Recent Improvements in Techniques for General Anesthesia for Bronchoscopy

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The bronchoscope is often used in the diagnosis of pulmonary diseases and there is no disagreement regarding the justification for this diagnostic procedure. Opinions are somewhat divided as to the best method of ensuring anesthesia with adequate ventilation and oxygenation during the procedure. The purpose of this article is to try to elucidate this problem and bring forward the most recent advances in techniques for general anesthesia for bronchoscopic procedures.

General Anesthesia for Rigid Bronchoscope

Techniques of ventilation used during general anesthesia have included, among others, the following: apnea with intermittent ventilation; insufflation of oxygen through a catheter with an apneic patient; general anesthesia with spontaneous respiration with the anesthetic gases delivered through the side arm of the bronchoscope; the use of curassé ventilator or external chest compression; the use of an endotracheal tube alongside the bronchoscope; the use of a ventilating bronchoscope. These techniques1 and variations of them until recently were the prime methods of ventilating patients during general anesthesia using the rigid bronchoscope. Anesthetic agents usually consisted of intravenous thiopental sodium (Pentothal) for hypnosis and intravenous succinylcholine for relaxation. When feasible, gases such as nitrous oxide with oxygen, halothane or even ether were used in addition. Usually arterial CO₂ levels were above normal and O₂ levels often fell below normal.

In 1967, Sanders² described a system** for ventilating patients during use of the rigid bronchoscope in which a 16 gauge needle was directed distally down the open proximal end of the bronchoscope to which it was attached. From the 16 gauge needle oxygen was jetted intermittently at pipeline pressure (60 lb per square inch) to cause ventilation of the patient’s lungs while the bronchoscope was in position (Fig 1, 2 and 3). With this technique of ventilation the usual anesthesia used was intravenous Pentothal for sleep and either a continuous succinylcholine drip or intermittent doses of succinylcholine to ensure relaxation. The apparatus was simple, inexpensive and could be used with existing bronchoscopes. Adequate ventilation could be obtained and the surgeon could work unobstructed by eye pieces (which are used with the ventilating bronchoscope) while the patient was being ventilated. It was this procedure which sparked a great step forward in improved anesthesia for bronchoscopy. However, there were certain drawbacks to this anesthetic technique. Even though reasonably good ventilation was accomplished and arterial CO₂ levels were kept below 40 mm Hg in patients with compliant chests, in those patients in whom the chests were not compliant (pulmonary collapse, emphysema, etc) inadequate ventilation was obtained and arterial CO₂ levels would climb above normal.³ Secondly, during the bronchoscopic procedure, arterial oxygen tension would fall progressively, often below 100 mm Hg.³

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Figure 1. A schematic representation of the Sanders Venturi ventilation system showing from right to left: oxygen at 50 psi entering an adjustable reducing valve, passing from there through a manually operated flow controller, and thence coming out of the jet into the bronchoscope causing entrainment of air.
particularly in patients in whom the pulmonary compliance was below normal. It is, of course, these patients in whom adequate oxygenation is most important since they also often have other complicating diseases. The physical data found when testing a system of this sort was as follows: as the oxygen was jetted from the 16 gauge needle, room air would be entrained and a mixture of oxygen and air would then proceed down the bronchoscope for inflation of the patient's lungs. It was found with a 7 mm bronchoscope and pipeline pressure at 50 lb per square inch, the actual pressure delivered to the patient's lungs was estimated to be approximately 12.5 cm of water.\(^4\) Reference to physics tells us that if the size of the jet is increased, the flow from the jet will increase. The flow rate of the gas from the end of the bronchoscope together with the pressure developed will increase and the amount of air entrainment will diminish.

It became obvious, therefore, that in order to improve ventilation during bronchoscopic procedures, larger jets must be used, and three variations of the Sanders technique have become available. One technique (Carden, Trapp and Oulton\(^5\)) described the use of the small side arm (originally intended for insufflating oxygen on some of the

Figure 2. Two adapters for jet ventilation designed to fit onto two different types of bronchoscopes.

Figure 3. A Sanders Venturi ventilation system complete showing from left to right: a bronchoscope with adapter (see Fig 2) in place, tubing running to the manual flow controller, tubing connecting this to an adjustable pressure reducing valve, tubing and adapter to connect to pipeline oxygen.
bronchoscopes) as the jet. The side arm had an internal diameter of approximately one-tenth of an inch. When utilizing this side arm as the jet rather than a 16 gauge needle, virtually no air entrainment occurred and 100 percent oxygen was delivered to the patient; also less than 50 psi pressure could be used. Studies also showed that pressure in the lungs was much higher than with the Sanders technique and adequate ventilation could easily be obtained together with high arterial oxygen tensions. A further modification of this technique entailed the use of a nitrous oxide oxygen blender, and mixtures of nitrous oxide and oxygen were then delivered to the patient through the side arm with this system allowing balanced anesthesia to be delivered (i.e., the use of supplemental narcotics together with the nitrous oxide rather than having to use intermittent doses of Thiopental). This means that the patient takes a much shorter time to recover from the anesthesia. Another variation of this system was designed by Komersaroff in Australia (the Bronchoflator system) and utilized an 11 gauge jet as the jetting system placed into the bronchoscope from which oxygen was intermittently jetted. This enabled positive pressure ventilation to be accomplished very adequately with high oxygen tensions and low CO₂ levels when desired. A similar system was then devised by Carden in the United States utilizing a 12-gauge jet mounted in a manner similar to the Sanders system and this system is available in the United States at this time. With this system, virtually no air entrainment occurs. High arterial oxygen tensions are available together with subnormal CO₂ levels if required.

**General Anesthesia for Bronchofiberoscopic Procedures**

In 1968, Ikeda described a flexible bronchoscope (bronchofibroscope) for the early diagnosis of peripherally located endobronchial neoplasms. It had an outer diameter of approximately 5 mm and the length was approximately 60 cm. It has enabled bronchoscopy and examination of the bronchial tree to be carried out much more easily than with a rigid bronchoscope. The flexibility of this instrument has been distal parts of the lungs to be examined that could not be examined with a rigid bronchoscope and its use in many centers has supplanted a rigid bronchoscope; however, it has not made the rigid bronchoscope obsolete by any means. There is a place for both bronchoscopes.

General anesthesia for examination with the bronchofibroscope, however, has created some problems. The primary problem is adequate ventilation during the procedure. The most common anesthetic technique consists of intravenous induction followed by intubation using succinylcholine, then insertion of the bronchofiberscope via the endotracheal tube while anesthetic gases are delivered to the patient through the same tube. It is best to keep the patient paralyzed during the course of the procedure. The patient, therefore, must be ventilated with nitrous oxide-oxygen mixture and preferably a small amount of halothane. However, the resistance to flow increases markedly with the bronchofibero-

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**Figure 4.** Standard (above) and a special low resistance endotracheal tube (below) with special adapters for fiberoptic bronchoscopic procedure. The adapters are shown unattached with the plug out above and attached to the tube with plug in place below.
scope in the endotracheal tube and it has been found that when a 5 mm bronchofiberscope is being used through an 8 mm endotracheal tube, the resistance to flow of gas becomes unavoidably and dangerously high so that inadequate ventilation occurs together with hypercarbia and possibly hypoxia. In order to minimize this problem, anesthesiologists try to use the largest possible endotracheal tube or they utilize a special endotracheal tube and connector designed to minimize the resistance to flow. This tube has a wide upper section of 11 mm internal diameter and a narrow lower section only in the area which goes through the vocal cords (Fig 4 and 5). It has been shown that the resistance to flow of gas through this tube with the bronchofiberscope in place in an 8 mm version of this tube is lower than when the bronchofiberscope is inside a 9.5 mm standard endotracheal tube. This enables the bronchofiberscope to be used in anyone who can tolerate a 7.5 mm endotracheal tube.

In order to maintain adequate ventilation, it is important that a tight seal be maintained around the bronchofiberscope at the point of insertion into the endotracheal tube. To do this a swiveling adapter was designed (Fig 5). It has a diaphragm with a hole which can be plugged when the bronchofiberscope is not in place. When the plug is removed, the bronchofiberscope can be inserted through the hole in the diaphragm and the diaphragm will seal against it allowing positive pressure ventilation to be accomplished without leaking of gas. Other similar adapters are also available which function in a similar manner.

DISCUSSION

The major advance in ventilation techniques during procedures with the rigid bronchoscope is the use of jet ventilation. It has seen various improvements since its inception in 1967 which shorten recovery time and improve ventilation and arterial oxygen tensions.

The problems of adequate ventilation during fiberoptic bronchoscopy have been partially solved by the introduction of a special low resistance to flow endotracheal tube and adapters to improve ventilation and to seal the airway when the bronchoscope is inserted into the endotracheal tube.

REFERENCES

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