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ENDOTRACHEAL NITROUS OXIDE-OXYGEN-ETHER ANAESTHESIA IN NEUROLOGICAL SURGERY

A

DISSERTATION ON

"ENDO-TRACHEAL NITROUS OXIDE-OXYGEN-ETHER

ANAESTHESIA IN NEUROLOGICAL SURGERY."

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INTRODUCTION.

The development of Neuro-Surgery has raised many difficult problems for the anæsthetist to solve, and no method has as yet been evolved which can be regarded as ideal. When Cushing and his followers showed that deliberate and careful operations, which might last up to ten hours, yielded better results than the more rapid operations, a long search was begun on the part of surgeons and anæsthetists for a method of anæsthesia which was both safe and satisfactory over such periods of time.

It is the aim of this Thesis to summarise briefly the various methods of anæsthesia to which this search has given rise, and then to pass to a detailed consideration of the method of endo-tracheal nitrous oxide-oxygen-Ether. This method has been in use for some years at the London Hospital for many of the cases of Mr. Hugh Cairns, and has been found satisfactory. During 1933 it was part of my duties as Senior Resident Anæsthetist to this Hospital, to administer the majority of these anæsthetics. Only two papers have been published which give the summarised results of a series of cases whose condition has been carefully observed throughout the operation by means of charted readings of the pulse-rate, blood-pressure, and respiration rate. Of these only one

deals with endo-tracheal nitrous oxide-oxygen anæsthetics. The later part of this Thesis will consist of a comparison between our results and those quoted in these two papers.

The forty-one cases under general anæsthesia, the fourteen cases under basal anæsthesia, and the five cases under local anæsthesia constitute the bulk of my personal experience of these cases. Certain cases have not been included: those whose records were incomplete, those operated on since the end of 1933, and the cases of exploration for brain abscess performed either by the Aural Department or by the Neuro-Surgical Department in which the condition was not accurately observed and charted.

ALTERNATIVE METHODS OF ANAESTHESIA.

I propose first to summarise the merits and demerits of the alternative methods of anæsthesia to Nitrous oxide-oxygen-Ether. These methods may be divided into five groups:-

1. General Anæsthesia, by means of Chloroform or Ether.
2. Local Anæsthesia - with or without basal narcosis.
3. Local Anæsthesia "controlled" by general anæsthesia.
4. Rectal Ether or Paraldehyde - often "controlled" by general anæsthesia.
5. Avertin - sometimes requiring supplementary general anæsthesia.

General Anæsthesia was widely used in the early days of intra-cranial surgery. Chloroform was the routine anæsthetic for Horsley's cases[13], but its advantages in the way of reducing hæmorrhage were more than outweighed by the ever-present danger of overdosage or toxic after-effects. The danger of toxic after-effects if Chloroform is administered for periods of five hours is sufficiently great, we feel, to form an absolute contra-indication to its use for such cases.

Ether, especially when administered by endo-tracheal methods, has furnished good results in the hands of Mennell [5; 13] and Gilbert Brown[1; 2], and is still in use at the Mayo Clinic (personal communication from R.M. Tovell).

It was extensively used in Cushing's work, and in Norman Dott's early cases[18]. It provides satisfactory anæsthesia for operations which do not exceed three hours in duration, but its use is open to several objections; it produces swelling of the brain, thus increasing hæmorrhage, and gives rise to objectionable after-effects, such as vomiting and occasional lung complications. Whenever the use of the Diathermal current is contemplated, the administration of Ether is contra-indicated because of the risk of an explosion.

Local Anæsthesia for Cerebral surgery was first suggested by Bier in 1912, and in the next year Th. de Martel[50] adopted the method as his routine and has used it ever since. It was used as his routine anæsthetic by Cushing for many years, and has been extensively used in various American Clinics, in Edinburgh, in London and in Scandinavia. Dowman[20], Olivecrona[10], Elsberg[11], Bailey[24], and Sachs[30] have all published work which states the case for local anæsthesia very fairly. It provokes less disturbance of the patient's general condition than any other anæsthetic, and gives rise to fewer after-effects; and it provides almost ideal conditions of work for the surgeon. Local anæsthesia is, however, unsatisfactory for Laminectomy operations: and since its effect wears off after about three hours, further solution usually has to be injected during a

Cerebral operation, a process which is somewhat painful and disturbing to the patient. Its greatest drawback is that the method involves dealing with a conscious patient, who often becomes restless and sometimes uncontrollable. This restlessness may be so marked as to make conditions of work impossible for the surgeon, and it tends to exhaust the patient. Even if the actual analgesia is perfect, the strain on the patient of remaining conscious during a five-hour cerebral exploration is very great, and is an ordeal to which they should not be subjected unless absolutely necessary. To some extent this can be mitigated by the administration of Morphia or Omnopon, but the majority of surgeons consider that the depressant action of these substances on vital centres probably already impaired by raised intra-cranial pressure, is dangerous. The various barbiturates can also be used, but they are uncertain in effect, depressant to the vital centres, and antagonistic in their pharmacological action to Novocaine(14).

Five cases operated upon with local anæsthesia of which I have records, illustrate these points well, and their Charts are therefore annexed as Appendix I. Chart 1 shows the course of a successful case, in which an acoustic tumour was removed with little disturbance of the patient's condition. She was quiet and calm throughout, having been given Morphia gr. 1/4th beforehand, and the conditions of

work were ideal for the surgeons. Chart 2 is the record of a man, apparently phlegmatic in temperament, from whom a right parietal meningioma was successfully removed in the sitting position. He had only had Morphia gr. 1/6th beforehand; and the striking features of his chart are the wide fluctuations of his blood-pressure. These began just when the bone flap was reflected, when severe bleeding had been encountered, and the patient was complaining of a feeling of faintness. Fairly severe hæmorrhage was again occasioned by the removal of the tumour, but a blood transfusion was given, and the patient made an uncomplicated recovery. These wide fluctuations in blood-pressure may have been due to the relative anæmia of the vasomotor centre occasioned by the erect position. If so, they were probably accentuated by the emotional strain on the man himself, who, although he exhibited great self-control, was in a state of terror during the operation. The fluctuations of blood-pressure shown by this record are greater and more frequent than in any of the cases operated upon under a gaseous anæsthetic.

Charts 3, 4, and 5 are included merely for comparison with the Charts in Appendix III, as "controls" to the effect of local anæsthesia after the induction of general or basal anæsthesia. In two of these cases the patient was comatose, and the operation uneventful. The effects of the injection

of Novocaine-Adrenaline on the patient's general condition are commented upon in a later section.

Local anæsthesia, then, is indicated in cases which are regarded as poor surgical risks. These are usually those cases which have suffered from raised intra-cranial pressure; and many of them are actually unconscious, in which case local anæsthesia provides good results.

Local anæsthesia "controlled" by general anæsthesia is not a very successful method. By the term "controlled" is meant the administration of a general anæsthetic for some period during the operation when the local anæsthesia is inadequate. In cerebral surgery it is essential that a general anæsthetic should be automatic in its administration, and that the patient's airway should be assured at all times. This state of affairs cannot be attained when general anæsthesia is induced during the operative procedure. Moreover, it is customary, and I believe necessary, that the patient's condition, as evidenced by the blood-pressure, the pulse rate and the respiration rate should be kept under constant observation. Unless two people are available, it will be impossible to induce and maintain general anæsthesia and still record these essential data. If the local anæsthetic proves unsatisfactory, the patient comes to the induction of general anæsthesia restless, excited, often

vomiting, and in a most difficult position on the table, and further surgery will have to wait until anæsthesia has been induced. The patients' faces are difficult of access because of the sterile drapings, and they may be either in the sitting position in a chair, or lying face downwards on the table. Under these conditions control of the airway is difficult and endo-tracheal intubation doubly difficult. Experience has led me to believe that no method of anæsthesia can be considered as safe for lengthy intra-cranial operations in which the airway is not under the control of the anæsthetist; and for this reason I am not in favour of those methods which necessitate "control" of a local or a basal anæsthetic by a general anæsthetic.

Rectal Ether has its advocates, but in her papers on this subject Miss Wood[6; 7] tells us that the resultant anæsthesia only lasts for about four hours, and that after that length of time the anæsthetist must be prepared to "control" the narcosis with a general anæsthetic. This practice is open to the objections just urged against using local anæsthesia "controlled" by general anæsthesia. Four hours is an adequate length of time for our Gasserectomies, but inadequate for most of our intra-cranial explorations.

Miss Wood uses in all 6½ ounces of Ether and 2-4 drachms of paraldehyde to produce four hours basal anæsthesia.

By the use of a similar quantity of Ether with Nitrous oxide and oxygen we usually obtain six-and-a-half hours anæsthesia (v.i.). Any rectal anæsthetic is open to the objection urged by Bailey[24], that once the dose is administered it cannot be recovered, and thus an overdose cannot be rectified as easily as in inhalation anæsthesia.

I have had no personal experience of this method, but from Miss Wood's papers, and Gwathmey's[53] account of Colonic Oil-Ether anæsthesia I cannot see what advantages the method presents over the administration of Avertin.

Avertin has been increasing in popularity for the last three years, and is, I believe, the most serious rival to general anæsthesia. In these Neuro-surgical cases the usual procedure is to use local anæsthesia, and to give sufficient Avertin is given as an enema which consists of a 2½% solution of Tribromethyl alcohol in water, the dosage being arranged on a basis of 0.1 of a gram of Avertin per kilo of body-weight. This is the maximum dose which should not be exceeded, and in small patients the light anæsthesia necessary for intra-cranial surgery can often be attained with as small a dose as 0.08 gram per kilo. Unfortunately patients vary considerably as to the depth of anæsthesia produced by a given dose, and a good deal of experience is required in judging the quantity to administer. Usually

it is found desirable to administer a suitable dose or doses of Omnopon in the course of the operation, as the effect of the Avertin gradually wears off after fours hours.

It is well known that Avertin causes a considerable fall in blood-pressure, although few of its advocates appear to have noticed that there are a number of cases in which, in spite of the fall in systolic pressure, the diastolic pressure shows a corresponding fall, and therefore the pulse-pressure undergoes but little change. When, however, Avertin is used in conjunction with Novocaine-Adrenaline, the rise of pressure produced by the Adrenaline tends to compensate for the fall of pressure due to the Avertin. Even so, a considerable percentage of cases show a lower systolic or pulse-pressure after both the Avertin and the local anæsthetic than before the induction.

A further drawback to the use of Avertin is that in a certain number of cases it is difficult or impossible to ensure an adequate airway when the Avertin has taken effect; while in other cases additional general anæsthesia during the operation becomes necessary. When either of these contingencies arise the use of Avertin is open to the objections stated above to any form of "control" of a basal by a general anæsthetic.

In spite of these drawbacks, a successful Avertin anæsthesia appears to provide better conditions of work for

the surgeon than any other anæsthetic, in that the brain is relaxed and the patient is unconscious and does not strain. Where the anæsthesia proves unsatisfactory the patient becomes very restless and is usually not co-operative; and the restlessness may be so marked as to make conditions of work difficult for the surgeon and the blood-pressure impossible to record for the anæsthetist.

The use of Avertin for intra-cranial surgery has many advocates. W.E. Dandy[3] finds it much more satisfactory than Ether anæsthesia, since there is less swelling of the brain, less post-operative vomiting (which may cause hæmorrhage), and less risk of pulmonary complications. N.M. Dott[18] of Edinburgh now uses it in the majority of his cases, and obtains satisfactory anæsthesia provided that the Avertin is re-inforced by suitable doses of Omnopon.

Maddox[21] takes the view that Avertin is not a suitable anæsthetic for cerebral cases which are usually suffering from the effects of increased intra-cranial pressure, since it has a depressant effect on the respiratory centre. He considers that its depressant effect on the blood-pressure is due to a general vasodilatation which it produces; and certainly patients who have had Avertin show an engorgement of superficial vessels which gives their ears a characteristic plum-coloured appearance. He points out that the fall in blood-pressure can be "stabilised" by the use of Adrenaline

or Ephedrine, in much the way that this is now carried out by the majority of workers with spinal anæsthesia.

Taylor and Lund[17] have published their blood-pressure readings in fifty cases of Avertin anæsthesia, and find that the average effect is a fall of 20 mm. Hg in the pulse-pressure. As in spinal analgesia, the more severe falls of blood-pressure are to be expected in hypertensive subjects. They advise against the use of Avertin in any case in which a severe fall of blood-pressure is to be expected from surgical causes, and record cases in which the fall of blood-pressure has occurred as long as an hour after the administration of the Avertin: a phenomenon which I have not encountered. G. Edwards[23] mentions that there may be a fall in systolic blood-pressure of from 10-30 mm. Hg but he does not give the effect of the Avertin on the pulse-pressure.

In the course of 1933 I administered Avertin to fourteen cases in the Neuro-surgical Department. Of these, six were cerebellar explorations, four were frontal explorations, two were for pituitary tumours, one for a section of the eighth cranial nerve, and one for a subtemporal decompression. In seven cases the anæsthesia was satisfactory - in seven cases unsatisfactory, in that either the patient was very restless or the airway gave rise to anxiety. There were several cases in which the respiration became obstructed as

soon as the Avertin had taken effect, and in these cases I resorted to endo-tracheal intubation. This involved the administration of Nitrous Oxide-oxygen through the endo-tracheal tube.

These fourteen cases were not, however, given the full dose of Avertin. Because of the possible danger of depressing the respiratory centre I used the smallest possible doses of Avertin, and only gave 1/6th of a grain of Morphia an hour beforehand, instead of 2/3rds of a grain of Omnopon as Dott recommends for use during the operation. In this series of cases the standard dose of 0.1 gm. per kilo was never exceeded, while the mean dose per case was as low as 0.0963 gm. per kilo.

While it is outside the scope of this Thesis to examine the records of these cases in detail, I have selected the Charts of four representative cases in which Avertin was used, for inclusion as Appendix II. These records are included as part of the evidence on which I base my views on Avertin, and they serve as an interesting contrast to the records in Appendix III, which give the details of the forty-one cases anæsthetised with Nitrous Oxide-oxygen-Ether.

Chart No. 1 in Appendix II is that of a woman of twenty-three years from whom a cerebellar astrocytoma was successfully removed with Avertin anæsthesia. It was an unsuccessful anæsthetic in that the patient was very restless

during most of the operation. By the time the closure was undertaken the effect of the Avertin had almost worn off, and the patient complained of so much pain that Nitrous oxide-oxygen had to be administered. In spite of this restlessness, the patient's condition remained good throughout and the induction with Avertin produced little change in blood-pressure.

The case shown by Chart No. 2 was quite successful in that anæsthesia was almost perfect throughout. A large glioma was removed from the parietal lobe of a young woman of nineteen years. Severe hæmorrhage was encountered during the removal of the tumour, and two blood transfusions were required; but the conditions of work were ideal for the surgeon, and the patient made an uninterrupted recovery.

Chart No. 3 is included to show the unusual phenomena following the administration of Avertin to a patient on whom a frontal exploration had been proceeding for two hours with local anæsthesia only. Instead of the usual fall of blood-pressure, this man exhibited a progressive rise, both of systolic and pulse-pressures during the seventy minutes which followed the administration of the Avertin.

Chart No. 4 is typical of a frequent complication after the administration of Avertin. The patient, a man of fifty-four years, was uneventfully induced with the full dose of 0.1 gm. per kilo of Avertin. But as soon as the

Avertin had taken effect his tongue fell back and caused respiratory obstruction. In this case an endo-tracheal tube was passed without further anæsthesia, but after an hour it became necessary to administer Nitrous oxide-oxygen through it for the remainder of the operation. A pituitary adenoma was successfully removed from this patient, and he made an uninterrupted recovery.

Later in this paper will be found a comparison of the behaviour of the pulse-rate and blood-pressure during Avertin anæsthesia and during a gaseous anæsthetic. It will be seen that although the injection of the local anæsthetic does offset the fall in systolic and pulse-pressure to some extent, yet there are still a number of cases whose condition is not so good after this induction as it was before the anæsthetic.

A point which I have not seen mentioned in the literature is that patients who have been induced with Avertin sometimes exhibit an amnesia covering as much as twenty-four hours after the actual operation, although they may appear perfectly conscious. This phenomenon is of frequent occurrence following the use of Omnopon-Scopolamine as premedication before a general anæsthetic, and sometimes occurs after a similar use of the barbiturates. This amnesia following Avertin is worthy of further investigation, and will probably form the subject of a future paper.

The experience of these cases of Avertin basal anæsthesia has not persuaded me of the superiority of Avertin over an endo-tracheal anæsthetic of the type to be described in this paper. The constancy of the latter can be guaranteed in experienced hands; and an anæsthetic in the course of which the patient coughs or strains a few times is regarded as unsatisfactory. An unsatisfactory Avertin anæsthesia, however, may either expose the patient to the risk of asphyxia, or end with a patient so restless that the surgeon has great difficulty in working.

Whether on no it is wise to use an anæsthetic having so marked a depressant action on the respiratory and cardio-vascular systems for this type of case, only increasing experience can show.

ENDO-TRACHEAL ANAESTHESIA.

Having surveyed the alternative methods, we now come to consider Nitrous oxide-oxygen-Ether as an anæsthetic in neuro-surgical cases. But since endo-tracheal methods are the very essence of our technique, it is appropriate to pause for a moment to consider briefly the evolution of this method, which probably represents the greatest advance in anæsthesia of this century.

In 1909 two American physiologists, Meltzer[15] and Auer[4], found that if a tube were passed down to the bifurcation of the trachea and air blown in at a slight positive pressure, life could be maintained for several hours in experimental animals which had been paralysed with curare. Provided that the positive pressure was adequate, full oxygenation of the blood was possible without respiratory movement. They at once saw that such a method had great possibilities if applied to anæsthesia in the human subject, and Elsberg[16], in the following year, so applied it with success. In the course of the next ten years the method became widely used, first in the United States and then in this country, and many ingenious machines were devised for the administration of air and Ether by the endo-tracheal route.

In Britain the method attracted the attention of

anæsthetists in 1912-14. Boyle and Gask[39] reported a series of twenty cases successfully anæsthetized by this method in 1913, and at that same meeting of the Section of Anæsthetics of the Royal Society of Medicine Sir Francis Shipway[40] demonstrated his apparatus for the endo-tracheal insufflation of Ether vapour. In the following year Kelly[41], who had been using the method for some time in Liverpool, spoke on the subject to the Section of Anæsthetics, and at that same meeting Boyle[42] mentioned the possibility of using Oxygen instead of air as the vehicle for the Ether. In support of this suggestion he urged J.T. Gwathmey's[53:pp.81-7] experiments showing that all anæsthetics have a greater margin of safety when given with Oxygen instead of air.

The essential points of Meltzer's method are:-

1. That the lungs are kept in a continuous inspiratory state of distension which facilitates the exchange of gases.
2. That the fresh air enters the lowest part of the trachea.
3. That the air escapes by another path than the one by which it entered.

Under these conditions full oxygenation of the blood can be maintained without respiratory movements.

The early workers with this method were not slow to see that it would enable great advances to be made in intra-thoracic surgery if a positive pressure in the lungs could be maintained; and they soon found that any surgery about

the head or neck was greatly facilitated if the anæsthetist and his apparatus were well removed from the operative field.

It is to the ingenuity of Messrs. I.W. Magill and S. Rowbotham that we are indebted for the more recent work on the subject. They were, in the years immediately following the Great War, the anæsthetists to Queen Mary's Hospital, Sidcup, where Gillies and his colleagues were doing a great deal of plastic surgery on patients whose faces had been disfigured by war wounds. They found that endo-tracheal methods were of the greatest assistance to the surgeon in these cases, since his asepsis benefited greatly by the absence of masks and movement around the face. Soon they sought a method to replace per-oral intubation in operations on the mouth, as the tube tended to impede the surgeon. The stiff gum-elastic catheters then in use could be softened and made flexible by being placed in warm water, and they found that these could equally easily be passed through the nose into the pharynx when soft, picked up there with a pair of forceps[9], and inserted into the trachea. In order to enable the pharynx to be packed off to prevent blood from entering the trachea, they began to pass a second tube through the other nostril, so as to fulfil Meltzer's second condition: "...that the air escapes by another path than the one by which it enters."

Meantime, the war-time experience of many workers had shown that the patient's condition during and after operation was better if Nitrous oxide-oxygen-Ether was administered than if Chloroform or Ether alone were used. Marshall[37] had read a paper to this effect before the Section of Anaesthetics in 1917, and Boyle had said on that occasion: "I believe that Gas and Oxygen, with a little Ether when necessary, provide us with a better anæsthesia and a more favourable after-state than can be obtained by any other method."

Rowbotham[36], when addressing the Section of Anæsthetics in 1921, said that while their patients at Sidcup did well on Ether, their general condition both during and after operation was decidedly better when Nitrous oxide-oxygen-Ether was used. Accordingly, he and Magill began to insufflate Nitrous-oxide oxygen-Ether endo-tracheally. By this time Magill was in the habit of passing a wide-bore rubber tube through the opposite nostril to that occupied by the tracheal catheter, into the glottis to provide a return airway[8]. Such a piece of rubber tubing, passed through the nose into the pharynx, had been used by Silk [38] some years before merely as an airway when administering "open" anæsthetics.

Quite by chance Magill found that this wide-bore rubber tube frequently entered the glottis if pushed on through the

nose, provided the patient was in the third stage of anæsthesia; and that the success of this manœuvre could be recognised by the sound of the breathing through the tube, and the feel of the tube as it passed through the glottis. It then occurred to him that by this means an inhalation endo-tracheal anæsthesia, in which the patient both inspired and expired through the same wide-bore rubber tube, could be substituted for the insufflation anæsthesia of Meltzer, in which the vapour was blown in through one tube, and escaped around it. Magill found that with increasing practice an increasing number of cases could thus be intubated "blind"; the term which he has coined to describe intubation through the nose without recourse to laryngoscopy; and he pointed out that, provided the tube is of ample length to reach from the nostril to the glottis, it must lie in the trachea if, when it is passed through the nose to its end, breathing still takes place through it.

He has described this technique fully in two papers[27;35] and several other articles, and this is the method of intubation which has been used routine for this series of neurological cases. Its advantages, as Magill points out are:-

1. That a free airway is assured under all conditions.
2. That the respiratory passages are protected from the entry of fluids.

3. That the absolute control of the larynx enables very light and yet smooth anæsthesia to be maintained.
4. That the anæsthetist can have complete control of the patient and yet be out of the surgeon's way.
5. That a nasal tube can be introduced "blind" even where there is trismus, or when the patient is not sufficiently relaxed for laryngoscopy to be performed.

The use of this method of anæsthesia involves a slightly different arrangement of the apparatus. In insufflation anæsthesia there is no re-breathing, and therefore no need for a bag. The vapour is delivered direct to the patient under slight pressure, and the machine is equipped with a gauge to record this pressure and a safety valve which will blow off before the pressure reaches a damgerous height. In inhalation anæsthesia the patient rebreathes from a bag which is kept filled with the vapour by the apparatus. At a point close to the endo-tracheal tube an expiratory valve is placed, and this allows for the escape of the gases when a continuous-flow machine is in use.

Naturally, the inhalation method, when gaseous anæsthetics are in use, is more economical than the insufflation method, in which a continuous stream of gases must be blown into the trachea under positive pressure. But respiratory movements are always essential to life when

inhalation methods are in use, unless a small tube long enough to reach the bifurcation of the trachea is used, and the gases are delivered at a positive pressure, in which case the type of anæsthesia is really insufflation with re-breathing. This combination has, in my experience, kept alive for six hours a patient whose respiration had completely failed from increased intra-cranial pressure, oxygen being used; and I infer that under these conditions sufficient oxygen reaches the alveolar air by gaseous diffusion to provide for adequate oxygenation of the blood. At any time when once such an endo-tracheal tube is in place, oxygen, or oxygen and carbon-dioxide can immediately be supplied direct to the bronchi should need arise; and by this means the efficiency of artificial respiration is greatly enhanced.

GASEOUS ANAESTHETICS IN NEURO-SURGERY.

The Literature.

Very little work has been published on the subject of gaseous anæsthetics in Neuro-surgery, and even casual references to them are infrequent.

Gilbert Brown, at the end of a paper[2] in which he describes a series of Cerebral cases which he has anæsthetized with Ether for Sir Henry Newland, mentions that he has anæsthetized a case of sub-temporal decompression with Nitrous oxide and oxygen. His comment on this case was that "The expense of gas anæsthetics limits their application in operations lasting four hours." This is probably true in Australia. In the course of this series of cases I found that my consumption of Nitrous oxide usually amounted to one and a half hours anæsthesia per hundred gallons of Nitrous Oxide. Thus, a five-hour operation at the current hospital prices for materials will cost about 10/6 in Nitrous Oxide, 2/3 in Oxygen (this covers twenty cubic feet) and less than a shilling for Ether: a total of 13/9. This does not seem unduly extravagant when compared to the cost of surgical equipment and materials.

At the Mayo Clinic, endo-tracheal Nitrous Oxide

anæsthetics appear to have been used for a number of cases. H.M. Tovell [25] says of them:- "For surgical procedures on the brain endo-tracheal anæsthesia has been satisfactory from the standpoint of both surgeon and anæsthetist. For operations on the cerebellum the method is particularly warranted because (1) the operative risk may be great; (2) a large percentage of the patients are children; (3) the prone position makes æration difficult under all methods of anæsthesia except the endotracheal method. Light but even anæsthesia can be maintained, and at any time artificial respiration can be applied without interfering with the sterile field." It is this absolute control of the airway which is the greatest argument for endo-tracheal anæsthesia in cerebral surgery.

As long ago as 1922 Boyle, in the course of discussion of a paper of Mennell's[13] on Anæsthesia for cerebral surgery, stated that he had anæsthetized a Sub-temporal Decompression with Nitrous-oxide-oxygen-Ether.

Miss D.A. Wood, in her paper[22] published two years ago, states that she never used gaseous anæsthetics because of "the uneveness of the anæsthesia." If Nitrous oxide-oxygen alone is used, this objection is valid, but if small quantities of Ether are added it becomes possible, after considerable practice, to obtain smooth anæsthesia with

Nitrous oxide-oxygen alone after the first hour or so. Although gaseous anæsthetics were not used, this paper of Miss Wood's is a most interesting summary of no less than five hundred and fifty cerebral cases, and I propose later to compare and contrast her results with those in this series.

In March, 1933, during the discussion on N.M. Dott's paper before the Section of Anæsthetics of the Royal Society of Medicine, Challis[19] gave a very brief resume of the method of endo-tracheal Nitrous oxide-oxygen-Ether which he originally used at the London Hospital on Cairns' cases. Wakeley pointed out, on the same occasion, that he was in the habit of using either endo-tracheal gaseous anæsthetics or Avertin combined with local anæsthesia for all his neurological work.

There has just been published a paper by McCarthy, McKesson and Clement[30] dealing with fifty cerebral cases which they have anæsthetized with either Nitrous oxide-oxygen, or Nitrous oxide-oxygen-Ether, and some of them by the endo-tracheal route. For this intubation they have used the rather complex endo-tracheal tube devised by Coryllos[31] of New York which consists of two pieces of metal connected by a flexible wire spiral covered with rubber. The whole is introduced by being passed outside an instrument resembling a distally illuminated bronchoscope

which is withdrawn when the catheter is in place. They agree that they have had recourse to the use of supplementary Ether to achieve this, although they invariably turn off the Ether as soon as the tube is in place. Their cases for Gasserectomy are heavily premedicated with Morphia, Hyoscine and Nembutal; and although they do not state exactly what is given to their craniotomies, one is left with the impression that some premedication is given. The average length of their operations was a hundred minutes, and apparently none of their patients experienced any after-effects from the presence of a metal foreign body in their tracheæ. I cannot but feel that for our more lengthy operations it is wiser to use the soft rubber tube devised by Magill, although probably we should do well to cultivate per-oral intubation in cases with obvious septal deflection or any other condition likely to give rise to bleeding on nasal intubation. On the other hand, the problems of fixing the tube securely during the performance of the operation are so much easier of solution with the nasal tube, that we have tended to make its use routine in all cases. Apparently McKesson and his colleagues have only been in the habit of intubating actual craniotomies, and of anæsthetizing for Gasserectomies with the plastic nasal inhaler; whereas we use the endo-tracheal method for all cases.

A section of their paper is devoted to the "McKesson Depression Test"(45, p.28), by which they recognise "anæsthetic shock." From the very fact that an increase in the oxygen percentage in the mixture causes a rise of blood-pressure, it would seem obvious that the Nitrous oxide-oxygen anæsthesia is being pushed to harmful limits in order to produce satisfactory anæsthesia. This justifies our preference for giving a little Ether rather than producing cyanosis with Nitrous-oxide-oxygen, for the quantity of Ether used is so small (v.i.) that the advantages of using it outweigh the disadvantages.

This paper, just published, is the only record of a series of neurological cases anæsthetized by this method which I can find in the literature. Miss Wood's paper, as the authors of this recent paper point out, is the only other giving a series of neurological cases which have been carefully observed as regards pulses and blood-pressure readings. I propose to devote some space later in this paper to a comparison of their results and ours in this series of cases.

OUR TECHNIQUE WITH NITROUS OXIDE-OXYGEN-ETHER.

As a general rule our cases are not premedicated, unless they are very nervous subjects, as it is felt wiser to avoid the depression of the respiratory centre by Morphia. They all receive an injection of Atropine an hour before operation, in doses varying from gr. 1/100 - gr. 1/60. An initial reading of the pulse-rate, respiration-rate, and blood-pressure is taken and recorded before induction. We use a large aneroid sphygmomanometer, both it and the phonendoscope being provided with lengths of rubber tubing about seven feet long.

The nose is examined beforehand to determine which nostril is least likely to offer obstruction to the passage of the tube, and in cases where obstruction is anticipated the nose and pharynx are cocainized during inspiration with 10% Cocaine solution in a nebulizer. In these cases there is much to commend this practice, for not only does it cause a shrinkage of the tissues in the nose and so minimize bleeding on intubation, but by anæsthetizing the glottis locally it enables the patient to tolerate the presence of the tube in his glottis without coughing at a lighter plane of anæsthesia.

The induction of anæsthesia is then begun. Any of

the well-known makes of apparatus can be used, although my personal experience is limited to the "Boyle's" apparatus and the continuous-flow "Magill" apparatus. Probably the "Nargraf" model McKesson apparatus would prove to be the most efficient and economical in use, but its initial cost has so far made its use prohibitive.

The anæsthetic is begun with pure Nitrous Oxide to which Oxygen and Ether are added. Whether the sequence is Nitrous Oxide-Oxygen-Ether or Nitrous Oxide-Ether-Oxygen depends on the patient; where the colour is good and the patient's pre-operative condition satisfactory the induction can be materially shortened by exploiting the hyperpnœa produced by the Nitrous Oxide to cause a more rapid absorption of the Ether. This hyperpnœa disappears when the Oxygen is added, and if the Oxygen is added first the patient will take longer to absorb a similar quantity of Ether. Patients suffering from Pituitary lesions usually require larger quantities of Ether, while cases showing increased intra-cranial pressure can be induced with remarkably small quantities. Full muscular relaxation and regular respiration occur in from five to ten minutes, and an attempt is then made to pass a Magill endo-tracheal tube "blind" through what has previously been determined as the less obstructed nostril, into the trachea. This manœuvre has been repeatedly described by Magill[27], Tovell[25], Austin[28], Hewer[29; p.86],

and others, but there are certain points which are of special importance in Neuro-surgical work.

1. It is of great importance in these cases that there should be no bleeding from the nose on intubation. I have seen several cases in which a tube containing blood picked up in the pharynx has become partially or almost completely obstructed three hours later by the coagulation of the mixed blood and mucus in it. Gentle rotation of the tube will often secure its passage through the nose, and a very thick coating of vaseline helps to minimize trauma. Gentleness of manipulation is essential, and the use of force is never permissible.

2. While one is attempting to use as little Ether as possible, I believe that if the tube cannot be passed "blind" at the first attempt, laryngoscopy should be resorted to at once. It follows from this that enough relaxation should be present to enable this to be done before intubation is attempted. Another reason for this view is that "blind" intubation is thereby greatly facilitated, and the possibility of trauma to the vocal cords is reduced. In any case experience has taught us to perform direct laryngoscopy in many cases, even after the tube has been passed "blind" in order to make sure that the pharynx is clear of blood or mucus. We sometimes pack off the pharynx with gauze soaked in liquid paraffin, but I am not sure whether the advantage

of obviating a gas leakage between the tube and the glottis is not outweighed by the disadvantage of accumulating possible vomitus in the packing.

3. The tube selected should be of the largest size which will pass through the nose without the use of any force.

4. Previous cocainization of the glottis and the judicious use of carbon dioxide greatly facilitate "blind" intubation.

As a matter of interest I recently took note of fifty consecutive cases of nasal intubation after a Nitrous oxide-oxygen-Ether induction, noting the number of laryngoscopies performed, and the quantity of Ether used for the intubation. In this series of fifty cases, forty-five intubations were performed "blind", giving a figure of 90%. Fourteen of these cases were un-premedicated (some were dental cases which were also unprepared), five were premedicated with Nembutal, twenty-nine with Omnopon and Scopolamine, and one with Morphia.

For the forty-five cases intubated blind, a total of 25 ounces of Ether were used, making an average of 4.4 drams per case. The five cases intubated under direct vision required a total of 30 drams of Ether, an average of 6 drams per case.

The tube, once in position, is fixed there by two broad strips of adhesive plaster over the nose. In doing this it is well to bear in mind the position which the patient will

occupy on the operating table, and to arrange the tube so that it will be as much out of the way of the surgeon as possible. Where possible, a right frontal exploration should be intubated through the left nostril, and vice versa. I have often experienced a good deal of difficulty and trouble with the metal angle-pieces which connect the endotracheal tube to the gas apparatus. In the course of a long case the vaseline with which the tube is lubricated frequently works its way between the tube and the angle-piece, and the latter slips out of the tube which can then disappear down the nose and have to be recovered from the pharynx with intubating forceps. This is especially liable to occur at the end of a case while the dressings are being applied and the head is being moved a good deal. For this reason Rowbotham's pattern of angle-piece is more convenient than the other patterns for these cases, and it would probably be helpful to have them specially made with sharp ridges to take a firm grip of the lumen of the tube.

The angle-piece is then connected to the seven-foot length of rubber tubing which fits on to the gas apparatus and carries the breathing bag and expiratory valve. As soon as this is in position the second set of readings is taken, and it is on the contrast between these and the original set of readings that I assess the effect of the anæsthetic. Meanwhile, assistants rub vaseline on those

parts of the patient which are liable to develop pressure-sores, and cover his eyes with gutta-percha tissue moulded into place by firm pressure with swabs wrung out in hot water. The patient is then transferred to the operating-table, and it is a wise precaution always to disconnect the apparatus from the endo-tracheal tube before lifting the patient, in order to prevent it from being accidentally pulled out.

Gasserectomies, and a few cases of intra-cranial tumours in which severe hæmorrhage is anticipated, are performed in the sitting position in a dental chair. Cerebellar and Occipital explorations and Laminectomies are performed with the patient lying prone, and the head supported on a horse-shoe-shaped rest. All other cases are operated upon lying supine on the table. The sterile sheets are made to cover a small instrument-table which passes across the patient's chest like a bridge, and a metal are projecting from the table causes them to form a projecting flap. Beneath this "tent" the anæsthetic apparatus is placed. The anæsthetist sits beside it, and thus has access to the patient beneath the sheets. Some idea of this arrangement of the apparatus can be gained from the frontispiece to Bailey's work on Intracranial Tumours.(24).

From then onwards further readings of the blood-pressure, and pulse and respiration rates are taken every ten minutes -

or more frequently if this is indicated by the patient's condition. The long breathing tube is secured to the substructure of the table by further pieces of adhesive strapping, so as to prevent it from kinking, the Boyle's apparatus is placed as far from the surgeon and the electric leads as possible, and the sphygmomanometer and phonendoscope, with their long lengths of rubber tubing, are adjusted in convenient positions.

It is usually possible, during the operation, to get a view of the lips, ears, or finger-nails under the sterile sheets; but in this half-light colour is deceptive, and the use of an electric torch facilitates the avoidance of cyanosis. Even so, it is wise occasionally to look at the colour of the blood at the site of operation. Owing to the position of the patient, in Cerebellar explorations and Laminectomies the face can only be reached by lying on the floor on one's back between the surgeon's feet and looking upwards. It is in this type of case that the assured airway provided by endotracheal methods is a factor of safety; and it is in this position that it is almost impossible to "control" a basal anæsthetic with a general anæsthetic.

My predecessors found by experience that if, at the close of the operation, the anæsthetic were immediately discontinued, the patient exhibited a further serious fall of blood-pressure during the inevitable movement caused by

the application of the dressings and the patient's removal to bed. We have accordingly continued the anæsthetic until the dressings are in place, and the starch and plaster cast which covers them has been moulded on the head. The bed is then brought into the Theatre and placed in readiness to receive him. When the dressing is complete, the long breathing tube is disconnected, and the patient is immediately lifted into bed. The endo-tracheal tube is gently withdrawn as soon as the patient shows signs of coughing, when it can safely be assumed that no material in the pharynx will be aspirated into the trachea.

THE USE OF ETHER.

Under this heading I propose to discuss the reasons for and the method of our use of Ether with Nitrous oxide and Oxygen in these cases. This method of anæsthesia represents a compromise between a pure Ether anæsthesia on the one hand and a pure Nitrous oxide-oxygen anæsthesia on the other.

We have come to the conclusion that endo-tracheal anæsthesia is desirable for Neuro-surgical cases, and the passage of such a tube in the un-premedicated patient requires the use of some Ether. When intubation has been performed there are three alternatives for the subsequent maintenance of anæsthesia:-

1. To administer a pure Nitrous oxide-oxygen anæsthesia.
2. To turn off the Nitrous oxide and administer an Ether-oxygen anæsthesia.
3. To add just enough Ether to a mixture of Nitrous oxide and ample oxygen to produce smooth anæsthesia.

The case for Nitrous oxide-oxygen rests largely on the work of Crile. In his book on "Surgical Shock"(46) he advances the theory that "shock" is the result of exhaustion of the neurones of the vasomotor centre, and that Nitrous oxide-oxygen when administered to a patient in a state of "shock" prevents the neurones from using oxygen and thus places them at rest. He claims that the fatigued neurone

shows certain histological changes, and that similar changes are demonstrable in the neurones after Ether or Chloroform anæsthesia, but absent after Nitrous oxide-oxygen anæsthesia. The vast clinical experience of Marshall(37) during the Great War showed conclusively that Nitrous oxide-oxygen was the anæsthetic of choice when dealing with a case which was already in a state of shock; and this view is supported by such authorities as Rowbotham(36) and Boyle(loc.cit.).

Almost all workers with Nitrous oxide-oxygen, however, admit that in many cases it is impossible to maintain smooth anæsthesia with this mixture of gases unless the oxygen percentage is reduced to a point at which cyanosis supervenes. It has been demonstrated both clinically by McKesson(32) and experimentally by Cattell(44), that such cyanosis gives rise to circulatory depression and a fall in blood-pressure. McKesson, as we have seen, terms this condition "anæsthetic shock" and has described a clinical test for it; in the course of a Nitrous oxide-oxygen anæsthesia the oxygen content of the gaseous mixture is suddenly raised for a few breaths, and if the patient shows a rise of blood-pressure he is said to have been suffering from "anæsthetic shock". Cattell, in the course of experiments on anæsthesia on animals already in a state of surgical shock, found that provided a proportion of 25% oxygen was used, Nitrous oxide-oxygen could be administered to these animals without causing a fall of

blood-pressure, where the other anæsthetics all produced that result. On the other hand, if a higher percentage of Nitrous oxide was used, then there was a fall of blood-pressure, which, with 16% or less of oxygen was as great as the fall caused by Ether. In describing the experiment he says:- "In some animals it is not possible to get complete abolition of the eye reflex without some fall in pressure, but this fall is less than with Ether."

The only other way of avoiding anoxæmia lies in increasing the positive pressure at which the gaseous mixture is administered.

The exact physiology of Nitrous oxide anæsthesia is still in debate, and is too large a subject for discussion here. Experience of some two hundred pure Nitrous oxide-oxygen anæsthesias has taught me that smooth anæsthesia without cyanosis can only be produced by raising the positive pressure at which the gases are administered. The assumption that this is because the oxygen is chiefly carried by the blood in chemical combination with hæmoglobin whereas the Nitrous Oxide is mainly in solution in the plasma explains this phenomenon. J.T.Gwathmey(53, p.129) puts forward this theory of its physiology; it appears probable when one remembers the great solubility of Nitrous oxide in water, and the work of Paul Bert(51; 52) suggests the same conclusion. I propose to assume this hypothesis in discussing the administration of Nitrous oxide at positive pressures.

In 1878 Paul Bert realised that the difficulty underlying the use of Nitrous oxide as an anæsthetic was that of maintaining a high concentration of Nitrous oxide in solution in the plasma and at the same time providing for adequate oxygenation of the blood. He found that this was possible with mixtures of Nitrous oxide and air provided that the gases were administered at a high positive pressure. He used as great a pressure as four atmospheres in experimental animals. If oxygen itself be substituted for air, less positive pressure will be required. The theoretically ideal conditions obtain for anæsthesia when enough oxygen is present in the alveolar air to ensure full saturation of all the hæmoglobin passing through the lungs, and yet enough Nitrous oxide is forced into solution in the plasma to ensure quiet even anæsthesia. Since the oxidation of hæmoglobin is a quantitative chemical reaction it will depend less on the positive pressure than the solubility of Nitrous oxide, which depends directly on that gas's partial pressure in the alveolar air, and the positive pressure at which the mixture is supplied.

Other physiological considerations make it unwise to apply much positive pressure where endo-tracheal methods are in use. It is an accepted physiological fact that the output of the heart is conditioned by its filling from the great veins, and this in turn depends on the intra-thoracic

pressure, which under normal conditions may vary from 5-30 mm. Hg.[33] If a gaseous anæsthetic is administered by endo-tracheal methods under positive pressure, the pressure in the apparatus is brought to bear on the intra-thoracic pressure, and this increase in the intra-thoracic pressure should, in theory, decrease the filling of the heart from the great veins and lessen its output. This appears to obtain in practice, since it is a matter of common observation that venous engorgement varies as the positive pressure at which a gaseous anæsthetic is administered, for venous hæmorrhage is greatly increased. I have also found that at pressures exceeding 10 mm. Hg. positive, the systolic and diastolic sounds become inaudible in the brachial artery.

In eleven cases in this series I noted the oxygen percentage and the positive pressure which produced smooth anæsthesia after the Ether had been turned off. The mean oxygen per cent was 18.6, which is only 2½% lower than the normal oxygen content of atmospheric air; and the mean positive pressure was 4 mm. Hg.

The second alternative, that of inducing the patient with Nitrous oxide-oxygen-Ether and then turning off the Nitrous oxide and administering an Ether-oxygen anæsthesia - is open to numerous objections. Many surgeons feel that the local effect of the Ether increases their difficulties,

and the use of Ether in larger quantities increases the incidence of post-operative pulmonary complications. But the method is still used as the routine at the Mayo Clinic by R.M. Tovell (personal communication).

Cattell's[44] experimental work on the effect of Ether anæsthesia on the blood-pressure provides a contra-indication to this alternative. He first confirmed the results of other workers, that the administration of Ether to a normal animal results in a rise of blood-pressure which is maintained for about two hours and is then succeeded by a progressive fall. There is, he found, a transient but constant fall during induction, but this is rapidly followed by a rise of pressure, and for the first two hours or so of surgical anæsthesia the pressure is maintained at a level above that of the initial reading. He demonstrated that this rise of blood-pressure is due to a peripheral vaso-constriction, and that it occurs in spite of relaxation of the myocardial tone which always occurs during Ether anæsthesia. He describes the effect thus:- "The fall in blood-pressure from Ether is brought about through an effect on the heart, and this is normally compensated for by a peripheral constriction through the vasomotor system."

But if Ether is administered to an animal in a state of surgical shock there is an immediate fall of blood-pressure instead of a rise. This he found was due to the

fact that in the shocked animal Ether produces a peripheral vaso-dilatation instead of a vaso-constriction.

These results in experimental animals support the clinical experience of many workers that where shock is present or is expected to occur, better results are obtained by the use of gas-oxygen anæsthesia than with Ether.

For these reasons we have pursued the third alternative whose aims are:-

1. To turn off the Ether completely as early as possible after intubation.
2. To prefer at all times to add minimal Ether to the gas mixture if the anæsthesia proves unsatisfactory, rather than to reduce the oxygen percentage.

The Charts of our cases contained in Appendix III are, I believe, good evidence that these small quantities of Ether added to the Nitrous oxide and oxygen do not have the same depressant effect on the myocardium and the blood-pressure as Ether alone. They therefore support the contention of Marshall, Boyle and Rowbotham (loc.cit.) that this combination of gases with minimal Ether gives better results than Ether alone.

In these Neuro-surgical cases the blood-pressure is usually at normal levels when the operation is begun, and under these conditions there is no objection to the use of small quantities of Ether. By the time that a serious fall

of blood-pressure has developed the Ether has usually been turned off for some time, and a pure Nitrous oxide-oxygen anæsthesia is being administered.

To satisfy myself as to the effect of adding minimal Ether vapour to the gas mixture I gave patients, who had then for some hours had only Nitrous oxide and oxygen, minimal Ether vapour for a few minutes before the next readings were taken. Of the eight occasions on which this was tried, the systolic pressure rose on seven occasions, the mean rise being 7.4 mm. Hg. The mean increase in pulse-pressure in these eight cases was 4 mm. Hg., although in four cases it did not change; and in one case the diastolic pressure dropped while the systolic remained constant. But in every case the addition of minimal Ether to the gas mixture produced either a rise of both systolic and diastolic pressures, or else an increase in the pulse-pressure. These results agree with Cattell's statement (v.s.) that at first, and in small quantities, Ether causes a rise of blood-pressure.

For these reasons we have had no hesitation in using small quantities of Ether if there was any difficulty in securing smooth anæsthesia with Nitrous oxide and oxygen without cyanosis. This has enabled us to use percentages of Oxygen considerably higher than is usual in general surgical cases.

But the quantity of Ether used, when once intubation has been performed, must be literally minimal. From the earliest days of its history the chief detractors of the Nitrous-oxide-oxygen-ether sequence have been wont to express the view that the method consists essentially of giving an ether anæsthetic by using Nitrous oxide and oxygen as the vehicles for carrying the Ether. Rood[34], at a meeting of the Section of Anæsthetics of the Royal Society of Medicine at which apparatus of this kind was demonstrated in 1920, tended to express this view. While it is true that for purposes of abdominal surgery a considerable quantity of Ether must be used to secure adequate relaxation, operations which require no relaxation can be performed, literally, with "minimal" Ether. In thirty-seven of our series of forty-one cases I carefully noted the total quantity of Ether used, and the time taken from the induction of anæsthesia to its close. These records, whose details are set out in Table I, show that the consumption of Ether in addition to Nitrous oxide and oxygen averaged one ounce per hour. In almost every case the whole of this quantity of Ether was used in the first hour, and the majority of it before intubation to secure relaxation. An Ether consumption which averages one ounce per hour over periods of five hours at a time can adequately be described by the expression "minimal ether."

TABLE I.

CONSUMPTION OF ETHER IN THIRTY-SEVEN CASES.

The maximum quantity of Ether used on any one case was 10 ounces.
The minimum quantity of Ether used on any one case was 2 ounces.
The total quantity of Ether used for 37 cases was 186.25 ounces.

The average Ether used per case was 5.03 ounces.

The duration of the longest case was eight hours fifty minutes.
The duration of the shortest case was one hour thirty minutes.
The total time of anæsthesia for 37 cases was 185.7 hours.

The average time of each anæsthetic was 5.016 hours.

Thus the consumption of Ether was approximately one ounce per hour.

Ether, as we have seen, is an unpopular anæsthetic with the cerebral surgeon, because it causes swelling of the brain and post-operative vomiting. One of the main features of the Cushing technique is its insistence on meticulous hæmostasis; but however careful the hæmostasis, vomiting is always liable, by increasing the intra-cranial pressure, to re-open bleeding points which have been carefully stopped. Nevertheless a restless patient who is congested and coughs or retches frequently, is more difficult for the surgeon to handle than a case which shows great swelling of the brain. Anæsthesia for cerebral surgery must above all else be smooth. No two cases are exactly similar in the amount of Ether which they require to produce this result, and it is for the anæsthetist to deal with each case on its merits. The most difficult period occurs some five minutes after the Ether is first turned off completely, for then the patient will usually show a tendency to cough, and very careful manipulation of the Nitrous oxide-oxygen percentage is required to avoid this without causing cyanosis. The addition of a small quantity of Carbon Dioxide at this point is often of great assistance, for the hyperpnœa which it causes will usually inhibit retching or coughing reflexes. It is also at this point that previous cocainization of the larynx is of great value in inhibiting these reflexes.

COMPLICATIONS DURING ANAESTHESIA.

The problem of maintaining smooth anæsthesia has already been dealt with when discussing the addition of Ether. The method of trial and error is the only way to discover whether a case requires the addition or no, and what percentage of oxygen at what positive pressure will be required. By constant observation of the movements of the rebreathing bag troublesome retching can be largely avoided after some practice, and if the respiration becomes irregular straining can often be prevented by the addition of a little Carbon Dioxide to the mixture.

The patency of the endo-tracheal tube must be carefully watched. If it has not been passed "clean" - i.e., if it has picked up blood or mucus in the course of its passage through the pharynx - coagulation may take place in its lumen and cause it to become obstructed. The signs of this complication are laboured respiration, increasing cyanosis, and decreasing movements of the rebreathing bag; and its occurrence can be confirmed by disconnecting the long breathing tube and listening to the respiratory sounds. If the condition is recognised sufficiently early, before coagulation has taken place, the tube can sometimes be cleared by strong suction on its disconnected end, but if clotting has already taken place it is imperative to remove the tube. While the

passage of an endo-tracheal tube de novo with the patient's head either face-downwards, sitting up, or at all events draped with sterile towels, is exceedingly difficult if not impossible, yet I have found that if a fresh tube is passed as soon as the obstructed one is removed it frequently re-enters the glottis. This is probably because the vocal cords, when for some time they have been held open by a foreign body, tend to remain open and flaccid for a short time after its removal. Naturally, if it is impossible to re-introduce the tube, the anæsthetic will have to be continued by other methods: usually either with a face-piece or else by intra-pharyngeal insufflation. While I believe that it is possible for mucus alone to cause such an obstruction, the condition is almost always due to bleeding on intubation, and the incidence of this complication can be almost completely avoided by the precautions mentioned above when intubating. If a thin-walled endo-tracheal tube is used, and the head is extremely flexed or rotated, it is possible for the tube to kink in the pharynx and so become obstructed. This can easily be remedied by manipulation of the tube in the nose until free breathing is again heard through it. Nasal intubation has been used in all our cases because of the greater ease with which the tube can be securely fixed in the nose, but it will probably be found wise in future to

intubate through the mouth by direct vision in those cases which obviously have deflected septa or enlarged turbinates. Trans-nasal intubation is contra-indicated in any case of otitis media because of the danger of carrying down pus into the bronchial tree from the nasal end of the Eustachian tube.

A troublesome complication which sometimes arises in the course of an intra-cranial case is a persistent hiccough, which tends to develop when the dura is first opened. Two such cases have occurred in my series, and while one yielded to the use of small quantities of Ether and Carbon Dioxide, the other persisted during the whole time the dura was open, only to subside again as soon as it was closed. I gather that this is also the experience of other workers: that some cases yield to the addition of Carbon Dioxide and Ether to the vapour, while others do not. The hiccough tends to occur at every fourth breath or so, and at each hiccough there is a slight movement of the head which may greatly inconvenience the surgeon, although the jerk which usually accompanies a hiccough is minimized by the patient's inability to close his glottis.

OBSERVATIONS ON THE PATIENT'S CONDITION.

In these protracted intra-cranial operations it is essential for the anæsthetist to have an accurate idea of the the patient's condition, and to keep the surgeon informed of it. With all the deference due to his great experience, I venture to differ on the question of blood pressure readings from the view expressed by Mennell[5], who regards them as valueless because the blood-pressure frequently becomes so depressed as to be impossible to read. Even when the situation has reached this point its relative gravity can be much more accurately estimated if its behaviour up till then is known. When no pulse is palpable at the wrist, pulsation can sometimes be felt in the femoral artery in Scarpa's triangle; and when this is impossible auscultation at the apex is the last resort.

Nor are estimations of the systolic pressure alone of the same value as records which enable the anæsthetist to see at a glance the variations of pulse-pressure, pulse-rate, and respiration-rate. Only by a consideration of all these facts can the anæsthetist hope to form an adequate opinion of the patient's condition.

As Marvin and Pastor[47] have pointed out, the range of experimental error in taking readings of the blood-pressure

is in the vicinity of 4 mm. Hg., but in intra-cranial cases accurate readings are difficult to obtain because of certain changes in character of the pulse when the dura is open. In the great majority of frontal and cerebellar explorations I found that the rhythm and tension of the pulse both assumed unusual characteristics during the time that the dura was open. The rhythm became completely irregular, until the pulse resembled that of a case of auricular fibrillation. At the same time, the tension was found to become irregular: some beats were audible through the phonendoscope at 116 mm., others at 112 mm., and others still at 110 mm. That the irregularity of the pulse-rate was not due to beats "not getting through" was shown by the fact that auscultation at the apex revealed no corresponding sound. Where these conditions obtained, the systolic pressure recorded on the chart was always the highest point at which any sounds could actually be heard.

Marvin and Pastor conclude, as the result of their work, that slight fluctuations in the blood-pressure during operations are of no importance, and that the only important changes are extremes of pressure due to "shock". Three of our cases appear to suggest that a severe fall in the pulse-pressure is of as great an importance as a severe fall in systolic pressure (v.i.)

When once the considerable variations which accompany induction and intubation have subsided, hæmorrhage is the chief factor which influences the blood-pressure and the pulse-rate. Charts showing the characteristic picture of hæmorrhage are:- Nos. 4, 11, 15, 17A, 19, 21, 37 and 38, in Appendix III. Their chief characteristics are: a rapidly falling blood-pressure, both systolic and diastolic, and a rising pulse-rate. Later the respiration-rate rises as well. Naturally, the rate of fall of the blood-pressure depends to some extent on the severity of the hæmorrhage.

In six of the eight cases referred to above, it is interesting to note that the fall in systolic pressure was immediately preceded by a slight rise in the diastolic pressure. Now Cannon, in his work on "Traumatic Shock"(43; pp.20-21 & 99) summarises the physiological arguments which go to show that in surgical shock there is an early peripheral vaso-constriction whose object is to counteract the fall in blood-pressure. Later, as the low blood-pressure becomes established and the vaso-motor centre begins to suffer from anaemia, this vaso-constriction relaxes, and then the diastolic pressure begins to fall as well. This appears to explain this phenomenon which I observed clinically; that an impending drop in blood-pressure is usually heralded by a slight but definite rise in the diastolic pressure. At the next reading, ten minutes

later, the systolic pressure is usually seen to have fallen, and the diastolic pressure with it.

Any coughing or retching will cause great fluctuations in the blood-pressure, but variations due to this cause should not be mistaken for hæmorrhage, since they recover at once as soon as the anæsthesia becomes smooth again.

When a fall in the blood-pressure from hæmorrhage occurs, the surgeon must be warned, in order that he may temporize, if necessary, until the arrival of a blood donor for transfusion. All our patients are grouped for transfusion before the operation is undertaken, and a donor is summoned as soon as it is recognised that a transfusion will be desirable. As an emergency measure intra-venous gum-saline solution will produce a temporary recovery in the blood-pressure; but the results of such an infusion are evanescent as compared with the more lasting benefit conferred by a transfusion of whole blood. Providing that no further bleeding occurs, the recovery in blood-pressure induced by a transfusion is comparatively lasting in character. Chart No. 4 in Appendix III shows well the contrast between one intra-venous saline, two transfusions given during hæmorrhage, and a third transfusion given after the end of the operation. Charts Nos. 17A, 19 and 37 in Appendix III also illustrate this point.

In hot weather the patient sometimes loses a considerable quantity of fluid by sweating, and in these patients the fall

in blood-pressure responds very satisfactorily to treatment by infusion of intra-venous saline.

Chart 27 in Appendix III illustrates the rather disappointing results of the treatment of hæmorrhage by rectal infusion of saline. These were given to a number of these patients, although they were not always recorded, and the results were usually disappointing.

A point of some importance is illustrated by nearly all of these Charts. The closure of the head in these cases may occupy from fifty minutes to two hours. During this time the pressure forceps are removed from the scalp, which is then sutured in layers with large numbers of discontinuous silk sutures. During this inevitably lengthy process a certain amount of blood is lost, and the blood-pressure always shows a slight but progressive fall. If there has previously been severe bleeding, it is wise to bear in mind that a further fall of blood-pressure rather than a recovery is to be expected during the closure of the scalp.

Three cases, however, in this series, exhibit a condition which does not correspond to the accepted definition of "shock". Their Charts are Nos: 10, 16 and 32 in Appendix III. The first was a Laminectomy, in the course of which a tumour was removed from the eighth dorsal roots; the second a Cerebellar exploration in a youth who had had very high intra-cranial pressure following a hæmorrhage into the cerebellar vermis;

and the third was a Frontal exploration in a man of fifty-four years.

All these three cases give rise to anxiety as to their condition because of the low levels of their pulse-pressures, and on inspection the patients were evidently very ill. They were greyish in colour, sweating profusely, with thin, thready pulses. But, as the Charts show, this condition was reached not so much because of a fall in systolic pressure as because of a fall in pulse-pressure. The diastolic pressure, instead of falling as it does in hæmorrhage, either remained constant, or even rose slightly. In these three cases the pulse-rates were between 120-140.

In "surgical" or "traumatic" shock, according to the many authorities who have written on it, the systolic pressure is low, and the diastolic pressure is correspondingly low. Cannon(43; 48) gives the average blood-pressures of a large number of cases of surgical shock during the late war, and the lowest pulse-pressures which he quotes have an average of 17 mm. Hg. This occurred in a series of cases whose average systolic pressure was as low as 47 mm. Hg. It must, of course, be remembered, that in all these wartime cases the effects of "shock" and those of "hæmorrhage" were inseparable.

In these three cases of ours the curious fact is that the patients appeared very ill, and yet had systolic pressures

but little below the normal limits, and diastolic pressures much higher than usual in relation to the systolic. Had this condition only occurred in Cerebellar explorations it might have been supposed to be due to surgical interference in the vicinity of the vaso-motor centre, but this does not explain the phenomenon during a Laminectomy or a Frontal exploration. In this latter case the sounds became inaudible to auscultation after a time, and further readings thus became impossible, but as the patient was pulse-less to palpitation at the time it was evident that some grave cardio-vascular disturbance was in progress.

To investigate the causes of this condition in detail is outside the scope of this Thesis. I have no right to theorize about the possible explanations suggested by some of the writings on "shock", for these lie in the realm of applied physiology; and must abandon any attempt to explain the phenomenon which I have just described.

The experience of my colleagues at the London Hospital, however, agrees with mine that cases showing this unusual state occasionally occur, and I believe it is important for the anæsthetist to realise that a patient may be gravely ill even though the systolic pressure is not much below the normal level when the diastolic pressure is preternaturally high.

INFLUENCE OF THE ANAESTHETIC ON THE PATIENT'S CONDITION.

As we have seen, Ether administered to the normal subject causes, first a transitory fall in blood-pressure during induction, then a rise of pressure above the normal level which persists for about two hours, and then a gradual falling off. It appears generally agreed among the writers of text-books that the administration of Nitrous oxide and air causes a considerable rise of blood-pressure, although Kemp[49] claimed that this was not so. Gwathmey[53] quotes Boothby and Cotton as saying that induction by the Nitrous oxide-oxygen-Ether sequence produces a rise of blood-pressure.

It is evident that this has occurred in the majority of this series of cases, as may be seen from the Charts contained in Appendix III to this Thesis. I have attempted to show the changes occurring during induction in tabular form in Table II, which was compiled to illustrate the contrast between the cases which were given a general anæsthetic and those which were given Avertin. The upper table on each page shows the changes produced by the administration of the anæsthetic or the Avertin alone, by comparing the readings before induction with those taken immediately after it.

If the upper tables on each page are compared, the following facts emerge:-

1. That on the administration of gaseous anæsthetic between 60 and 70 per cent of cases show an increase in systolic and pulse-pressures, whereas with Avertin the systolic pressure fell in 92 per cent of cases, and the pulse-pressure in 53 per cent.
2. That the mean pulse-rate of the cases which had gaseous anæsthetic is markedly higher than that of the Avertin cases.

A study of the Charts brings out another point: that of the five cases induced in the sitting position, four showed a fall, usually of both systolic and pulse-pressures, instead of the usual rise. If the rise of blood-pressure during an Ether induction is due, as Cattell[44] suggests, to a peripheral vaso-constriction, it may be that in these cases the fall in blood-pressure results from the relative anæmia of the vaso-motor centre induced by the upright position.

The third part of Table II consists of the average readings of five local anæsthesia cases. They are included for use as "controls" when considering the lower tables on the first two pages, to give some idea of the usual effect of Novocaine-Adrenaline when used alone. They show that usually the local anæsthetic raises the systolic pressure slightly and as a rule raises the pulse-pressure as well. There is usually a considerable increase in the pulse-rate.

The lower tables on the first two pages of Table II are devoted to a comparison between the original readings before the induction of anæsthesia, and those taken after both the general anæsthetic or Avertin and the local anæsthetic had taken effect. It is evident that even after the injection of Novocaine-Adrenaline, the pressures are higher with general anæsthesia than with Avertin, a greater percentage of cases showing a rise after general anæsthesia. On the other hand, the depressant effect of Avertin on the blood-pressure is to a considerable extent counteracted by the effect of the Novocaine-Adrenaline, since after the injection of the local anæsthetic the majority of cases show either a rise of systolic pressure or else a rise of pulse-pressure. After the injection of the local anæsthetic, the pulse-rate of the cases with general anæsthesia shows little change, while that of the Avertin cases shows a definite rise.

Thus, normally, the induction of anæsthesia by Nitrous oxide-oxygen-Ether produces a rise both of systolic and pulse-pressures. The cases in which a fall of these pressures frequently occurs are:-

1. Cases induced in the sitting position,
2. Cases with raised intra-cranial pressure,
3. Cases which exhibit arterial hypertension,
4. Patients under ten years of age.

Judged by these usual criteria, it is true to say that the Nitrous oxide-oxygen-Ether sequence stimulates the patient, whereas Avertin depresses him.

TABLE II.

A comparison of the effects of induction and the injection of local anæsthetic on the blood-pressure.

A. With Nitrous Oxide-Oxygen-Ether.

1. The pressures before induction compared with the pressures after induction.
41 cases.

	No.of Cases	Approx. %	Mean Variation	Mean Pulse.
Systolic press. rose	25	60	21 mm.Hg.	135
Systolic press. fell	10	25	11 mm.Hg.	121
Systolic press. unchanged	6	15	-	121
Pulse-press. rose	28	68.3	21 mm.Hg.	135
Pulse-press. fell	10	25.4	10 mm.Hg.	117
Pulse-press. unchanged	3	7.3	-	120

2. The pressures before induction compared with the pressures after both the general and the local anæsthetic had taken effect.
31 cases.

	No.of Cases	Approx. %	Mean Variation	Mean Pulse.
Systolic press. rose	24	77.4	17.2mm.Hg.	133
Systolic press. fell	6	19.3	10.6mm.Hg.	118
Systolic press. unchanged	1	3.3	-	104
Pulse-press. rose	28	90.3	25.6mm.Hg.	130
Pulse-press. fell	3	9.7	15.3mm.Hg.	119
Pulse-press. unchanged	Nil	-	-	-

TABLE II.

B. With Avertin.

1. The pressures before induction compared with the pressures after induction.
13 cases.

	No.of Cases	Approx. %	Mean Variation	Mean Pulse.
Systolic press. rose	1	7.7	8 mm.Hg.	90
Systolic press. fell	12	92.3	14.5 mm.Hg.	99
Systolic press. unchanged	Nil	-	-	-
Pulse-press. rose	2	15.4	11 mm.Hg.	98
Pulse-press. fell	7	53.8	5.4 mm.Hg.	100
Pulse-press. unchanged	4	30.8	-	98

2. The pressures before induction compared with the pressures after both the Avertin and the local anæsthetic had taken effect.
9 cases.

	No.of Cases	Approx. %	Mean Variation	Mean Pulse.
Systolic press. rose	5	55.5	17.6 mm.Hg.	120
Systolic press. fell	4	44.5	9 mm.Hg.	117
Systolic press. unchanged	Nil	-	-	-
Pulse-press. rose	8	88.8	22 mm.Hg.	119
Pulse-press. fell	1	11.2	10 mm.Hg.	140
Pulse-press. unchanged	Nil	-	-	-

TABLE II.

AS CONTROL.

C. With Novocaine-Adrenaline.

The influence on the blood-pressure of injecting Novocaine-Adrenaline; the pressures before the injection of the local anæsthetic compared with the pressures after the injection.
5 Cases.

	No.of Cases	%	Mean Variation	Mean Pulse.
Systolic press. rose	4	80	13 mm.Hg.	133
Systolic press. fell	Nil	-	-	-
Systolic press. unchanged	1	20	-	102
Pulse-press. rose	4	80	19 mm.Hg.	124
Pulse-press. fell	1	20	24 mm.Hg.	138
Pulse-press unchanged	Nil	-	-	-

MORTALITY.

In estimating mortality in this series of cases I propose to consider patients who died, either before their discharge from this Hospital, or before any further operation. Of these there were three, of whom one died two hours after the completion of the operation, and the other two during it.

The first of these (Appendix III: Chart I) was a woman aged 37 years, from whose left frontal region a large glioma was removed. Severe hæmorrhage was encountered during the enucleation of the tumour, and a transfusion of 700 ccm. of whole blood was given as the tumour was removed. This raised her systolic pressure from 44-90 mm. Hg., but her pulse-rate continued to rise. During the closure, the blood-pressure again fell off, but as the pulse-rate had by then dropped from 160-130, it was thought that she would improve on her return to bed. This, however, did not occur, and she died two hours later.

The second fatality (Appendix III: Chart 2) occurred in a man aged 43 years, on whom a Cerebellar exploration was undertaken for the removal of a tumour. This is the only cerebral case in which I have ever used any chloroform: fearing a difficult induction with a gaseous anæsthetic, I induced the patient with A.C.E. mixture. The induction was

uneventful, but the patient bled freely from his nose on intubation, and the pharynx was not swabbed out. The general anæsthetic had produced a rise of both systolic and pulse-pressure, and the operation proceeded uneventfully for an hour and a half. At 1.10 p.m. he had a blood-pressure of 142/78 mm. Hg. and a pulse-rate of 66, with respiration at 26 per minute. Two minutes after these readings were taken, I noticed that the respiratory movements had ceased, found no pulse at the wrist, and observed a livid colour of the hands. The surgeon, who was about to open the dura, performed a ventricular tap, and, with oxygen and carbon-dioxide supplied to the endo-tracheal tube, artificial respiration was resorted to. These measures were of no avail. When the endo-tracheal tube was removed some twenty minutes later, its lumen was found to be almost occluded by a large blood-clot. The autopsy revealed no cause of death, and the pathologists stated that the post-mortem findings did not correspond with those of a death from asphyxia. The local condition in the brain was found to be a chronic basal meningitis. Thus, the cause of death in this case remains unsolved. The patient was undoubtedly alive and in good condition at 1.10 p.m. and dead at 1.12 p.m.; and it seems unlikely that the blocking of the tube, even if it did occur ante-mortem, could have caused death in so short a time. The fact that the tube was not completely obstructed, and the post-mortem findings are both

against asphyxia as the cause of death. Nevertheless, it is probable that the obstruction to respiration, even if not complete, contributed to the fatal outcome, and for this fatality the anæsthetic must be regarded as responsible.

The third death occurred in a woman 60 years of age, (Appendix III: Chart 2) from whose left frontal region a very vascular meningioma was removed. The surgeon, anticipating severe hæmorrhage, decided to operate with the patient in the sitting position, in the hope of minimising it. It is noteworthy that this case, which ended fatally, is the one exception to the rule, stated above, that patients induced in the sitting position usually exhibit a fall in blood-pressure. In this case there was a slight rise of both systolic and pulse-pressures. The first fifty minutes of the operation were uneventful; then severe hæmorrhage set in during the sawing of the bone-flap, and this continued to a lesser degree during the removal of the tumour. A transfusion donor had been summoned when the bleeding began, but owing to a misunderstanding he only arrived two hours later. By that time the blood-pressure had for 90 minutes stood at about 50/40 mm. Hg. and the pulse-rate had suddenly risen to 140, and was beginning to fall rapidly, becoming more and more irregular. The transfusion was given, but the patient died

during its administration. There can be little doubt that, had the donor arrived earlier, the patient could have been saved, and the anæsthetic cannot be considered as having played any part in determining this fatality.

Apart from these three cases, all the other patients of this series survived, either to their discharge from hospital, or else to a subsequent operation. Thus the gross mortality in this series of cases was 7.3 per cent.

NOTEWORTHY CASES.

Certain other cases in this series are deserving of comment. A youth of 16 years of age (Chart 16) was admitted almost comatose from increased intra-cranial pressure, and a cerebellar exploration was undertaken. Induction and intubation were uneventful, but a few moments after the introduction of the endo-tracheal tube the patient's respirations failed. His pulse, although rapid, was good in volume, and with the tube in place it was an easy matter to perform efficient artificial respiration. He was at once taken into the operating theatre, placed on the table, and a ventricular tap was performed. He immediately began to breathe again, at first very slowly, and then more rapidly, until thirty minutes later his respiration was again normal. His blood-pressure, which had undergone a considerable fall, soon recovered to a higher level than that of the original reading, and his pulse-rate, which had risen to 176 per minute, was gradually coming down. He was found to have had a hæmorrhage of unknown origin into the vermis of the cerebellum. The remainder of the operation was uneventful, and the patient recovered. During the first week after operation, however, he developed a persistent hiccough which did not yield to inhalations of Carbon Dioxide and Oxygen.

This persisted for five days and then suddenly subsided.

It may be that the failure of respiration was due to the effect of the Ether in raising an already high intra-cranial pressure still further; or possibly that the effect of the Ether was to block the few nervous pathways still conducting. It was turned off when the respiration failed, and was not used again; but the respiration did not recover until after the ventricle had been tapped. The patient made a good recovery, and nine months later was leading a normal life.

The operation recorded by Chart No. 38 is noteworthy in that it consisted of the removal of a meningioma weighing ten and a half ounces from the left temporal region of a young woman aged seventeen years. The total time during which anæsthesia was maintained was eight hours and fifty minutes. A fair amount of hæmorrhage occurred just as the tumour was being removed, but the blood-pressure and pulse-rate responded satisfactorily to treatment by an intra-venous infusion of saline, and a transfusion of 600 ccm. of whole blood. Her blood-pressure before operation was 110/66, and at the end of the operation 90/62 mm. Hg. She made an uninterrupted recovery. This was the longest case in this series, although one other case, shown by Chart No. 19, extended over seven and a half hours. Thus it would seem that this type of anæsthetic can be administered for periods up to eight hours without apparent harm to the patient.

COMPLICATIONS.

The following complications occurred during convalescence in this series of cases:-

Excessive post-operative vomiting	2
Persistent hiccough	1
Epistaxis after operation	1
Parotitis	1
Slight hoarseness after intubation	2
Nephritis	1

The case of persistent hiccough has already been discussed.

In a small but definite number of cases complications attributable to trans-nasal intubation are known to occur. The usual complication is sore throat which occurs, in my experience of about 600 cases, in about 2% of cases. In this series there were no complaints of sore throat, but two cases were slightly hoarse for a few hours on the following morning, and one case bled from the nose for three hours after the nasal tube had been withdrawn.

Wood[22] records three cases of parotitis following a cerebral operation. The one case which occurred in this series was noticed on the second day, and cleared up in

thirty-six hours. It was thought to be due to an ascending infection of Stensen's duct resulting from stasis of saliva in the cheek during operation.

The case of Nephritis recorded here is probably similar to that which Wood (loc.cit.) mentions as "cardiac dilatation". Our case occurred in a healthy man who has altogether been operated upon five times to date. The two operations which come into this series were the second and the third of the five; and their Charts are Nos. 17 and 17A. On the second occasion he developed a severe nephritis, with albuminuria, hypertension, and cardiac enlargement, which improved greatly with medical treatment. These sequelæ are known occasionally to follow transfusions of blood, and in this case they were thought to be due to a blocking of the glomeruli of the kidney by red blood cells.

One case in our series had had a furunculosis of the external auditory meatus for some days before operation. During the first few days after operation she showed a high temperature accompanied by a discharge from this ear, but the temperature subsided and the discharge cleared up with local treatment.

It has been suggested that nasal intubation may give rise to an otitis media on the side in question by causing an ascending infection of that Eustachian tube. If this is so, then these cases in which the nasal tube remains in

position for five hours should be more likely to develop such a complication than shorter cases. No middle ear complications have occurred in this series of cases: the case mentioned above was obviously independent of the process of intubation since it was already present before the anæsthetic, and the infection was situated in the external ear.

It is noteworthy that in this series of cases there have been no pulmonary complications. Wood[22], using Ether only, reports an incidence of seven cases of post-operative pulmonary complications, some of which ended fatally. This represents an incidence of 1.27% of her series of 550 cases.

On the other hand, McKesson et al.[33], using gaseous anæsthetics, found no pulmonary complications in a series of 50 cases. While it is impossible to draw conclusions from these two small series of cases, it is my opinion, based on the experience of my predecessors extending over a much larger number of cases, that fewer pulmonary complications are encountered with Nitrous oxide-oxygen-Ether than with Ether alone.

RESULTS.

In this series of 41 cases the following operations were performed with endo-tracheal Nitrous oxide-oxygen-Ether anæsthesia:-

Explorations and removal of tumours:

Occipital or Cerebellar	6
Frontal	7
Pituitary	4

Exploration without tumour removal:

Occipital or Cerebellar	5
Frontal	7
Pituitary	1
Gasserian Ganglionectomies	4
Laminectomies	3
Subtemporal decompressions	3
Elevation of depressed fracture	1
Total	41

The gross mortality in this series of cases was three: and these occurred either at operation or within two hours of its close. The remaining thirty-eight cases survived to their discharge from hospital.

The only two papers so far published giving tabulated results of such a series of cases are those of Wood[22] and McCarthy, McKesson and Clement[33]. In Table III our results are tabulated and compared with theirs on a similar basis. McKesson[26] has defined three stages of "surgical shock", of which he regards the first two stages as warnings

of impending shock, and the third as meaning that a shocked state has actually occurred. In assessing the incidence of shock in our cases I have adhered to the definition of this state which McKesson gives in his recent paper: "When the progressively falling blood-pressure reaches 80 systolic with a pulse-pressure of 20 or less, and the increasing pulse-rate approaches 120... surgical shock is now present." It will be noticed that this state occurred more frequently in our series of cases than in either of theirs.

Both Wood and McKesson estimate their "death rate" as the percentage mortality among cases which exhibited this state of shock, but do not include their deaths during the post-operative period. Miss Wood does not state her gross mortality at all: apparently seventeen cases in her series died as a direct result of the operation, and her paper makes it clear that a number of other cases did not ultimately survive.

In this series of cases the gross mortality was three, or 7.3%. Two of these deaths were undoubtedly due to shock at the time of the operation, and the cause of the third remains unknown although it was probably intensified by partial asphyxia. Since this third death occurred during the operation, and presumably because of it, I have included it as a death from shock.

In McKesson's series, only one death is regarded as having been due to surgical shock, but no less than nine other cases, or 20% of the total, did not survive to their discharge from Hospital. Only 14% of his cases showed surgical shock during operation.

It is evident that the nature of the operation performed very largely determines the extent to which shock is to be expected, and that craniotomies involving the removal of brain tumours carry the greatest risk, especially when the patient has been suffering for some time from chronic internal hydrocephalus. Unfortunately McKesson does not distinguish, in his paper, between brain tumours and brain abseesses, nor between explorations for tumours and operations involving their actual removal. Thirty cases, or 60% of his series, were either explorations for brain tumours which may or may not have been removed, or for the drainage of brain abscesses.

In the present series of forty-one cases, thirty, or 73% were either explorations for brain tumours, or the actual removal of a whole or a part of the tumour. No cases of cerebral abscesses are included in this series.

To some extent, then, this serves to explain the higher figure for the "incidence of shock" in our series. The higher "death rate" is due to the fact that all our fatalities occurred either during or just after operation.

TABLE III

A comparison of our results with those of Wood, and of McCarthy, McKesson and Clement.

	Wood	McKesson	Author
Total cases	550	50	41
Shock occurred in	94	7	12
Incidence of shock	17%	14%	29%
Deaths from shock	17	1	3
Death-rate from shock	18%	14%	25%
Post-anæsthetic pulmonary complications	7	Nil	Nil
Total deaths	?	10	3
Gross mortality	?	20%	7.3%

In spite of these facts, the gross mortality in this series is only one-third of that recorded by McKesson and his colleagues.

CONCLUSIONS.

1. That endo-tracheal Nitrous oxide-oxygen-Ether is a safe and reliable form of anæsthesia for protracted neurological operations.
2. That this method compares favourably with other methods, both in its effect on the patient, and as regards the conditions of work with which it provides the surgeon.
3. That it gives rise to few serious complications.

SUMMARY

1. The alternative forms of anæsthesia to the method in question are reviewed briefly.
2. The technique of endo-tracheal Nitrous oxide-oxygen-Ether is fully described and discussed.
3. A series of forty-one cases anæsthetized by this method is presented, showing a total mortality of 7.3%.
4. This series of cases is compared and contrasted with the results of two other series by different workers.
5. The actual observations on which this Thesis is based are submitted in the form of Appendices. The first deals with five cases operated upon under local anæsthesia, the second contains the records of four cases operated upon with Avertin basal anæsthesia. The third, to which the first

two act as "controls", contains the observations on the series of forty-one cases in question.

ACKNOWLEDGEMENTS.

In conclusion I wish to thank Mr. Hugh Cairns for the valuable experience afforded by these cases, and for his advice on the preparation of this Thesis.

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Finally, I wish to make it clear that no share of the credit for the adaptation of this method of anæsthesia to this type of case is mine. It was my colleague, Mr. J.H.T.Challis who first learnt and adapted Magill's technique to these cases. The method was perfected by Mr. L.H. Morris, my predecessor as Resident Anæsthetist. I have merely followed where they have led, and striven unavailingly to imitate their skill in the management of this method.

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