# Neurosurgical Anaesthesia

A. R. Hunter

Second edition

# NEUROSURGICAL ANAESTHESIA

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SECOND EDITION

BLACKWELL SCIENTIFIC PUBLICATIONS

OXFORD LONDON EDINBURGH MELBOURNE

Osney Mead, Oxford,
85 Marylebone High Street, London, W1M 3DE,
9 Forrest Road, Edinburgh
P.O. Box 9, North Balwyn, Victoria, Australia



ISBN 0 632 00091 0

FIRST PUBLISHED 1964
SECOND EDITION 1975

*Distributed in the United States of America by*
J. B. LIPPINCOTT COMPANY, PHILADELPHIA,
*and in Canada by*
J. B. LIPPINCOTT COMPANY OF CANADA LTD, TORONTO

*Printed in Great Britain at*
THE ALDEN PRESS
*and bound by*
THE KEMP HALL BINDERY, OXFORD

# PREFACE

## TO THE SECOND EDITION

Though this volume bears the title of its predecessor it is a new book. Only a very few parts of the first edition remain and these have been extensively revised to include current material and views. The pattern of the earlier volume is retained in that the basic physiological and pharmacological facts upon which the practice is neurosurgical anaesthesia are first presented. The explosion of knowledge about cerebral blood flow and the wide use of osmotic diuretics has, however, resulted in so tremendous an expansion that these subjects now merit chapters on their own. The pathology of the various diseases for which operations are performed now seems to belong more appropriately to the parts of the book which deal with individual conditions and anaesthesia for their surgical treatment. This organization has permitted the whole book to be so arranged that the anaesthetist who seeks information about the manner of dealing with a specific case can look up the subject in the index and then by turning to the relevant pages find not only an account of an appropriate anaesthetic technique but a sufficient description of the pathology of the condition to allow him to have a real comprehension of the significance of what is suggested.

It is not the author's view that there is only one satisfactory anaesthetic technique for each operative procedure. To this end some alternatives are offered where these seem appropriate. But the author has found one particular technique to give good results in his hands for each of the operations performed by his colleagues in the Manchester Neurosurgical Unit, though it does not follow that they will be equally satisfactory for the same operations performed by other surgeons.

It must be admitted that the method of technique selection has not always been based on the application of rigid statistical analysis of results obtained, though this has been employed wherever possible. The patients who come for operation are indeed so variable that an effective series of comparable cases cannot be built up in reasonable time. One is driven back on the principle of allowing the dog its first bite but destroying it after its second. In other words if an untoward incident mars the course of some type of anaesthesia on one occasion this is not sufficient reason for abandoning it. If the same untoward incident reappears on a second occasion then the technique is assumed to be responsible and is rejected or at least suitably modified.

The author is indebted to Mr R. T. Johnson and to Dr Bruce Foster for reading the manuscript and for many helpful suggestions, and to Dr Ian Isherwood for permission to reproduce the radiographs. As previously the Department of Medical Illustration helped vastly with their excellent line drawings and photographs. Mrs Ivy Allcock typed the manuscript more times than the author likes to remember and the other members of the secretarial staff of the Department of Anaesthetics also helped in this task. Illustrations were also provided by the manufacturers of apparatus. To these and to the long-suffering publishers who bore with delays in the preparation of the final form of the manuscript, the author is eternally grateful.

## TO THE FIRST EDITION

This book is an attempt to put on record the various methods of anaesthesia, which in the course of some 20 years' experience of neurosurgical work, have in the author's view, proved their worth. It is perhaps unfortunate that he is unable to offer controlled series of investigations to prove the various points made. It is, however, a regrettable fact, that the cost of a failure on the part of a neurosurgical anaesthetist must be paid by the patient who is returned to bed with his operation uncompleted and it is simply not justifiable to persist with the techniques with appreciable failure rates. This means of course that the basis of development has been a process of trial and error. Fortunately the errors have been fairly few but in the course of these years a great deal has been learned by the author about the brain and its response to drugs, and it is hoped that this experience will be of interest to those working in related fields.

It is hoped too that this book will be to some extent a work of reference and for this reason a fairly extensive bibliography of relevant recent work has been included. For like reason no attempt has been made totally to eliminate the duplication of material, especially in the sections which deal with anaesthesia for particular types of intracranial operations and with the disturbances of the vital functions liable to arise in neurosurgery. Perhaps the specialist reader to whom all sections of the book are of interest will be willing to forgive the reduplication for the benefit of those to whom some chapters are of more importance than others. Also some upsets of the vital centres like hypothalamic disturbance and grosser disturbances of lower brain stem function, though they were common enough once upon a time, seem largely to have disappeared from the author's practice. From casual sentences in the papers of others, however, it would seem that they still occasionally occur. For this reason they too have been mentioned.

The author wishes to place on record his tremendous debt to the late Professor Sir Geoffrey Jefferson to whom this book is dedicated and who read one of the earlier versions of the manuscript. But for his inspiration and kindly encouragement this book would never have seen the light of day. The author is also indebted to Mr R. T. Johnson, Mr J. M. Potter and Mr J. E. M. Dutton with whom he has been privileged to work as the anaesthetist member of a team. His thanks are also due to the Departments of Medical Illustration at the United Manchester Hospitals and at Wythenshawe Hospital for their help in the preparation of illustrations and for permission to reproduce them and to the various manufacturers and journals who have provided blocks or photographs. Not least he is indebted to Mrs Ivy Allcock who has typed a large proportion of the manuscript.

A. R. HUNTER

*October, 1963*

# ACKNOWLEDGEMENTS

The author is grateful to those who have given permission to reproduce illustrations from other sources in this book. Figures 2, 3, 5, 15, 17, 27, 34, 35, and 53 come from the files of the Department of Neuroradiology of Manchester Royal Infirmary, and are reproduced by kind permission of Prof. Ian Isherwood. The author is also grateful to Mr. D. W. C. Northfield for permission to use Figure 35 taken from his book *Surgery of the Central Nervous System*.

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# INTRODUCTION

The basis of modern neurological surgery was laid by Harvey Cushing. He began his work as a pupil of Halstead at the Johns Hopkins Hospital in Baltimore at the turn of the century and later moved to Boston as Professor of Surgery at Harvard University. Following in the footsteps of his teacher, he developed a technique of meticulous and careful operating and case recording which persists with comparatively few modifications wherever neurosurgical operations are performed in the English-speaking world and in many places outside it.

Neurosurgical anaesthesia also had its beginnings in the Cushing clinic. It was then felt that local anaesthesia was the best method of all. Where unconsciousness had to be produced open ether gave satisfactory results. In the seventy years since Cushing began his work there have been changes in anaesthesia and anaesthetic drugs even more far reaching than those in neurosurgery. Thus though the original principles laid down by Cushing remain unchanged, it is necessary to review the agents and techniques now available by the same method of careful recording and assessment of results to consider what is the bearing of all the modern knowledge and skills in anaesthesia on the handling of the neurosurgical patient. Both Halstead and Cushing began their work on the basis of anatomy, physiology and pathology. The present work has similar starting points.

# CONTENTS

# CHAPTER I

# THE CEREBROSPINAL FLUID

## THE INTRACRANIAL PRESSURE

The most important consideration in relation to anaesthesia for neurosurgery is its effect on the intracranial pressure. The reason for this will become apparent later, but for the time being let it suffice to say that fully half the operations of neurosurgery will either be rendered impossible or will be performed at considerable prejudice to the patient's ultimate complete recovery if the activities of the anaesthetist raise the intracranial pressure. The factors which determine the pressure within the skull are therefore of supreme importance.

The intracranial pressure is determined by changes in three variables which are, to a greater or lesser extent, interrelated. These are:

1 The circulation of cerebrospinal fluid through the ventricular system and subarachnoid space.
2 The degree of hydration of the brain substance, or in less exact terms, the presence of or absence of cerebral oedema.
3 The state of the circulation in the cerebral arteries, veins and capillaries, and particularly the cerebral blood flow.

## THE CEREBROSPINAL FLUID CIRCULATION

The cerebrospinal fluid is formed by the choroid plexuses, mainly in the lateral ventricles whence it passes through the foramina of Monro to the 3rd ventricle and by the iter or aqueduct of Sylvius to the 4th ventricle. It escapes into the general subarachnoid space through the foramina of Luschka and Magendie which lie in the roof of the last-named cavity under the overhang of the cerebellar hemispheres. Most of the cerebrospinal fluid then passes upwards in the subarachnoid space of the posterior fossa, by way of the anteriorly placed cisterna pontis and by the cisterna ambiens. It then gains access to the supratentorial compartment of the skull. Part of the fluid then travels directly upwards over the cerebral hemispheres in the sulci to the arachnoid granulations alongside the superior longitudinal sinus. The remainder passes through the cisterna chiasmatis and finds its way to the same granulations either by passing round the genu of the corpus callosum into the space between the cerebral hemispheres or out along the Sylvian fissure.

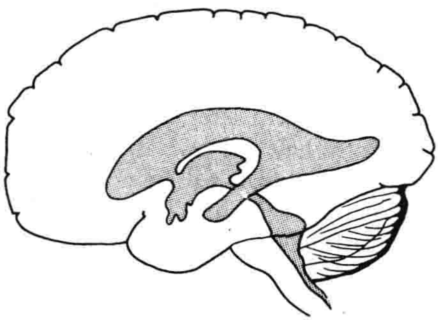

FIG. 1. The ventricular system of the brain.

The bulk of the cerebrospinal fluid is absorbed into the blood stream through the arachnoid granulations or Pacchionian bodies. Direct absorption into the veins probably occurs also. The forces producing absorption are not known for certain but the sponge-like structure of the granulations suggests a unidirectional valve [1]. Plasma protein osmotic pressure is not involved. Indeed protein escapes from the subarachnoid space through the arachnoid granulations. The remainder of the cerebrospinal fluid passes down alongside the spinal cord. Some is absorbed into the blood stream around the nerve roots and some escapes along the dural sleeve extra-spinally.

The normal total amount of the cerebrospinal fluid is about 150 ml in an adult. Of this, some 20–25 ml is contained in the lateral ventricles and the remainder distributed throughout the subarachnoid space around the brain and spinal cord.

## RADIOLOGY OF THE VENTRICULAR SYSTEM

The ventricular system of the brain is readily outlined, for purposes of diagnosis, with the aid of air which is relatively radiotranslucent (Fig. 2), or by putting a small amount of radioopaque oil (Myodil) into it (Fig. 3). The procedure is known as ventriculography or encephalography. In the former the contrast medium is put directly into the ventricles; in the latter air is introduced into the spinal subarachnoid space either by lumbar or cisternal puncture.

## CEREBROSPINAL FLUID PRESSURE

The accepted normal limits for the pressure of the cerebrospinal fluid are 60 to 180 mm saline (or c.s.f.). The rate of absorption of c.s.f. is directly proportional to its pressure down to 68 mm [2]. Below this value absorption ceases. This means that the c.s.f. pressure will always be positive (in the horizontal position).

The actual pressure recorded depends on the site of its measurement. In the sitting position the pressure in the lumbar theca is higher than that in the cisterna magna, but a straightforward hydrostatic relationship does not exist between the two. Somehow the degree of filling of the veins in the subarachnoid space modifies the picture. On the other hand there is a direct relationship between the distance from the theca to the right atrium and the cerebrospinal fluid pressure. Thus the vertebral venous plexus is 80 mm from the right atrium. In the lateral position both are at the same level and the pressures are the same. In the prone position the theca is 80 mm above the right atrium. The c.s.f. pressure is therefore 80 mm lower. In the supine position the reverse holds and the pressure in theca is 80 mm higher than it would be in the lateral position [3].

The cerebrospinal fluid pressure is not static. It varies with both the arterial pulsation and the respiration. The respiratory swing is imparted to it by the changes in central venous pressure. The arterial swing is the result of the pulsation of the arteries within the subarachnoid space.

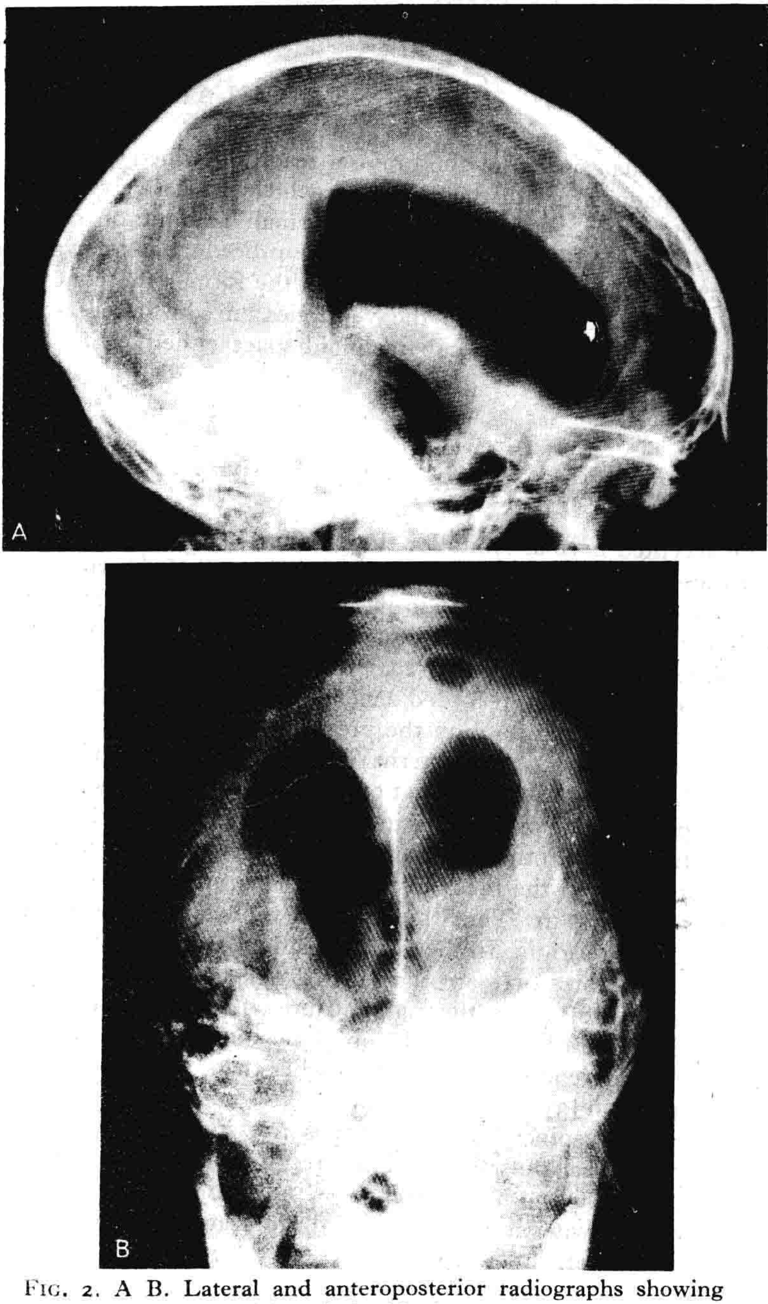


FIG. 2. A B. Lateral and anteroposterior radiographs showing (hydrocephalic) ventricles filled with air.

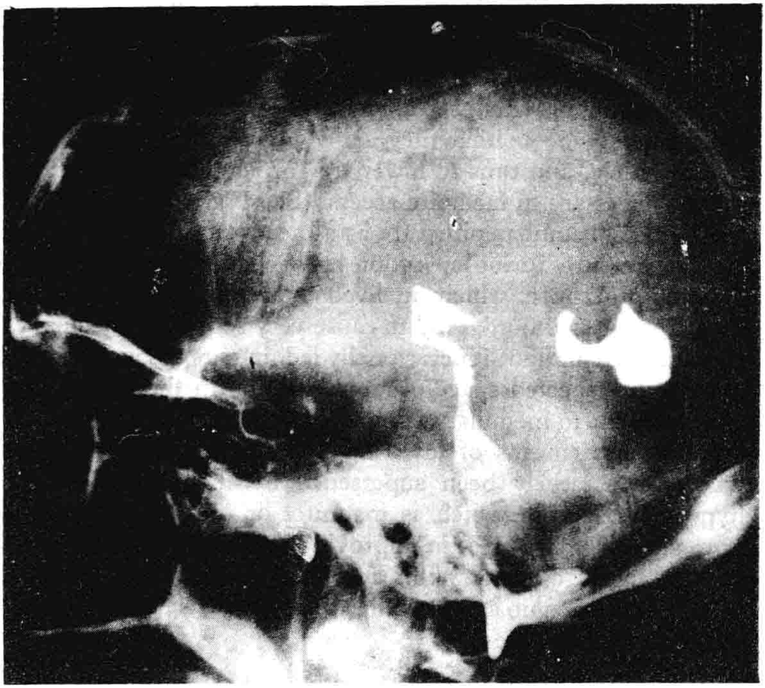

FIG. 3. Myodil ventriculogram. Posterior part of lateral ventricle and 3rd ventricle, item of sylvius and 4th ventricle outlined.

## SURGICAL REMOVAL OF CEREBROSPINAL FLUID

Removal of cerebrospinal fluid from the ventricular system of the brain by tapping can be achieved during most neurological procedures. The effect of such tapping is, of course, a fall in the pressure within the brain and a reduction in brain bulk. The degree of accessibility of the ventricular system varies considerably with the operative procedure and the pathology of the lesion. If the lesion is in the posterior fossa and the ventricles are dilated and hydrocephalic, the surgeon will have little difficulty in tapping them and allowing cerebrospinal fluid to escape thus reducing the intracranial pressure.

If, however, the ventricles are small, as they will be in the patient with a bulky suptratentorial tumour, the ventricle on the side of operation may be exceedingly difficult to find. Some neurosurgeons will, in such cases, make an initial burr hole on the contralateral side so that they are able to tap the frontal horn of that ventricle, and thus to lower the intracranial pressure should this be necessary to facilitate access. (See Fig. 17.)

The use of lumbar puncture as a means of lowering the intracranial pressure during operation [4] has largely ceased. Not only did this procedure, which involved the removal of practically all the cerebrospinal fluid, tend to cause very serious headache in the postoperative period; it occasionally led, in patients in whom there was an unsuspected space-occupying lesion in the supratentorial compartment to medullary coning (p. 232).

Mechanical means of lowering the intracranial pressure as a whole have largely been superseded by the administration of hypertonic solutions such as mannitol or urea. Ventricular tap, however, still has a place in improving the access to aneurysms on, or close to, the circle of Willis, for then the removal of some 15 or 20 ml of cerebrospinal fluid will lead to very considerable improvement in surgical access.

## CEREBROSPINAL FLUID PHYSIOLOGY

Cerebrospinal fluid can be regarded as an ultra-filtrate of blood plasma but some substances, for example bile pigment, never reach it; other components are present in different concentrations in the two fluids.

Some of the constituents of the cerebrospinal fluid are set out in Table I alongside the comparable figures for blood. The main difference is in the protein content which is negligible in cerebrospinal fluid and present in large amounts in blood. The amount of glucose in cerebrospinal fluid is a little less than that in blood. The extra 15 to 20 milli-equivalents of chloride serve to balance the concentration of the cations such as sodium, a function which is discharged in the blood by the plasma proteins. Cerebrospinal fluid is a slightly more acid than normal plasma (mean pH 7.33) [5]. It is generally agreed that the bicarbonate concentration in the cerebrospinal fluid is slightly lower than that of plasma though not

TABLE I. Some constituents of the cerebrospinal fluid and blood (modified from *Documenta Geigy*) [15]

| | Cerebrospinal fluid | Blood |
|---|---|---|
| Protein | 24–40 mg/100 ml | 6.0–7.4 g/100 ml |
| Urea | 10–30 mg/100 ml | 19–32 mg/100 ml |
| Glucose | 45–80 mg/100 ml | 75–91 mg/100 ml |
| Sodium | 141 ±0.45 mEq/l. | 134–154 mEq/l. |
| Potassium | 2.96 ±0.45 mEq/l. | 4.1 ±0.3 mEq/l. |
| Calcium | 2.45 ±0.45 mEq/l. | 2.2 ±2.6 mEq/l. |
| Chloride | 115–135 mEq/l. | 100–107 mEq/l. |
| Bicarbonate | 23 mEq/l. | 24 mEq/l. |
| pH | 7·32–7·35 | 7·35–7·4 |
| Lactate | 1.9 mM/l.* | 0.9 mM/l. [5] |

* Other authors quote c.s.f. lactate values of 0.93–1.9 mM/l. [16]

all accept this [6]. The difference involved, however, is only two-thirds of a milli-equivalent. Cerebrospinal fluid has a higher osmotic pressure than plasma [7]. The mean $P_{CO_2}$ of cerebrospinal fluid is 47 [5], that is it is in approximate equilibrium with the cerebral venous $P_{CO_2}$ and not with $Pa_{CO_2}$ (which under comparable circumstances will have a value of 40 mmHg).

Normally cerebrospinal fluid contains a very few cells, not more than five being present in one cubic millimetre of lumbar cerebrospinal fluid and none at all in the ventricular fluid.

There is also histological evidence to support the conception that the barrier between the blood and the cerebrospinal fluid is selective. Thus the glomerulus of the kidney, which is the organ which characteristically produces a protein-free filtrate of the plasma, is covered by a flat endothelium. The cells of the choroid plexuses, on the other hand, are cubical in shape and resemble much more closely the active cells of a secreting gland.

The fact that cerebrospinal fluid is not a passive ultra-filtrate is clearly illustrated in the recent work on the chemical control of respiration (p. 29). In this it has been shown that there exists between the plasma and the cerebrospinal fluid a barrier [8] which does not allow the free passage of hydrogen ions or bicarbonate ions, though it is permeable to carbon dioxide [9]. It is therefore not surprising that there is a pH and bicarbonate concentration difference between the two fluids in the normal individual (Table I). Both adenosine triphosphate and carbonic anhydrase are involved in the transfer of electrolytes from the plasma to the cerebrospinal fluid. As would be expected from the involvement of adenosine triphosphate energy is expended in the process [10].

Other aspects of the physiology of the cerebrospinal fluid have gone into the melting pot again in the last few years. Protein is added everywhere throughout the nervous system where there is contact with the circulation [11]. The function of the Pacchionian granulations is not primarily fluid absorption but protein absorption. The purpose of the choroid plexuses is to provide the bulk of of the fluid—they do not seem to add any more protein than any other part of the nervous system in contact with cerebrospinal fluid. These ideas call for some alteration in the current views concerning the aetiology and pathogenesis of hydrocephalus but until their meaning has been more fully worked out it is probably more satisfactory to think in terms of the older ideas of Weed [12] who regarded cerebrospinal fluid as secreted by the choroid plexuses, and circulated through the cerebrospinal fluid pathways, with the reservation that this is almost certainly an oversimplification.

Recent work suggests that the mechanism of escape of cerebrospinal fluid from the subarachnoid space is identical with the escape of aqueous humour from the anterior chamber of the eye [13]. This latter occurs by a process involving the development of vacuoles in the endothelial membrane of the trabecular membrane which separates the anterior chamber from the canal of Schlemm [14]. These vacuoles ultimately rupture on the outer surface of the cells forming in effect temporary canals allowing the escape of the fluid. Similar vacuoles have been demonstrated in the lining cells of the arachnoid mater adjacent to the superior longitudinal sinus.

## CHANGES IN THE CEREBROSPINAL FLUID IN DISEASE

The constituents of the cerebrospinal fluid are subject to alteration in disease states. Most of these conditions interest mainly those