Ventilation During Bronchoscopy : the Oxygen Injector Technique

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SUMMARY

The Sanders oxygen injector technique of bronchoscopic ventilation is discussed and the principle underlying the method is explained. A short study confirmed the effectiveness and safety of the technique, and the advantages over other methods of bronchoscopic ventilation are presented.

When bronchoscopy is performed under general anaesthesia it is usually preferred to have the patient completely relaxed and apnoeic. Thus it is imperative that an effective means of artificial ventilation be employed to prevent hypoxia and hypercarbia. Problems arise in this regard where there is competition for the airway between the anaesthetist and the bronchoscopist. From the number of different techniques described in textbooks of anaesthesia it is obvious that there was no single method which satisfied both the anaesthetist and the bronchoscopist until Sanders described 2 ventilating attachments for bronchoscopes in 1967.[1] That this is a safe and effective means of bronchoscopic ventilation has been confirmed by numerous subsequent studies.[2-6] The method is adaptable to special techniques, such as photography where widebore photographic telescopes are used, and where the procedure is prolonged by teaching.[7] Since Sanders' original description there have been several modifications of the technique, described by various authors.[8-11]

The principle of the technique depends on the entrainment of air down an open bronchoscope. The technique is often erroneously called the 'Venturi system'.

When a high-speed jet emerges from the nozzle, as at point 'A' in Fig. 1, in air there exists a highly unstable region at the boundary between the jet and the stagnant air. This instability will cause the jet to become highly turbulent. Due to the turbulence, minute pockets of air will mix with the gas from the jet and carry this along with it. The jet will subsequently slow down and spread out radially at the same time. As more air is drawn in downstream and carried along with the jet, it will be replaced by air moving in radially towards the jet. The figure will give some idea of the change in velocity in a downstream direction as well as the spread of the jet. Although the average velocity would decrease from 'A' to

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'B', the momentum, which is proportional to the density of the gas, multiplied by the quantity of gas in the jet, multiplied by the velocity, would be the same as at 'A', this being due to the fact that a large amount of air has been entrained in the jet by the time it reaches point 'B'.
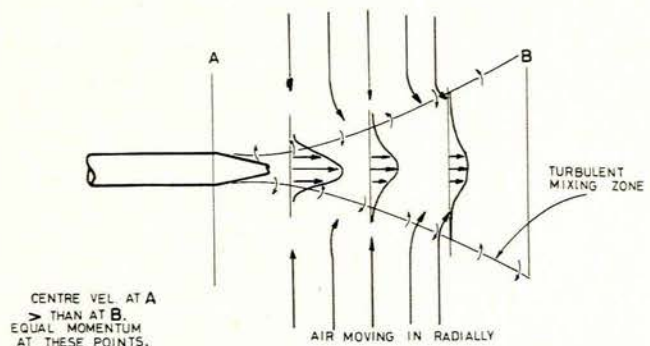

Fig. 1. Free jet emerging from a nozzle.

In the case of the bronchoscope, the jet is surrounded at a distance by the outer tube. This is shown diagrammatically in Fig. 2. The mechanism of entrainment is exactly the same as above, except that the air cannot move in radially from an infinite distance due to the presence of the outer tube of the bronchoscope. As a result, air is drawn from the upper opening of the tube roughly parallel to the jet. In this case there is no question of a Venturi effect. When the jet has expanded to the full diameter of the surrounding tube, entrainment is no longer possible and the proportions of the different gases will remain constant from point 'B' onwards.
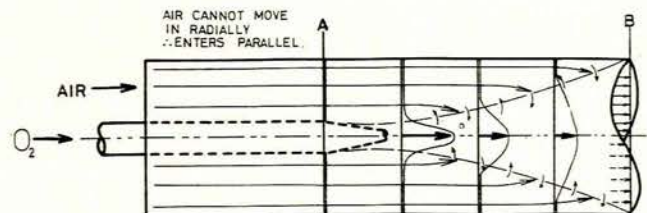

Fig. 2. Jet emerging from a nozzle surrounded by an outer tube.

The Venturi, which is an application of Bernoulli's principle, has found many applications in medicine and anaesthetics, and Marston in 1898 patented a device for administering chloroform by using a Venturi.[12] It is pre-

ferred to call this method of ventilation 'the oxygen injector technique'.

APPARATUS

The apparatus consists of a narrow-bore nozzle and in this particular study a 15-SWG Luer fitting injection needle was used. The point of the needle is cut off square and the needle mounted in a solid brass holder with a screw clamp (Fig. 3). The angle of the needle and the design of the clamp are such that it offers minimal interference to the view of the operator and it can be adapted to fit any open-ended bronchoscope, at either the distal viewing end or the side tube of the newer fibre-optic bronchoscopes, used to connect the conventional anaesthetic apparatus. With regard to the latter, the effect is just as efficient in spite of the oxygen and entrained air entering the bronchoscope obliquely.[7] This offers a further advantage to the operator to view without interference.
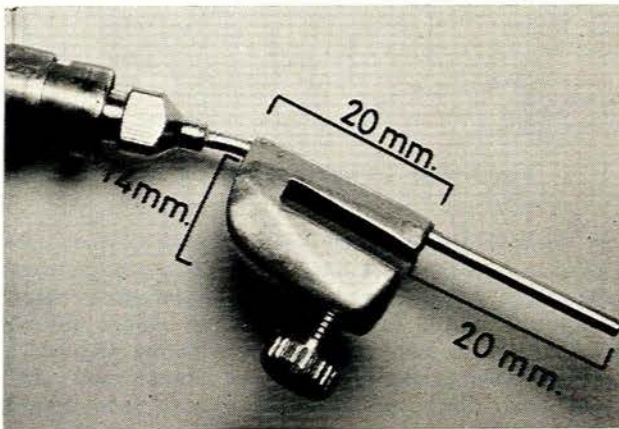

Fig. 3. Injector nozzle showing 15-SWG Luer fitting needle mounted in brass holder with screw clamp.

The injector nozzle is connected by a Luer connection to a suitable length of polythene pressure tubing attached to an on/off switch. This is a Schrader product such as is found at service stations and has an easy action and comfortable grip. The on/off switch is in turn connected via a length of pressure hose either directly to the theatre oxygen pipeline supply (414 kPa, 60 PSI), or to a reducing valve (Fig. 4.)

The apparatus is simple, cheap and takes up minimal space. It can be readily assembled or manufactured locally. Further improvement may be achieved by substituting the on/off switch by a Bird Mark 14 ventilator fitted with a flow accelerator, when ventilation is rendered automatic and the nozzle pressure can be varied[13] (Fig. 5). This has an advantage in that the anaesthetist has his hands free to administer increments of drugs and monitor the patient.
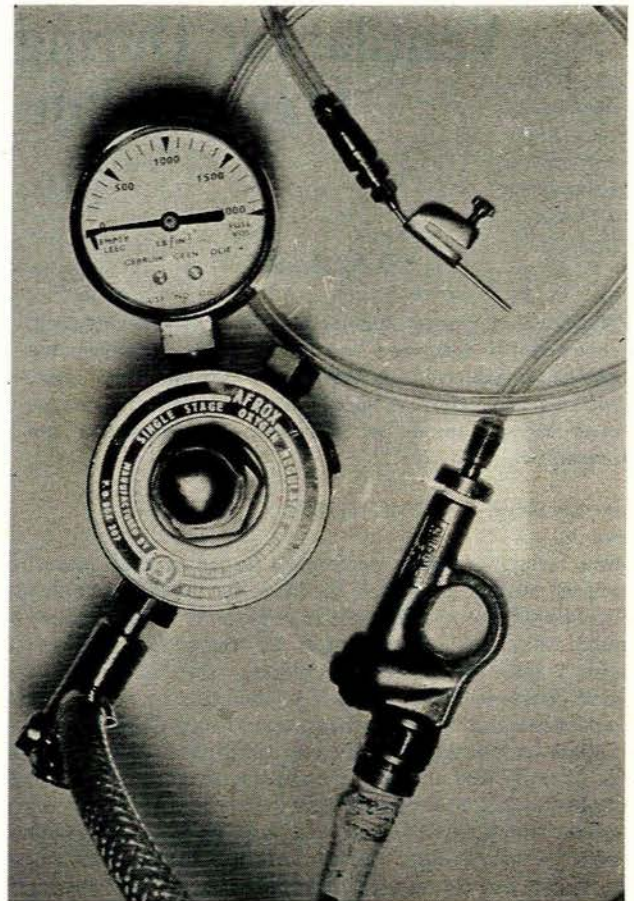

Fig. 4. Assembled circuit with injector nozzle, Schrader 'on/off' switch and reducing valve.

METHOD

The following short study was undertaken to demonstrate the effectiveness of Sanders' method of ventilation with the simple apparatus manufactured at Groote Schuur Hospital. Sixteen patients requiring diagnostic bronchoscopy under general anaesthesia, mainly for investigation and biopsy of bronchial carcinoma lesions, were studied. Their ages ranged from 22 to 81 years (mean age 55). Some had severe obstructive disease of the airways, either as their main problem, or as an associated finding.

Premedication for inpatients was atropine 0,6 mg and diazepam 10 mg given 1 hour pre-operatively, whereas outpatients received atropine 0,6 mg intravenously immediately before induction of anaesthesia. Induction of anaesthesia was by thiopentone 200 - 300 mg, followed by suxamethonium chloride 50 - 100 mg, after which the patients were hyperventilated with 100% oxygen by mask until fasciculation had ceased. The laryngeal inlet and trachea were sprayed with 2 - 4 ml of 4% lignocaine hydrochloride and the bronchoscope inserted by the operator. Further increments of thiopentone 25 - 50 mg and suxamethonium chloride 20 - 30 mg were given as required
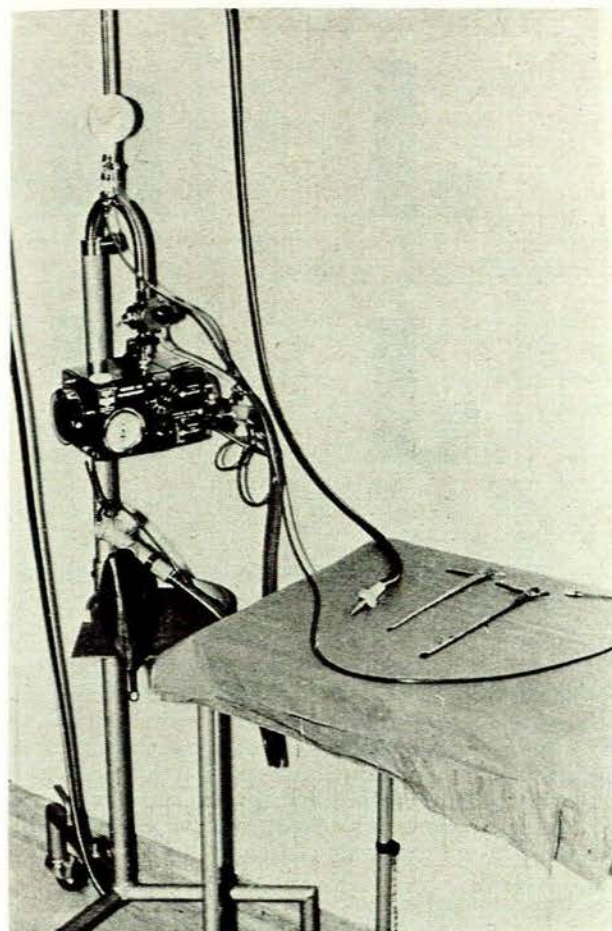
Fig. 5. Bird Mark 10 ventilator with attached flow accelerator connected to injector nozzle mounted on bronchoscope.

TABLE I. MEAN CHANGE IN ARTERIAL BLOOD GASES AT SOURCE PRESSURE OF 414 kPa (0 - 5 MIN) WITH PULMONARY VENTILATION

Patient	Age	Diagnosis	$\triangle$ p$_a$ O$_2$ (mmHg)	$\triangle$ p$_a$ CO$_2$ (mmHg)
1	46	Ca bronchus	+ 36	−12
2	42	Ca oesoph.	+ 40	−15
3	40	Lung abscess	+156	−13
4	50	Ca bronchus	+118	− 9
5	69	Ca bronchus	+187	−16
12	56	Chronic bronchitis	+174	+ 7
Mean	51		+119	−10

obvious that this was too effective, the remaining 10 patients were ventilated with a pressure of 276 kPa (40 PSI) at the injector nozzle (Table II). The injector nozzle size was kept constant at 15 swg.

TABLE II. MEAN CHANGE IN ARTERIAL BLOOD GASES AT SOURCE PRESSURE OF 276 kPa (0 - 5 MIN) WITH PULMONARY VENTILATION

Patient	Age	Diagnosis	$\triangle$ p$_a$ O$_2$ (mmHg)	$\triangle$ p$_a$ CO$_2$ (mmHg)
6	81	Rt pleural effusion	+ 95	− 9
7	60	Ca bronchus	+ 97	0
8	54	Ca bronchus	+ 57	− 2
9	43	Lung abscess	+ 90	− 2
10	73	Ca bronchus	+ 35	− 1
11	22	Kartagener's syndrome	+ 66	+ 3
13	74	Ca bronchus	+199	+ 4
14	68	Ca bronchus, pleural effusion	+ 58	− 5
15	55	Ca bronchus	+ 93	−14
16	40	Ca bronchus	+131	0
Mean	57		+103	− 3

during the procedure. The maximal dose of thiopentone required was 500 mg, and 125 mg of suxamethonium. When the bronchoscope was in the trachea the injector nozzle, already attached to the bronchoscope, was connected to the oxygen supply and ventilation commenced. Ventilation was controlled by the manual switch at the rate of 10 - 12 breaths/min, and the chest and abdomen bared to enable the depth of respiration to be observed. Pulse, blood pressure and colour were monitored during the procedure. When ventilation had been in progress for 5 min from the time of entering the trachea with the bronchoscope, arterial blood samples were collected anaerobically in heparinised syringes and immediately analysed for pO$_2$, pCO$_2$ and pH using a Radiometer BMS 3 blood gas system. If the bronchoscopic examination was completed before the end of the period of 5 min, the bronchoscope was left in the trachea till the 5-min period, determined by the protocol, was completed. Comparisons were then made with arterial blood gas samples collected immediately before induction of anaesthesia.

Of the 16 patients studied, 6 were ventilated using an oxygen source of 414 kPa (Table I), and when it became

When the driving pressure of 416 kPa was used, the system was connected directly to the theatre oxygen pipeline system, whereas when 276 kPa was used, a reducing valve set to 276 kPa was connected to an oxygen cylinder.

When the distal end of the bronchoscope with the attachments as used in the study, was connected to an aneroid manometer, pressures obtained with the switch kept in the open position, were as shown in Fig. 6. These therefore are the maximal possible pressures which can be produced by this system in the lungs. It has been shown that in practice airway pressures are lower.[7] With this system, oxygen concentration measured with a Servomex paramagnetic oxygen analyser from a 2-litre bag attached to the lower end of the bronchoscope, varied between 30% and 40%. All the examinations were done with an adult size Negus bronchoscope. With smaller bronchoscopes it should be borne in mind that pressures at the distal end of the instrument will be greater, using the same nozzle
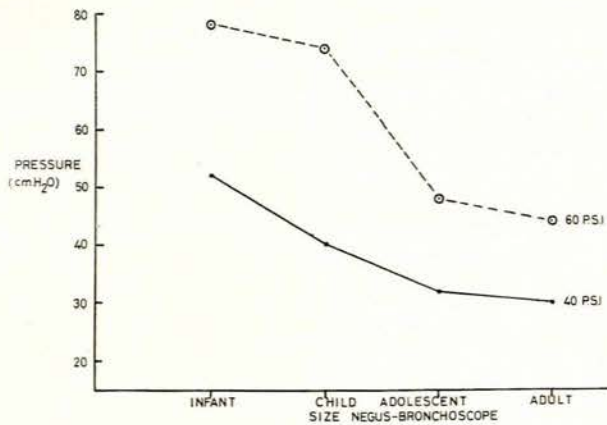
Fig. 6. Maximal pressures developed at 276 and 416 kPa respectively in bronchoscopes of different sizes using 15-SWG size nozzle.

Fig. 7. Mean blood gas analysis of ventilation with oxygen injector.

size and source pressure. As with other entrainment devices, as back pressure increases, the amount of entrainment decreases. Entrainment will also decrease—that is, there will be a higher oxygen concentration as the size of the injector nozzle increases, relative to the diameter of the bronchoscope.

RESULTS

The results confirm the findings of other investigators, that the method is effective and safe. It provides the operator with an undisturbed and clear field for viewing, removal of secretions by suction, and for taking specimens of suspect lesions for biopsy. The thoracic surgeons who normally perform the bronchoscopies at Groote Schuur Hospital have readily accepted the method. None of the patients studied developed any cardiac arrhythmias, neither were there any marked fluctuations in blood pressure. The patients were all awake within a few minutes of the end of the procedure, and able to cough and maintain an adequate airway without prolonged special care. In the case of the outpatients it was noted that in spite of intravenous atropine before induction, excessive secretions were invariably present at the end of the procedure. In view of this it is recommended that outpatients should also receive intramuscular atropine 0,6 mg 1 hour before induction.

All patients showed a marked improvement in oxygenation (Fig. 7). The 6 patients ventilated with a source pressure of 414 kPa had a mean age of 51 years, and showed a mean increase in arterial oxygen tension of 119 mmHg, while arterial carbon dioxide tension decreased by a mean of 10 mmHg. The 10 patients ventilated with a source pressure of 276 kPa (mean age 57 years), showed a mean increase in arterial oxygen tension of 102 mmHg and a mean decrease in carbon dioxide tension of 3 mmHg.

Three patients in the series showed a rise in arterial carbon dioxide tension. Patient 11 with Kartagener's syn-
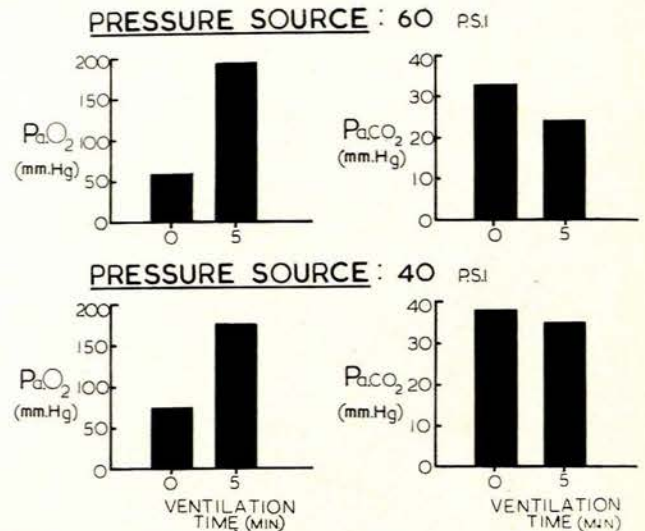
drome, patient 12 with stridor and chronic bronchitis, and patient 13 with a diagnosis of carcinoma of the bronchus, all showed marked improvement in arterial oxygen tensions, but it is suggested that when there is a severe airway obstruction, or in patients with reduced compliance due to 'stiff lungs', higher ventilating pressures should be used. Ventilating pressures may be altered by incorporating a variable reducing valve in the circuit.

CONCLUSION

In conclusion, the study confirms that the Sanders' oxygen injector technique of ventilation is the method of choice for bronchoscopy performed under general anaesthesia. It has definite advantages over the apnoeic diffusion or intermittent ventilation techniques where carbon dioxide tension rises at an average rate of 3 mm/min,[14] where viewing has to be interrupted periodical y, and where oxygenation is uncertain.

Advantages of Injector Technique

1. Blood gas tension studies show a marked improvement in oxygenation, and hypercarbia is prevented.

2. The operator has an unobstructed field, free of interference.

3. There is a rapid return of all reflex activity.

4. The system is cheap and easy to operate.

5. The system is readily adaptable to modifications and different patient or operator requirements.

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