THE INTRATRACHEAL INSUFFLATION OF ETHER.*

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THE method described by Meltzer and Auer[1] in 1909 as "continuous respiration without respiratory movements" has found much favour in the United States since its introduction into the practice of surgery by Elsberg. In this country interest has been gradually aroused, and more attention is being given to a method which is destined to claim an increasingly large share in the practice of anaesthesia. It differs from all other methods in that it combines a system of artificial respiration, a system of anaesthesia, and the means whereby positive pressure can be obtained in intrathoracic surgery. It differs also from inhalation methods by reason of the fact that the respiratory mechanism is not called upon to carry out the function of respiration, and at the same time to perform the fatiguing work of introducing the anaesthetic into the blood stream. Moreover, it can be shown that a minimum amount of the anaesthetic is administered, that this remains constant, being uninfluenced by respiratory changes and by the obstructive accidents which frequently complicate anaesthesia, and that the anaesthetic can be almost completely eliminated at the close of the administration.

PRINCIPLES.

A continuous stream of warmed and moistened air is introduced at the bifurcation of the trachea by means of a catheter which has been passed through the larynx from the mouth. The catheter is of sufficient size to fill about one-half of the glottis. The air returns between the catheter and the wall of the trachea, and issues from the upper air passages. The volume of air (reduced several times a minute) is under pressure, and is ample to fulfil the function of respiration in the absence of respiratory movements. The explanation is simple. The real respiration is an exchange of gases between the tidal and alveolar air by diffusion. The movements of respiration only change the air in the trachea and larger bronchi. By cutting out the greatest part of the dead space, that is, the space between the atmospheric air and the alveoli, and by supplying a stream of air under pressure at the bifurcation, a rapid diffusion of gases within the bronchi results. Oxygen is taken up by the air cells; carbon dioxide is given up. In an animal under curare, with the thorax widely open, "the lungs are found more or less distended, of pink colour, and completely quiet, while the heart is beating efficiently and regularly."

Resuscitation of animals poisoned by strychnine and other drugs has been accomplished, and cases are already on record of patients being successfully rescued from morphine poisoning. In tetanus and in diseases which paralyse the respiratory muscles the method must prove invaluable in the future. Meltzer, Crile, Carrel, and others have done many remarkable operations on the lungs, heart, great vessels, and oesophagus; intratracheal insufflation will probably replace the positive and negative pressure cabinets now used for intrathoracic surgery.

GENERAL ANAESTHESIA.

For the purposes of anaesthesia, the air current is made to pass either wholly or in part through or over ether. This is the simplest and safest form of ether administration, for it is under accurate control and combined with artificial respiration. The respiratory centre is kept active, and the movements of respiration still continue, but they are very slight, and have little if any influence upon the aëration of the lungs. In the human subject a state of apnoea can be obtained in which for some time blood pressure and circulation remain satisfactory, but this state is neither necessary nor is it desirable. If the ether administration is pushed in an animal beyond the stage of surgical anaesthesia, respiration gradually disappears and the respiratory centre succumbs. Blood pressure begins to fall slowly, but the pulse does not begin to fail until the pressure has become dangerously low. The vasomotor centre and the cardio-vascular system offer a stronger resistance than the respiratory centre. At this stage danger is imminent, but a decrease in the strength of the ether vapour or the substitution of air rapidly restores blood pressure and pulse. The safety of the method when a toxic dose is given is thus apparent. Failure of respiration is not in itself alarming, as the insufflation well supplies the deficiency, but it is a signal that the safety zone has been passed and the danger zone reached. Deep narcosis of this extent is very seldom used; indeed, I have only once found it necessary to abolish respiration and slow the pulse to an extreme degree in the attempt to obtain complete abdominal relaxation.

On the other hand, excessive ventilation must be avoided, for the work of the physiologists on the value of carbon dioxide has taught us the risk of severe shock arising under the circumstances. With a view to determining the ventilation used in actual practice, and the character of the gaseous interchange, Dr. Pembrey and I are making some investigations. Some interesting results have been obtained, and a full report will appear later.

I have published elsewhere[3] an appreciation of this method. In this paper I propose to give my impressions derived from a study of 208 cases.

ADVANTAGES OF THE METHOD.

1. A free airway is obtained. It is one of the most valuable features of this method that obstruction arising from spasm or congestion in the upper air passages is abolished. Cyanosis is absent, and a sufficient supply of air is uniformly presented to the patient. For these reasons intratracheal insufflation is invaluable in any case in which the surgical procedure may interfere in any way with respiration. This large class includes, for example, operations on the thyroid and neck, the face, the head, especially cerebellar cases in which failure of respiration may occur, and large abdominal tumours causing dyspnoea. It is in cases of goitre, especially when obstruction is present, that so convincing a demonstration of the superiority of the method over all others can be given. All anxiety is removed—a smooth, calm, safe anaesthesia is obtained. I have reported[2] a case of thyroid tumour causing severe stridor, in which the use of this method converted a difficult and dangerous operation into one of ease and safety. Several other cases of a similar kind have been met with. The change from the picture frequently seen with other methods of obstructed embarrassed breathing, cyanosis, and rapid pulse, to a state in which the patient appears to be sleeping calmly, with perfect colour and good circulation, and quiet, almost suspended respiration, is indeed remarkable. The difficulties of anaesthesia in patients lying in an awkward position—for example, in renal and spinal operations—are easily overcome. The same remark applies to the anaesthetization of thick-necked muscular and alcoholic subjects.

2. Even and constant administration of a weak, warm vapour, which is under control and can be accurately regulated. The result of this uniformity is that anaesthesia can be kept unusually light.

3. The anaesthetist is out of the way of the surgeon, and the field of operation can be kept sterile.

4. The recurrent air stream creates a strong upward draught at the glottis, which effectually prevents the aspiration of blood, mucus, vomit, or infective material. Moreover, the modified respiratory act constitutes a second line of defence, for inspiration is short and expiration comparatively long. For operations on the mouth and pharynx, and in cases where bleeding may occur into the air passages, the method is ideal. The surgeon has a clear field, without anxiety about the anaesthesia, oxygenation is complete, and blood, etc., can be removed at leisure; after-vomiting is rare, and aspiration pneumonia does not occur. Shock is, for reasons to be given later, diminished, so that carcinoma operations can be undertaken in one stage. Cases of intestinal obstruction with vomiting present no dangers from aspiration of stercoraceous material. Meltzer's experiments have conclusively proved this.

5. Operations on the abdomen, especially above the umbilicus, are facilitated by the slight character of the respiratory movements, and by the absence of reflex phenomena caused by traction upon or examination of the

*Founded upon a paper read before the Bristol Medico-Chirurgical Society, preceded by a demonstration of the method at the Bristol General Hospital.

viscera. There is also great flexibility; anaesthesia can be rapidly deepened or lightened.

6. Operations which may involve the accidental opening of the pleura—for example, caries of sternum or rib, or recurrent mammary carcinoma—can be done without risk or anxiety.

7. Shock is diminished. One of the earliest impressions formed by the sisters and surgeons at Guy's Hospital who had charge of these cases was that they made an excellent recovery from severe operations, with rapid return to consciousness, little or no vomiting, and very little depression. I had also been struck with the slight degree of shock during the anaesthetization of patients for such operations as the abdomino-perineal excision of the rectum, extensive removal of ribs, and gastrectomy; and I have been forced to the conclusion from observation, not of isolated instances but of a considerable number of cases, that intratracheal insufflation combined where possible with the subcutaneous infusion of saline solution, offers the best chance of recovery to feeble and exhausted patients and for critical conditions in general, whether due to sepsis, haemorrhage, trauma, or cardiac disease. I think that the advantages of insufflation in the last class outweigh the objections put forward by some anaesthetists to the use of ether on the ground that its stimulating effect is followed by cardiac depression. Each case must, of course, be judged on its merits, but there are ample reasons for the claim that no other method of anaesthesia can place the patient in such a favourable condition to husband his slender resources. The absence of cyanosis and of impeded respiration, the constant supply of air, the even delivery of a weak vapour, the uniformity of the anaesthesia—these are the all-important factors in general anaesthesia, and when combined with a system which mechanically "breathes" the patient must help to relieve circulation and respiration of much strain. Another point presents itself. There is a notable absence of exhausting reflexes under light anaesthesia: patients lie placid, and seem to resent surgical stimuli less than with other methods.

Cases.

Face, head, and neck, 47, including parotid tumours, skin-grafting, mastoid, cerebral and cerebellar operations; thyroidectomy 10; oesophagoscopy; removal of glands in the neck 8; frontal sinus 3; exostosis of upper jaw, enucleation of tonsils, submucous resection of septum, excision of growth of laryngeal cords, examination and removal of portions of growth in the air passages. In two of these the catheter was inserted through a tracheotomy wound made for the purpose. One of the thyroid operations was for an advanced case of Graves's disease, in which the technique of Crile was successfully carried out.

There have been 23 cases of epithelioma of lip, floor of mouth, tongue, tonsil, and soft palate; in all but 3 glands were removed at the same time. The longest administration lasted one hour and fifty minutes. Ages ranged from 30 to 71; of 9 tongue cases the average age was 62, the tenth patient being a man of 30 years. There have been 4 cases of epithelioma of the lip, with an average of 64 years, and 4 of growth of the floor of the mouth, average age 51.

Abdomen 94; gastro-jejunostomy 12; gastrectomy, exploratory above the umbilicus, 15; appendectomy 20; colectomy 3; nephrectomy or exploration 10; herniae 13; cholecystotomy and cholecystectomy 5; abdomino-perineal excision of rectum, ovariotomy, etc. There were 2 cases of prostatectomy in patients aged 72 and 78.

Thorax 11; amputation of breast, resection of ribs, empyema.

Limbs 21; plating fractures, amputations, cartilage of knee, etc.

Genito-urinary organs and *anus* 10.

The youngest patient was 10 years old, the oldest 78. The longest administration lasted one hour and fifty minutes in a case of resection of intestinal growth and lateral anastomosis.

Technique.

Preparation and Induction.—Most of the patients have been given an injection of morphine and atropine, sometimes combined with scopolamine; atropine has always been used. Induction is usually carried out with chloroform-ether or gas and ether.

The catheter should be smooth and flexible with comparatively thin walls, and one lateral opening. Silk-woven catheters have generally been used, passed on a stilette, as they are not sufficiently rigid to be introduced alone. For this reason Mayer and Meltzer have lately made for me linen-woven catheters; they are more rigid and have proved very satisfactory. Catheters are best sterilized by keeping them in formalin vapour for at least four days. A mark must be placed on them at 26 cm. from the tip; this is the average distance in men from the bifurcation to the incisor teeth. In women and children the distances are respectively 23 cm. and 17 cm. The size of the catheter varies but slightly in different individuals, and a little experience will soon guide the anaesthetist in his choice. It may be said that 23 F is the best size for men, and 22 F for women. In girls and youths 20 F to 21 F will be found satisfactory. The catheter must bear such a relation to the lumen of the larynx that too much of the ether does not escape to prevent anaesthesia being obtained, and that the elimination of carbon dioxide is not hindered. If the correct size is used, a deep anaesthesia can be obtained in which the cords are widely abducted and the exit of carbon dioxide is free. Cyanosis and slow, distressed expiration, follow the continued use of too large a size, and one smaller must be promptly substituted. We may say, then, that for muscular and alcoholic subjects, and for operations on sensitive structures, the sizes mentioned above are not usually suitable: 24 F in men, 23 F in women should be chosen. In extreme types I have used 25 F. In cases of goitre with marked obstruction Kelly* has pointed out the advisability of using a smaller catheter than in normal subjects.

In buying catheters it is necessary to check the gauge, for the maker's numbers are frequently incorrect.

Introduction of the Catheter.—Of the two methods of introduction, the direct and the indirect, the former is undoubtedly the better. The advantages are that it is certain, the cords are plainly visible, and the catheter can be inserted without damage to them and without contamination by the mouth and pharynx. I use a modification of Hill's direct laryngoscope. The passing of this instrument is the real difficulty to the beginner, but I venture to think that a careful attention to detail and a little practice will remove most of his troubles. My plan is to paint the pharynx and entrance to the larynx with 5 per cent. solution of cocaine during induction as soon as consciousness is lost, and then to carry the induction to the stage at which the jaw muscles are relaxed and the corneal reflex is becoming dull. If cocaine has not been used deep anaesthesia is absolutely essential, and even then in difficult subjects troublesome reflexes may arise which make catheterization far from an easy procedure. The laryngoscope is passed at the angle of the mouth, not by the mid-line route, and it is seldom necessary to alter the position of the patient's head, although in some cases slight lowering is advantageous. From the start of induction to the insertion of the catheter not more than ten minutes elapse. Care must be taken to avoid injury to the teeth, to pass the catheter gently and without damaging the trachea, and to keep the lateral opening uppermost, so that ether vapour may not be in too close contact with the mucous membrane. It is, of course, very important not to insert the catheter further than the appropriate distance, so that the pressure may be evenly distributed over both lungs.

If anaesthesia has not been deep, or the patient has partly come round, spasm and cough immediately ensue. The gag is kept in, the tubing from the apparatus connected up, ether at "half" turned on, and the motor, which has been running slowly from the beginning of induction to warm up the tubes, is slightly accelerated. Pressure should be kept low at first and the air current broken two or three times by opening the tap provided for that purpose, in order to prevent an undesirable strain being placed upon the lungs. If spasm and cough are unduly prolonged, an increase in the ether vapour to "three-quarters" or "full," or a slight withdrawal of the catheter, will quickly produce calm anaesthesia.

This state is characterized by a healthy pink colour, firm full pulse, muscular relaxation, fixed globes, and shallow, almost inaudible respiration. A constant stream of air issues from the mouth, and weak expiratory efforts alternate with faint inspirations. It is hardly necessary to point out that the higher the level of the ether in the ether chamber, the stronger the vapour.

Subsequent Conduct of the Anaesthesia.—The anaesthetist must regulate the percentage of ether vapour and the pressure in accordance with the necessities of the case, and in consonance with the principles previously enunciated, remembering that anaesthesia can be kept unusually light, and that a rapid increase or decrease in

the depth is at his command. I think the wisest course is to keep respiration present, avoiding on the one hand its complete absence and on the other such an amount of respiratory movement as to defeat the aims of insufflation. Pressure should be kept below 25 mm. Hg; above this the safety valve should blow off. In feeble and in emphysematous patients, or in operations on the chest where one lung is disabled, pressure must be kept proportionately low. The anaesthetist must take care that compression of the trachea during thyroidectomy or the forcing back of the tongue or lower jaw in mouth operations, or flexion of the head in the prone position, does not interfere with the free return of air. Reductions in the air stream are made a few times a minute to allow the great veins of the thorax to fill and the slight collapse of the lungs to drive out any excess of carbon dioxide. Towards the end of the administration, less ether can be given, and finally pure air alone is driven into the lungs. Normal breathing is resumed almost immediately after the catheter is withdrawn, and the return to consciousness is very rapid.

After-results and Complications.

Time does not allow me to enter fully into this subject, which has received adequate attention elsewhere. Briefly it may be said that vomiting is very infrequent. A boy of 11 after an hour's operation for glands of the neck did not vomit at all. It has been noticed that patients who have previously had anaesthetics have made a much more comfortable recovery, without nausea or sickness. I have not met with severe vomiting; kidney cases have been conspicuously free from this complication. The same may be said of the mouth cases, in which blood cannot enter the stomach during operation.

Pharyngitis is liable to occur in the early period of the anaesthetist's practice from unskilful handling of the laryngoscope.

Laryngitis occurred once, and was of a mild degree. A very small number of patients, chiefly women, have complained, on being questioned, of some discomfort; it passes off in a few hours.

Bronchitis, Pneumonia.—Figures from nearly 2,000 cases show that the least that can be said of the method is that post-operative pulmonary sequelae are not more common than after other methods. Indeed, there is reason to believe that their frequency is less. Peck[4] found that in 216 cases no post-operative pneumonia occurred, while during the same period he had five other pneumonias following other methods of anaesthesia. In the busy routine of a large general hospital, many cases of lung sequelae pass almost unrecorded; their number is certainly fairly high. Complications due to, or occurring after, new methods receive a larger share of attention. This is but right, but makes a true comparison difficult. We have now, however, the figures from the Mayo Clinic for the year 1912,[5] which show 89 cases of post-operative pulmonary lesions in 5,835 operations. Ether was the anaesthetic most used; the lesions followed almost entirely operations in which the peritoneum was handled, renal operations, and thyroidectomy. Of abdominal operations, as is to be expected, a large number were above the umbilicus. This is my experience with intratracheal insufflation. An atypical case of Graves's disease with some bronchial catarrh at the time of operation had an exacerbation which quickly passed off. There was one case of bronchopneumonia of a mild type following gastrostomy in a man with carcinoma of the oesophagus, and two of bronchitis after gastro-jejunostomy, the symptoms in one being subacute. I had at that time substituted a motor and pump for the foot-bellows, and have no doubt that the absence of a suitable air filter and wash-bottle to cleanse the air of oil and saturate it with moisture was partly responsible for these complications. They have not recurred.

Meltzer and Githens have shown that the insufflation of ether for one hour every day for ten days in dogs already suffering from lobar pneumonia produces no harmful result. An interesting case occurred in my series which enforces this lesson. A young man was admitted to the hospital late one afternoon with acute abdominal symptoms. Nothing abnormal was found in the chest, and although the case was not considered in every way typical of perforation, exploratory laparotomy was advised in view of the urgency of the symptoms. All the viscera were healthy, and the abdomen was closed. The same night early left basal pneumonia was diagnosed. The disease ran a mild course, and the patient was sent to a convalescent home on the eleventh day.

Disadvantages.

After a careful inquiry into the after-condition of each patient, and without being, I hope, unduly enthusiastic, I feel that the objections to this method are three in number:

1. The apparatus is costly.
2. The apparatus is somewhat cumbersome and the outfit elaborate. Much simplification is possible if foot-bellows are used, and the cost is considerably reduced, but I think that the continuous mechanical ventilation by the motor and pump is more efficient. Good specimens of these are not noisy.
3. The introduction of the catheter is the stumbling-block which at present stands most in the way. Each anaesthetist must decide for himself whether he will learn a new method and adopt a new technique, or be content to dispense with the most valuable addition to his weapons and the most notable advance in anaesthesia made for many years.

There has been such a considerable amount of evidence collected, the method has been so thoroughly tested, and the comments by onlookers on the type of anaesthesia, its advantages, and the freedom from post-operative distress have been so uniformly favourable, that intratracheal insufflation may be said completely to have made good its claims and definitely to have established its value.

The ether apparatus is made for me by the Surgical Manufacturing Company, Mortimer Street, W.

References.
[1] *Journ. Exp. Med.*, 1909, xi, 622. [2] Loc. cit. [3] *Brit. Journ. Surg.*, 1913, i, 94. [4] *Ann. Surg.*, July, 1912, 192. [5] *Ann. Surg.*, May, 1913, 718.

A CASE OF A RUPTURED ANEURYSM OF THE DESCENDING AORTA.

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The following case is interesting in view of the fact that (1) the man had not complained of any previous symptoms; (2) for years he had been doing severe muscular work without any inconvenience.

J. H. E., aged 54, a rail-straightener, formerly in the Royal Artillery; had never been ill in his life except for accidents. His wife states that he sometimes complained of pain in his chest, which he called a chill.

At 8.30 p.m. on November 2nd, whilst in a public bar, he was suddenly seized with acute pain in the pit of the stomach which caused him to fall to the ground and doubled him up and made him shout. The pain radiated round the right side and up between the shoulders; it made him catch his breath, but there was no shivering. He was taken home, and was seen by Dr. Weeks at 9.25 p.m. He was then walking about the room, groaning and holding his breath. His face was cyanosed and had an anxious expression. He stated that he felt as though there was something closing round the bottom of his oesophagus. He tried to retch, but there was no vomiting during the whole of the illness. The pulse was 100, regular and equal on both sides; the volume was rather poor; there was no thickening of the arteries.

The first sound of the heart at the apex was weak, and was followed by a faint systolic murmur. The second sound was absent both at the apex and over the aorta. Breath sounds were heard all over the lungs, but were diminished, owing to his restricting respiration. There was neither dullness nor friction. There was no rigidity of the recti muscles, but there was pain on deep palpation just below the xiphisternum. The liver dullness was present and the liver was enlarged.

The patient became somewhat easier and went to bed.