulvérisateur de gaz. Pendant l’anesthésie avec ventilation spontanée on a trouvé 1% d’air par kg de poids du corps dans les échantillons de gaz de respiration. L’effet de venturi a été virtuellement absent, même lorsque la pulvérisation a été faite à des débits importants, ce qui laisse penser que la ventilation artificielle empêche le mélange d’air.

**DIE MENGE DER LUFTMISCHUNG—VERABREICHT MIT EINER DÜSENVORRICHTUNG—BEI PÄDIATRISCHER NARKOSE**

**ZUSAMMENFASSUNG**


**LA MAGNITUD DE UNA MEZCLA DE AIRE CON UN DISPOSITIVO DE BOQUILLA EN LA ANESTESIA PEDIATRICA**

**SUMARIO**

Se ha investigado la mezcla de aire aspirado mediante el uso de un sistema de insuflación pediátrica basado en una boquilla. Durante la anestesia con ventilación espontánea se encontró un promedio de 1% de aire por kilogramo de peso del cuerpo en las muestras de gas tráqueal. El efecto Venturi estaba prácticamente ausente incluso en flujos de alta eyeción, lo que sugiere que la ventilación artificial evita la mezcla de aire.