a spinal so valuable, for, say, abdomino-perineal excision of rectum, or for the removal of vascular growths in the abdomen. In such cases, vaso-pressors may almost destroy this virtue of spinal analgesia. In connection with this point, it is interesting to note that at a recent meeting of the Section of Anaesthetics of the Royal Society of Medicine, many speakers emphasized that curare was contraindicated for abdomino-perineal excision of the rectum because of the very marked bleeding that occurred during the perineal dissection. For long, spinal analgesia has been a method of choice for this operation, largely because of the avascularity of tissues which it produced.

Of complications specifically due to spinal analgesia the neurological ones are the most important. There seems little doubt that the majority of these complications are due to infection of varying grades of severity of the meninges at the time of lumbar puncture. One cannot emphasize too strongly the need for scrupulous asepsis when administering spinal analgesia. It is probable that the majority of spinal headaches are infective in origin.⁸ It has long been believed that headaches may also be caused by leakage of C.S.F. through the puncture hole in the dura into the epidural space. A recent paper from Scandinavia⁹ indicates that there is little doubt that leakage is also an important factor. To those who have difficulty in imagining the escape of much liquid through such a small hole, I would remind them of the fact that negative pressure exists in the

epidural space.¹⁰ All grades of headaches are met with after spinal analgesia from the very mild affair about which the patient may not complain spontaneously, to the severe headache where the patient resembles one with mild meningitis. From long observation, I now believe that even under the best conditions, the incidence of headache is much higher than published reports indicate. The figure usually given is between 5 and 10 per cent. The true figure is probably much higher. The frequency with which this complication is recorded depends on the diligence with which it is sought. Many may go unrecorded because of the large meshes of the net which gathers them. I do not know of any reliable way of differentiating clinically between the headaches due to infection and those due to leakage. In any case, the treatment is symptomatic for three or so days. By this is meant darkened room, head down position, quietness and sedatives. If at the end of this time no improvement is noted, or the headache gets worse, it is time to call in one's medical colleague to consider the possibility of meningitis and its treatment by chemotherapy.

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INHALATIONAL ANAESTHESIA

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Inhalational anaesthesia is just over one hundred years old. It is difficult to believe that this indispensable auxiliary of surgery was unknown in past civilizations but evidence from historical writings is too meagre in descriptive detail to permit any deduction whatsoever that alleviation of pain was ever practised with the same assurance for patient and surgeon as has been possible since the introduction of ether in 1846. In early times, surgical intervention was determined mainly by urgency and great necessity, factors which outweighed the many difficulties involved—not the least of those being the suffering of the patient. The extremely slow development of operative surgery

over a period of centuries might justifiably be considered an indication that dependable anaesthesia had not yet arrived and that methods of preventing pain were unsatisfactory and of insufficient help to surgeons in extending the scope of their work.

Primitive anaesthesia was probably inhalational in type, this mode of entry of medicinal drugs being preferred to swallowing because of the association of the latter with poisoning. Herodotus (c. 500 B.C.) wrote the earliest known account of inhalational anaesthesia when he described the intoxication resulting from smelling and inhaling vapours obtained by burning cannabis

(hemp). Seven centuries later (c. A.D. 250). Hoa Tho, a Chinese surgeon, made use of aconite, datura and hyoscyamus in his surgical practice and John Snow believed that those agents were vaporized and inhaled. In A.D. 1569 Porta described the soporific powers of a quintessence which Snow considered must have been the oil of vitriol (sulphuric ether) discovered thirty years earlier by Valerius Cordus.

From the Elizabethan era until the first half of the 19th century, a period of rapid development in many other spheres of human endeavour, methods for the relief of pain remained static. The potions and vapours of the middle ages continued in use and in the years immediately preceding Morton's successful demonstration of etherization, partial insensitivity was still being contrived by the giving of homely narcotics such as wine, spirits and laudanum. In recent times tests carried out on the old anodynes have proved the insufficiency of the latter for major surgery and it is not surprising that 'hypnotic' analgesia was introduced by Elliotson (1791-1868) and Braid (1795-1860) as an alternative to the medicinal agents.

The latter half of the 18th century was notable for great activity in chemical research. Priestley discovered nitrous oxide (1772) and oxygen (1774) while Lavoisier investigated the process of combustion and the related physiological problem of respiration. Humphry Davy, from personal experience, described the effects of breathing nitrous oxide and significantly noted its analgesic value. His suggestion (1800) that it might be administered to patients undergoing surgical operations was not acted upon until forty-four years later, despite the fact that the Napoleonic wars had been going on for a considerable part of the time and might have been expected to stimulate research into methods of relieving pain to facilitate military surgery. In the intervals desultory investigations continued but without purposeful direction towards the objective of surgical anaesthesia until Hickman (1823) performed his planned experiments with carbon dioxide on animals. Hickman saw clearly the vision of anaesthesia for surgery and to him may be accorded the credit of establishing the principle of the inhalational method.

From 1844 when Wells demonstrated the possibilities of nitrous oxide gas until the World War of 1914-1918 the progress of inhalational anaesthesia was slow. The agents employed, nitrous oxide, ether, chloroform and ethyl chloride, had all been introduced in the decade of initial discovery 1840-1850. Changes in technique were insignificant. Apparatus was simple; that of Clover and its various modifications by Hewitt and others remained in favour over a long period of

years. The shape of things to come was indicated by the gas machines of Teter, Connell, Hewitt and Boyle, by the work of Benedict (1909) on carbon dioxide absorption and by Jackson's application of this principle to inhalational anaesthesia with nitrous oxide on laboratory animals in 1915. Meanwhile the 'open mask and bottle' more than held its own with the relatively more elaborate apparatus of the time.

In the years between the two global wars anaesthesia improved more rapidly than ever before. New agents and better designed apparatus were introduced into practice. Chloroform and even ether had to yield to cyclopropane, which in conjunction with the closed technique of absorption of carbon dioxide brought inhalation anaesthesia to its highest peak of efficiency. Greater regard was paid to the pharmacological and physiological effects of the wider range of agents that were available. With the general adoption of endotracheal intubation and controlled respiration, to mention only two advances of the period, the administration of anaesthetics became more of a science and less of an art than formerly. The threat of supersession by the intravenous barbiturates stimulated improvements in inhalational technique. Appropriately, a compromise has been evolved whereby the two methods may be employed as a sequence or in combination with very definite benefit to the patient.

These developments have been the inevitable reaction to the ever increasing dissatisfaction of most surgeons and anaesthetists concerning the proved toxic effects of chloroform and ether. The tendency to abolish these drugs has become marked although many still would not agree with the complete elimination of ether because it may be used with relative impunity in a large proportion of cases. In operations of great extent or severity, however, where several serious downgrading factors may affect the patient, ether must share responsibility for much of the post-operative morbidity which occurs.

The agents and elaborate methods of the present time have not yet reached their fullest promise and may indeed sometimes be compared unfavourably with the simpler fashions of the past; responsibility for this lies not with the modern techniques but rather with lack of skill in those who use them. Nor have the latest methods eliminated all the undesirable features of their predecessors and it is salutary for the anaesthetist to assess their effects along the broadest lines and pay heed to justifiable criticism which may come from surgical colleagues.

In the course of a surgical operation several issues of mutual concern may raise discussion between surgeon and anaesthetist. Amongst these

the traditional problem of relaxation still takes first place because modern inhalational methods have not yet eliminated it entirely. Adequate reduction of muscular tone to facilitate a surgical procedure has always been, rightly, a primary criterion to be satisfied by the anaesthetic technique. In the past, relaxation, particularly of the abdominal wall, was too frequently a matter of 'all or none.' Some exponents of the older methods could produce purposely variations in depth of anaesthesia to suit particular circumstances. Anaesthetists generally, however, strived to meet surgeons' requirements by putting patients well and truly 'under' regardless of detrimental after-effects, a practice which in the period between the two world wars undoubtedly vitiated much of the extensive abdominal surgery then developing. In defence it must be said that variation of the plane of anaesthesia was more difficult when chloroform and ether with their high co-efficients of fixation in lipoids were used than nowadays with an agent such as cyclopropane which can be eliminated rapidly and is much more flexible in control. With the volatile drugs administered by open mask, frequently without oxygen, it was difficult to compromise between providing adequate relaxation and preventing anoxia. In some schools the problem was solved by abandoning general anaesthesia and employing regional analgesia in its stead thus restricting the quantity and distribution of the agent and avoiding generalized interference with cellular metabolism. It is, of course, possible to have toxic effects from local analgesics and serious disturbances of respiratory and circulatory function when spinal analgesia is employed. Generally, however, such undesirable effects can be modified more easily by the anaesthetist than similar complications produced by general anaesthetic agents whether inhalational or intravenous in type. The choice of a regional block in cases considered poor risks reflected the adverse opinions of surgeons regarding the toxicity of general anaesthesia. Moreover the method when precisely carried out ensured muscular relaxation, and an ischaemic field the latter being of marked benefit to both patient and surgeon. In many continental and American clinics the method has been in favour for years.

But for the introduction of cyclopropane and the technique of absorption of carbon dioxide there might well have been a mass changeover to regional analgesia because of its recognized advantages over deep general anaesthesia especially in extensive and lengthy operations. Cyclopropane checked the decline in reputation of inhalational anaesthesia despite having meanwhile, an additional rival, the intravenous barbiturates, with which to contend. By virtue of its potency and

ease of elimination this hydrocarbon gas provides a safe and very sufficient range in depth of anaesthesia and is more readily controlled than other agents with the exception of nitrous oxide and ethylene. In effectiveness cyclopropane can stand by itself without the dubious support of an admixture of ether. Relaxation at least equal to that obtainable with the latter drug is possible but the achievement of this end requires skill, experience and confidence on the part of the anaesthetist. In practically every respect cyclopropane is superior to all other inhalational anaesthetics and the mastery of its administration is the best possible training in the physiological aspects of the inhalational method.

It will be unfortunate if the advent of curare deprives the rising generation of specialist-anaesthetists of sufficient opportunities to learn the full scope of general anaesthetic agents which must still be used but in restricted fashion in conjunction with this potent relaxant. Undoubtedly curare has affected to some extent the status of general anaesthesia and relegated cyclopropane and other drugs to a subsidiary role. In the future in so far as major surgery, particularly that of the abdomen, is concerned the function of general anaesthetics is likely to become that of ensuring adequate narcosis and insensibility to pain while a specific relaxant or regional block provides muscular relaxation.

Ranking next to the problem of muscular relaxation is that of excessive bleeding in the field of operation. Under regional methods, including spinal block, this undesirable feature is of rare occurrence. During inhalational anaesthesia however it is common and can be very distracting to the surgeon. Unfortunately the loss of blood and prolongation of operating time entailed may be serious for the patient. The difficulty is not new and existed when chloroform or ether was the only choice. Formerly, when it was desired to reduce bleeding in operations where this was liable to be excessive, for example mastectomy, the anaesthetist might choose or frequently the surgeon would indicate a preference for chloroform. Nowadays, with cyclopropane or ether administered in closed circuit apparatus, it would appear that the problem has become more acute or at least is attracting more attention. Perhaps unwittingly, many anaesthetists have tended to ignore the persistent oozing which is associated so often with modern inhalational methods. The less toxic quality of the newer agents is emphasized as an overwhelming advantage with the implication that this should silence criticism in regard to bleeding. From the point of view of scarcity of donors alone the problem is a pressing one and it is possible that more might be done by anaes-

thetists towards reducing the necessity for so much blood transfusion as is employed at the present time. A pint of blood saved may well be worth two from the 'bank.'

For lack of an adequate or convincing explanation from his anaesthetist a surgeon may be inclined to blame the anaesthetic apparatus, cyclopropane, curare or even 'too much oxygen' for troublesome bleeding. These objects of suspicion are frequently culpable in some degree but a more precise ascertainment of the fundamental causes of abnormal bleeding during inhalational anaesthesia is desirable. Unavoidable factors not related to the anaesthetic procedure may be present. Thus, pathological conditions such as blood dyscrasias, hypertension, pyrexia and metabolic disturbances in which the basal rate is raised are possibilities to be kept in mind. The first of these raises the question of prolonged coagulation time of the blood. Without sufficient reason, an alteration in coagulation time is sometimes incautiously suggested as the cause of excessive oozing. Actually, anaesthetic drugs have no significant effect on bleeding time or coagulation time. The latter is slightly prolonged by nitrous oxide but with chloroform and ether it is shortened. Cyclopropane and the barbiturates produce no change. Only in patients suffering from certain diseases of the blood can excessive bleeding during general anaesthesia be attributed to slow clotting.

Important factors which can influence the amount of bleeding are the action of the anaesthetic on circulatory and respiratory function and the depth of anaesthesia. To some extent these are interdependent.

Chloroform, ethyl chloride, ether and cyclopropane all cause vasodilatation. The first two have additionally a depressant action on the heart resulting in a reduction in output and less bleeding. With the last two there is an initial increase in cardiac output and this in combination with vasodilatation is responsible for profuse peripheral bleeding which continues while the anaesthesia remains in a light plane or until the patient has lost much blood. During light anaesthesia also the blood pressure rises in response to surgical stimuli, unless these are severe, and causes further loss. Increased concentration of the anaesthetic vapour or gas produces central depression, lowered blood pressure and less bleeding. With inhalational agents therefore bleeding can only be minimized by concentrations sufficient to produce deep anaesthesia unless the anaesthetist chooses to use chloroform which through its direct action lowers the blood pressure even when anaesthesia is light.

The effects of the anaesthetic agent and technique on respiratory function bear an important relationship to bleeding during operation. In

this connection the anaesthetist is concerned mainly with the prevention of a rise in blood pressure rather than positive measures for reducing normal pressure although even that is possible if he is prepared to carry out hyperventilation through soda lime and so lower the tension of carbon dioxide in the patient's blood to a level which interferes with the dissociation of oxygen and causes anoxia.

Simple mechanical respiratory obstruction produces partial asphyxia with impedance of carbon dioxide and an insufficient intake of oxygen. The resulting venous congestion, capillary dilatation and raised blood pressure cause profuse bleeding followed, however, by a reduction due to vasoconstriction and increased viscosity of the blood when the tension of carbon dioxide reaches a high level. This complication which is as old as anaesthesia itself still occurs but in the modern style the difficulty is sometimes of the anaesthetist's own making and often its exact location is not readily discovered as for example when a tracheal tube becomes blocked or because of extra length it passes beyond the bifurcation of the trachea. Closed circuit technique is not above suspicion as a cause of venous congestion and increased bleeding. Resistance in the apparatus to respiration is sometimes sufficient to do this and may be demonstrated by removing the rebreathing bag and noting the reduction in venous oozing in an operation such as thyroidectomy.

More common are the complications which arise as a result of hypoventilation. Shallow respiration and even apnoea are common features of general anaesthesia when closed circuit apparatus and cyclopropane are employed. If, in addition, curare is given to the patient peripheral respiratory paralysis increases considerably the disorganization of respiratory function. Such a condition is easily controlled but in its lesser degrees hypoventilation is sometimes inadequately rectified and in consequence there may be considerable retention of carbon dioxide followed by a rise in blood pressure and increased bleeding in the field of operation. Even without curare this may happen and in such circumstances the anaesthetist must always assist the patient's pulmonary ventilation and ensure that an efficient tidal exchange is maintained. If, after elimination of carbon dioxide, the blood pressure remains higher than normal, the cause, whether curare is being used or not, probably lies in the inadequacy of the narcosis.

Inhalational anaesthesia in its modern form has many advantages for the patient being much less disagreeable in the induction period and having fewer post-operative sequelae. For thoracic operations, and others not requiring maximal muscular relaxation, it is probably superior in an

all round sense to other methods but even in its most refined standards it is doubtful whether, alone, it serves fully the requirements of the long and severe operations now carried out in the abdomen. Success with inhalational anaesthesia demands a much higher degree of technical dexterity and more fundamental physiological and pharmacological knowledge on the part of the administrator than ever before. In the hands of the inexperienced there are many things that may

go wrong and create dangers that are just as great, if not greater because they are more insidious than those associated with the older, and simpler methods.

The observation so often made in the past that the choice of the anaesthetist is more important than the choice of anaesthetic is indeed truer today than ever for the scope for unintentional foolishness and possible disaster has widened considerably.

A SYSTEM OF ANAESTHESIA USING D-TUBOCURARINE CHLORIDE FOR CHEST SURGERY

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The exciting and exploratory spirit which has become apparent of recent years in surgery would have been frustrated were it not that anaesthesia advanced contemporaneously. In no field has this spirit in surgery and this progress in anaesthesia been more in evidence than in the radical treatment of disease of the thoracic viscera. The pioneer work of Sauerbruch (1904) in Germany and the modern developments in America and Great Britain have produced an era in which surgical procedures of a gravity and extent hitherto considered impossible have become everyday events. The total or partial removal of a lung is now a rather less hazardous proposition than a major abdominal operation. Intra-cardiac surgery and the operative treatment of congenitally abnormal vascular channels are possible and new hope has been given to many patients hitherto doomed to starvation by removal and reconstitution of the diseased oesophagus. Moreover the surgery of tuberculous disease of the lungs has progressed far since the first thoracoplasty was performed in this country by Mr. H. Morriston Davies in 1912. It is the purpose of this paper to show how one of the most recent discoveries in anaesthesia is playing its part in these advances and materially contributing to successful surgery within the thorax. It is necessary first, however, to consider how the upset to a patient consequent upon the creation of an open pneumothorax can be offset by the anaesthetist.

Controlled respiration. In the presence of an open pneumothorax or when the pleura has been freed from the chest wall in thoracoplasty, certain

mechanical disorders in the respiration are likely to occur. On the affected side the lung will collapse on inspiration and expand on expiration. This phenomenon has been described as 'paradoxical respiration' and it results in a certain amount of vitiated air passing from the collapsed to the normally expanded lung on each inspiration, and, if there is a sufficiently big respiratory excursion, it may lead to the spread of infected secretion into the bronchial tree and so from the diseased to the sound lung. Paradoxical movement of this kind will cause the mediastinum, if it is mobile, to swing away from the open side on inspiration and back on expiration. This 'flap' may interfere with the normal inspiratory filling of the opposite lung and by reducing the venous return to the heart result in sudden circulatory collapse.

For these reasons it is advisable during a thoracoplasty under general anaesthesia and essential in the presence of an open thorax, to control the respiration and avoid such irregular movements. Sauerbruch (1904) devised two methods of counteracting these undesirable effects both of which depend upon the production of a pressure gradient between, on the one hand, the atmosphere breathed by the patient and, on the other, the exposed lungs. In his 'Unterdruck Kammer' the head of the patient was occluded by an airtight rubber diaphragm from a room in which the remainder of his body together with the surgeon and his assistants were subjected to a pressure lower than atmospheric. The patient continued to breathe air at atmospheric pressure. Thus when the chest was opened there was no increase of