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SPINAL EPIDURAL ANALGESIA

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BY

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PREFACE

MANY of the more enthusiastic accounts of epidural analgesia were written before the advent of curare and the great advances in anaesthetic practice that have accompanied the introduction of the intravenous relaxant drugs and there is little doubt that if these accounts could be written again to day they would be presented with greater reserve Nevertheless, this study originated as a reaction from the limitations of the relaxant techniques, these notwithstanding their virtues, contribute nothing to the solution of the problems of operative blood loss and post-operative analgesia and encumber the anaesthetist with the treatment of paralytic apnoea

During the past half-century a great deal has been written about epidural analgesia, but it is widely scattered through the literature and to the beginner, seeking confidence in the experience of others, the task of appraising the technique is formidable This book is based on the records of 1,000 personal administrations over a period of five years, and is intended to present the available information on the subject, and to relate its theory and practice to known physical, anatomical, and physiological facts There is still much that is unknown about the epidural space and epidural analgesia, and for this reason I have hesitated to be opinionative except where my own experience has forced me to take sides in a doubtful issue

When using a new or a different technique the anaesthetist is entirely dependent on the attitude of his surgical colleagues In this respect I have been singularly fortunate, and it is a great pleasure to acknowledge the encouragement I have received from them

I am grateful for much gained in discussion with other anaesthetists, notably Professor R R Macintosh, Dr J Gillies, and Dr R Bryce Smith, and especially Dr C J Massey Dawkins, who was among the first to use lumbar epidural analgesia in England and whose experience in this field is so widely recognised

I am indebted to those authors and publishers who have given permission for the inclusion of various illustrations (cited

in the appropriate legend), and particularly to Professor R Walmsley for kindly allowing me access to his anatomical specimens and for providing the photograph shown in Fig 1

My thanks are due to Dr C J Harwood Little and Dr D P King for carrying out eosinophil counts, to Mr N Cridland for checking the statistics in Chapter VI to Dr J H Baird for radiographs, and to Mr E S Peacock for his care and skill in preparing the photographs

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P R B

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CONTENTS

CHAPTER I

INTRODUCTION

THE epidural space * region of fat and blood vessels between the dural envelope of the spinal cord and the bony walls of the spinal canal began to attract clinical attention at the turn of the last century Within this narrow space injected solutions track up and down, and outwards through the intervertebral foramina offering opportunities to the radiologist and the anaesthetist The space may be entered between the laminae of the vertebral arches (the "spinal" route), or from below through the sacral hiatus only the former approach concerns us in this book

Epidural analgesia of one sort or another has been practised since 1901, when Sicard[1] and Cathelin of France popularised the sacral approach Corning[2] has been credited with being the first to use the method in 1885 but from his own description of the two experiments he carried out it is evident that he neither intended nor achieved a genuine epi dural injection After the favourable reports of Sicard and Cathelin Tuffier attempted epidural analgesia by the lumbar route later in the same year[4] but his lack of success and the natural difficulties of locating a space two to four millimetres wide at a depth of ten to twenty times that amount discouraged all further attempts for many years In 1913 Heile tried to revive the idea of high epidural blocks by approaching the spinal canal laterally through the intervertebral foramina instead of by midline puncture.[5] Heile used this approach for surgical analgesia and for therapeutic purposes but his method does not seem to have had much following outside Germany In the meantime, the caudal route became established as the only safe approach to the epidural space and there was a tendency to limit the field of analgesia to the area supplied by the cauda equina[6] since efforts to carry the block higher met with very variable results owing to the wide variations of the sacrum and its foramina

* Extradural "Peridural and Epidural are synonyms Although the first of these is probably the most correct etymolog cally Epi dural is the shortest and trips most read ly from the tongue

This state of affairs continued until 1921 when Fidel Pagés' renewed interest in the midline lumbar approach pointing out the increased ease of access and wider applicability of this route as compared with the caudal route Pages method of identifying the epidural space was primarily tactile demanding great dexterity from the operator in order to detect the "feel" of the needle passing from the ligamentum flavum into the epidural space The degree of skill required for Pages' method was clearly a limiting factor to the technique, and other workers set about establishing mechanical substitutions for manual dexterity These refinements gradually developed, and it is now possible to obtain a very high success rate in lumbar epidural analgesia without possessing an unusual sensitivity of touch

Spinal epidural analgesia has never enjoyed a wide popularity in Britain, the possibility that the elements of hazard and virtuosity might be associated with its use have been sufficient to exclude the technique in favour of better tried methods With the advent of neuromuscular blocking agents, local injection techniques of every sort have suffered a decline, and any form of regional analgesia must be able to withstand severe scrutiny if it is to survive in competition with the safety, simplicity and efficiency of the intravenous relaxant drugs

In my opinion, however, spinal epidural analgesia is a simple, safe and effective method, having certain definite advantages over current relaxant techniques, in a limited field of surgery, as well as possessing a number of therapeutic applications The method provides a prolonged differential spinal block without the disadvantages of a subarachnoid injection, in which analgesia and reflex flaccidity exist in the presence of unimpaired motor power This is a state of affairs which is particularly desirable in abdominal surgery, since full spontaneous respiration can continue in spite of a completely relaxed abdomen, and the unique combination of complete analgesia and normal vital capacity persists in the early post operative phase Varying degrees of vascular hypotension are also obtainable, so that blood loss is diminished and operative conditions improved—a point of some importance in procedures involving extensive dissection and surgical extirpation Apart from these surgical considerations, epidural injections

have therapeutic applications in virtue of the sympathetic blockade which they induce

What of the difficulties of the method, and the incidence of failure? That there is a definite failure rate cannot be denied, but it is, or should be, a small one I find that my own incidence of failure, using a standardised technique, varies between 1 per cent and 1½ per cent, with a total number of fourteen failures in over 1,000 cases, if I varied my technique the failure-rate would be higher Later in this book emphasis will be laid on the necessity for the anaesthetist to make things easy for himself, that and the ability to be careful, is the only formula for uniform success A failure rate of this magnitude is accept able If one could not be assured of achieving success in more than 95 per cent of cases it would probably not be worth while retaining the method for routine use, but the odd 1 per cent that does go astray will be pardoned for the sake of the results in the other 99 Even the failed epidural (when intended for surgical purposes) is not beyond redemption with the relaxant drugs, which are always at hand to provide a good second best at short notice

Although epidural analgesia can be used in a wide field of surgery, including the chest and upper limbs, the real indica tions for its use are to be found in major surgery below the diaphragm, and as a therapeutic measure in a variety of pain ful and vasospastic conditions It is favoured for thoracoplasty by some, but in my opinion indications for epidural analgesia seldom arise as first choice in chest surgery, superior results being obtained by other methods Epidural analgesia should not be used indiscriminately, but it is a good method for many purposes, and in certain circumstances the best, and it is a technique which demands the serious attention of all anaes thetists who are prepared to give the care necessary for its satisfactory employment

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CHAPTER II

ANATOMY

WITHIN the cranium, the endosteal and meningeal layers of dura mater are closely united, but below the foramen magnum the two layers separate, the outer becoming the periosteal lining of the spinal canal, while the inner layer forms the spinal dura mater Between these two layers lies the epi , extra , or peri-dural space The spinal canal is triangular in cross section, and the epidural space is widest in the midline posteriorly, in the lumbar region averaging about 5 mm between the ligamentum flavum and the posterior surface of the spinal dura Owing to the obliquity of the verte bral laminae, the depth is increased slightly in close proximity to the inferior border of the lamina

The boundaries of the epidural space are —

Above The foramen magnum where the periosteal and spinal layers of dura fuse together Below The sacrococcygeal mem brane In front The posterior longitudinal ligament covering the posterior aspect of the vertebral bodies and the interverte bral discs Behind The anterior surface of the vertebral laminae and the ligamenta flava Laterally The pedicles of the vertebrae, and the intervertebral foramina

The ligamentum flavum is a landmark that is intimately concerned with the induction of epidural analgesia It is composed of tough elastic fibres disposed in a vertical direction connecting the upper and lower borders of adjacent laminae It is thinnest in the cervical region, becoming progressively thicker lower down the spine, and is thickest in the lumbar region The interspinous ligament, lying immediately super ficial to the ligamentum flavum in the median plane, is another landmark which is thickest and best defined in the lumbar region

CONTENTS OF THE EPIDURAL SPACE

1. The Spinal Dural Sac, with its segmental prolongations covering each pair of spinal nerve roots The dural tube tends to hug the anterior wall of the spinal canal, so that the anterior portion of the epidural space is narrow while posteriorly the

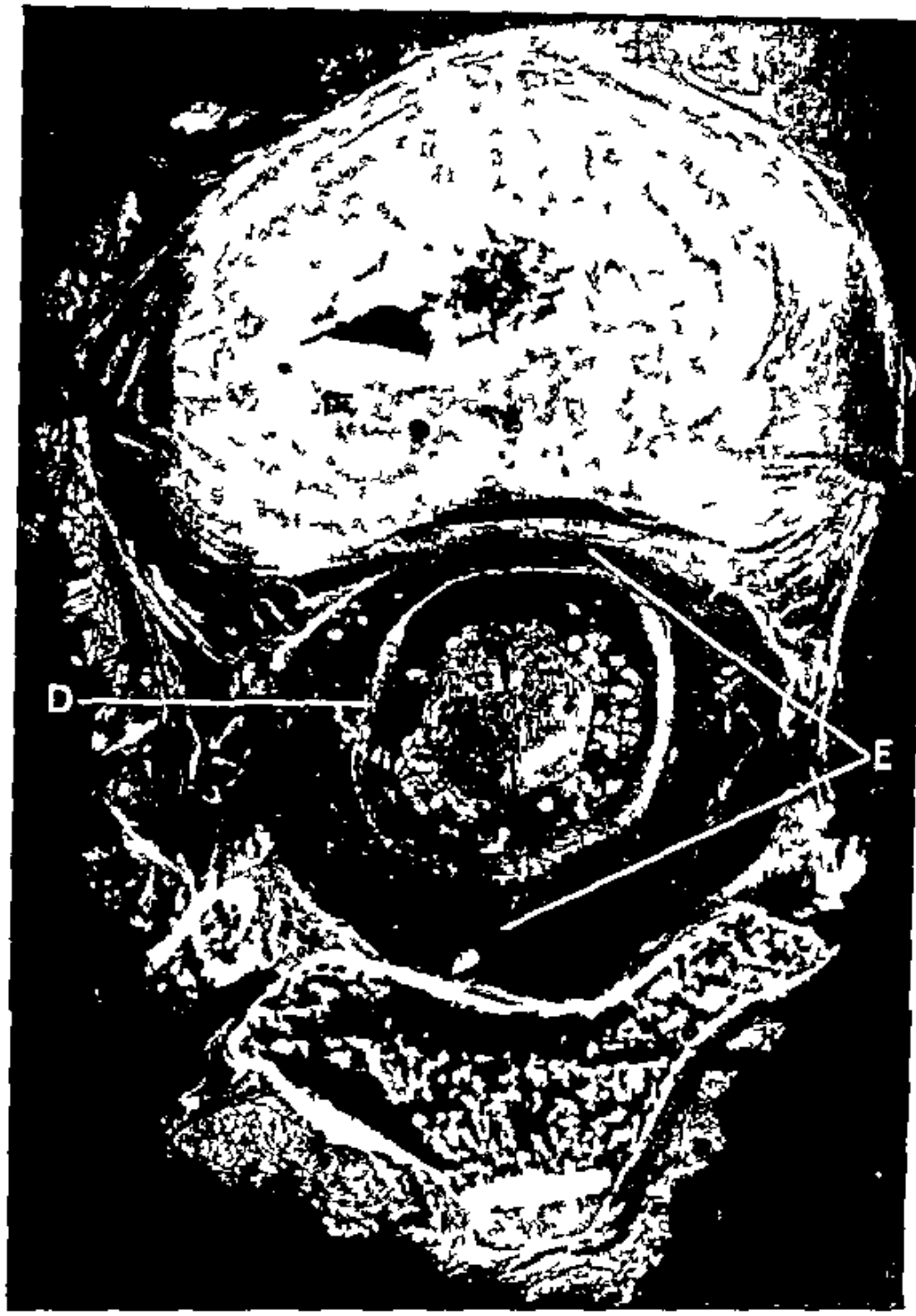

FIGURE 1

Transverse section of spine between 1st and 2nd lumbar vertebrae of three year old child (×3·5) D Dura mater thickest posteriorly E Epidural space wider posteriorly than in front

(Photograph kindly supplied by Professor R. Wolfenden)

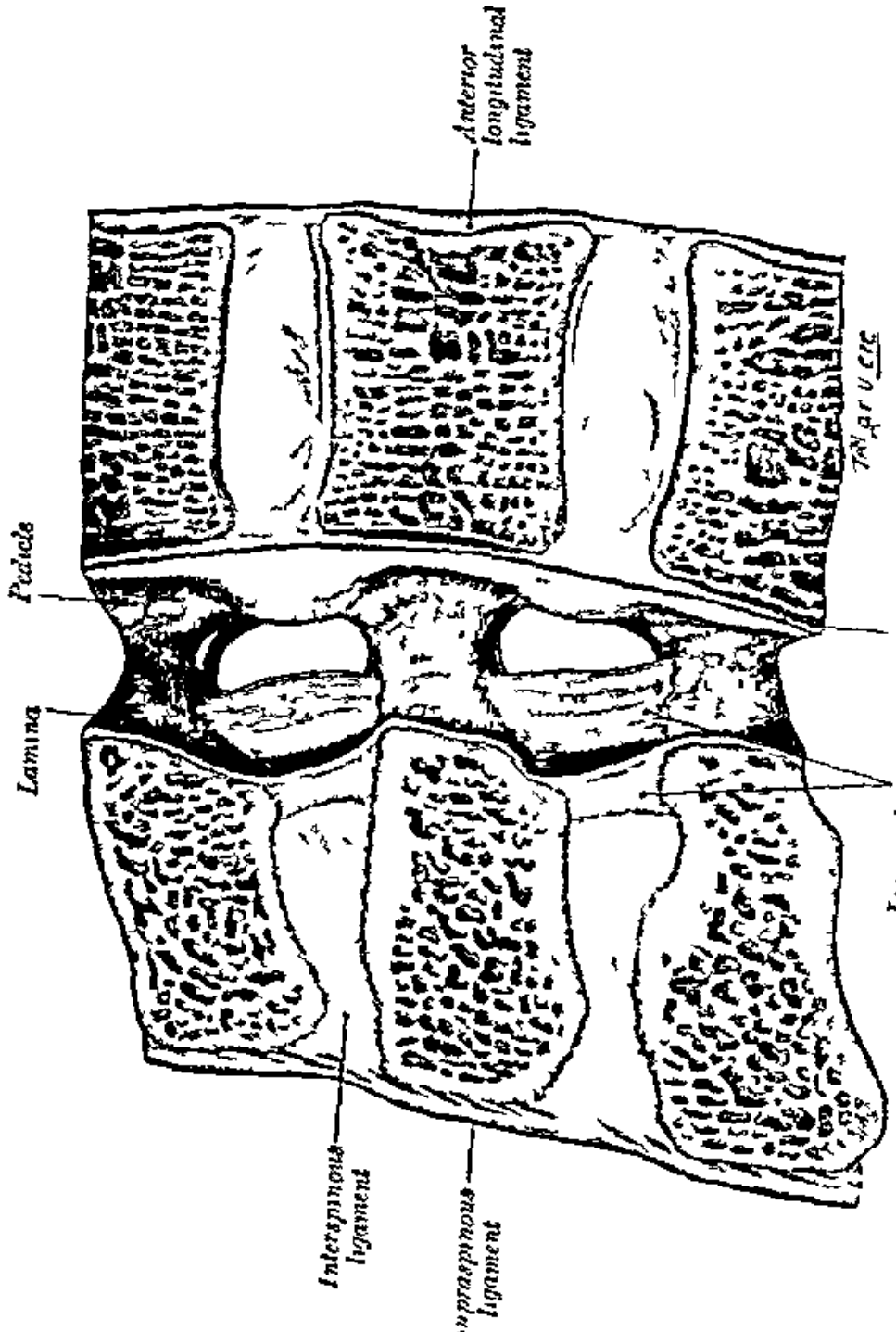

FIGURE 2
Median sagittal section through a portion of the lumbar region of the vertebral column (Drawn from a specimen)

space is much wider The dura is thickest posteriorly Fibrous strands pass from the posterior longitudinal ligament to the anterior aspect of the dura, anchoring it in place In the upper cervical region the spinal nerve roots and their dural coverings pass horizontally to their respective intervertebral foramina, but lower down they become more inclined, owing to the discrepancy between the length of the spinal cord and the spinal canal, until the lower lumbar and sacral roots are almost vertical Dural prolongations sheathe each pair of spinal roots enclos ing a small subarachnoid cul-de sac, and end by adhering

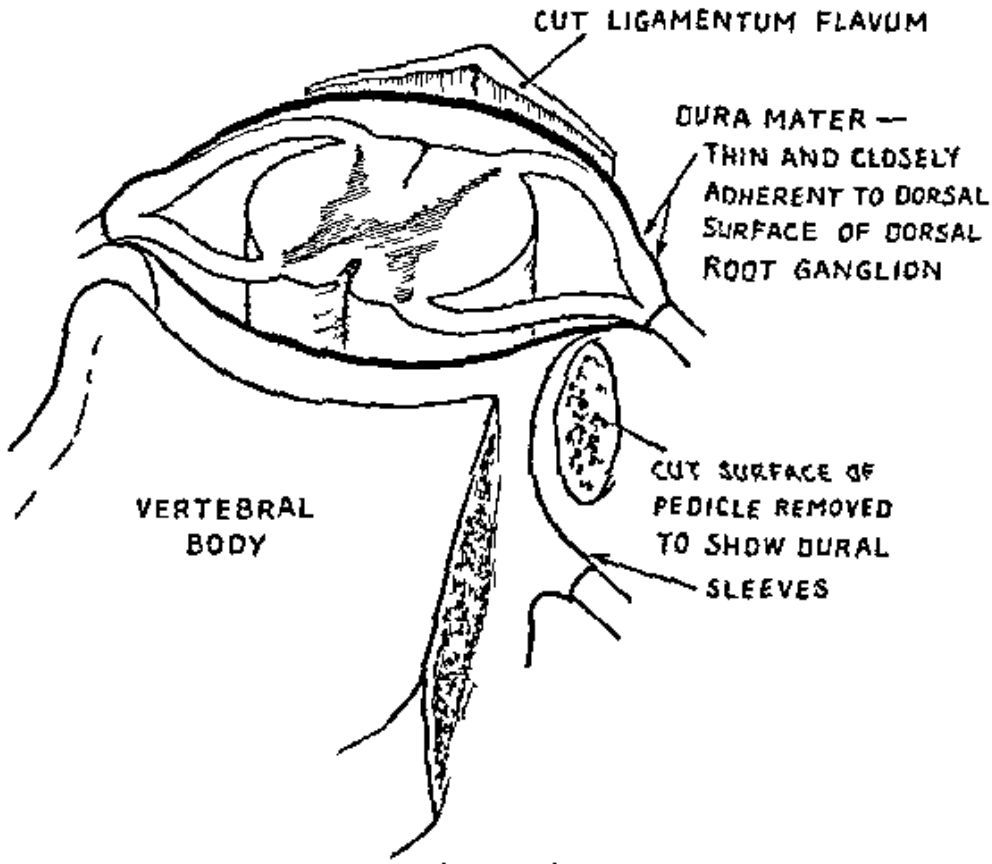

FIGURE 3
The dural cul de-sac surrounding a pair of spinal nerve roots

closely to the distal portion of the spinal ganglion at the point where the anterior and posterior roots fuse to form the " nerf de conjugaison " or first part of the mixed nerve, and here the dura is slightly thinner posteriorly Beyond this point the nerve is covered by perineurium The terminations of the dural cuffs occupy different positions in relation to the intervertebral foramen at different levels In the cervical region this termina

it is related to the internal aspect of the foramen, and in the lumbar and sacral regions it lies entirely within the sacral canal

2. Spinal Arteries.—Arteries derived embryologically from the intersegmental arteries enter the intervertebral foramina to supply the osseo ligamentous spinal canal and the spinal cord In the adult these arteries arise from the vertebral the ascend ing cervical, deep cervical, intercostal, lumbar and ilio lumbar arteries They anastomose with their neighbours above and below, and across the midline, and lie chiefly in the lateral parts of the epidural space

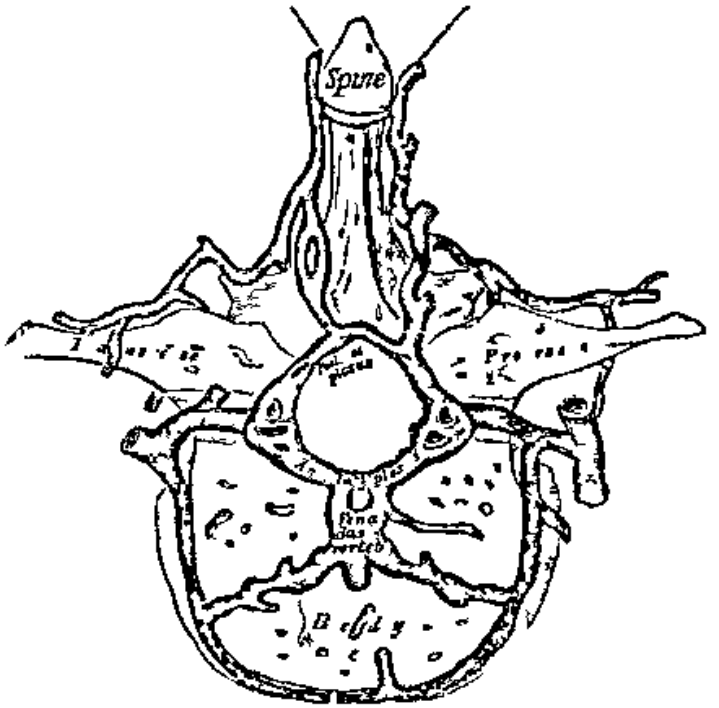

FIGURE 4
Transverse section through a thoracic vertebra showing the vertebral venous plexuses

3. Epidural Veins —The internal vertebral plexus, draining both cord and canal, lies mainly in the antero lateral parts of the epidural space It has rich segmental connections at all levels, and opens into the intervertebral veins which pass out through the intervertebral foramina and end in the vertebral, posterior intercostal, lumbar and lateral sacral veins Through this venous network increased intra abdominal and intrathor acic pressures (as in coughing or straining) are transmitted to the epidural space Under the stress of these pressures the

epidural veins distend and diminish the effective volume of the epidural space, so that if coughing occurs during, or immediately after, epidural injection the solution tends to spread more widely than usual

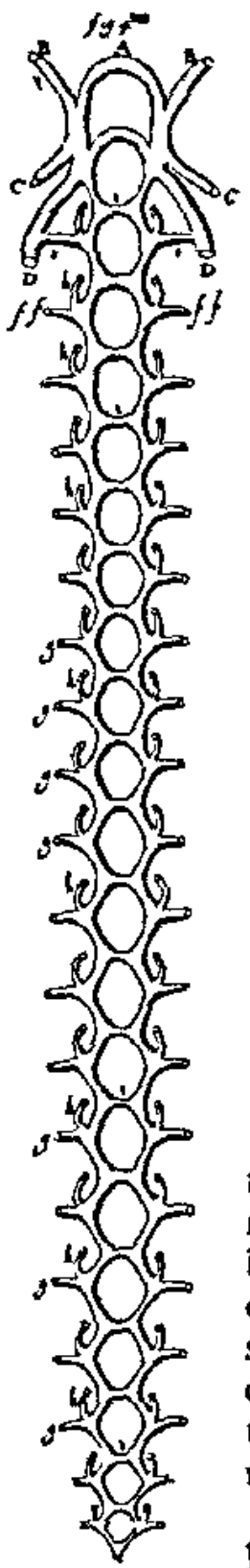

FIGURE 5

Diagram from Thomas Willis book Cerebri Anatome (1664)[1] showing the connections of the internal vertebral (epidural) venous plexuses

A Venous loop at the level of the foramen magnum

BB Connections between the vertebral plexuses and the cranial sinuses (occipital sigmoid and basilar)

CC Channels connecting the junction of the vertebral plexus and vertebral veins to the internal jugular vein

DD Vertebral veins

ee Tributaries from the vertebral plexus to the vertebral veins

ffff, gggg Intervertebral veins

hhhh Veins of the spinal cord connecting with the internal vertebral plexus

iiii Segmental commissural vessels opposite each vertebra

Above, the vertebral plexuses communicate with the occipital, sigmoid and basilar sinuses (Willis, 1664)[1] This primitive venous network forms a vascular highway between the pelvic and cranial cavities, and it has been shown that during abdominal compression material injected into the dorsal vein of the penis can be made to travel up the epidural veins to the cranial sinuses (Batson, 1940)[2] It has been suggested that this alternative route to the caval venous drainage of the pelvis explains the frequency of cerebral emboli and vertebral metastases from primary lesions in the pelvis

4. Fat.—The contents of the spinal canal lie cushioned in a packing of semi fluid, lobulated fat Solutions injected into the epidural space track up and down between the lobules of this fatty areolar tissue

The amount of fat in the epidural space tends to vary with that elsewhere in the body, obese patients having a well-stuffed and capacious epidural space

5. Lymphatics.—Lymphatic networks, surrounding and draining the dural cul-de sacs, empty into longitudinal channels in front of the vertebral column

OUTLETS OF THE EPIDURAL SPACE

A study of the outlets from the epidural space is important The patency of these outlets will determine the speed with which injected substances pass out of the space, and hence the height to which epidural injections will travel, and also the quantities required, and their persistence in the space The portals of exit are the intervertebral foramina, and the lymphatic and venous drainage routes

The Intervertebral Foramina.—There are fifty-eight foramina in all The areolar tissue around the exit of the intervertebral foramen varies in density according to age In the young it is soft and tenuous, but with age it undergoes increasing condensation, and can form a definitely recognisable structure Dr J Forestier, working with dried specimens, describes it thus—"As the nerve trunk leaves the intervertebral foramen it encounters an easily dissectable fibrous sheet which forms a sort of fibrous operculum to the external orifice of the intervertebral foramen"[3 4] Due to the effect of age in decreasing the patency of these main escape routes, it may be expected that a given volume of solution will travel further, and persist longer, in the aged than in the young

Lymphatic and Venous Drainage.—Injected solutions are absorbed quite rapidly by the epidural veins In 1901 Cathelin showed that methylene blue appeared in the urine sooner when injected epidurally than when administered by the subcutaneous route Absorption from the epidural space is delayed by vasoconstriction, or diminished venous blood flow The former can be brought about by adding adrenaline to the epidural solution, and the latter by the use of controlled vascular hypotension

SPREAD OF ANALGESIC SOLUTIONS IN THE EPIDURAL SPACE AND THEIR SITE OF ACTION

In 1901 Sicard[5] investigated the spread of coloured solutions injected through the sacrococcygeal membrane of dogs and human cadavers, and he found that the extent of the spread depended on the speed of injection and the quantity injected In 1904, Sicard and Cestan injected indian ink suspensions into the subarachnoid spaces of one group of dogs, and the epidural space of another[6] Ten days later they found that there had been no passage of ink either from within outwards, or without inwards across the dura in the group with epidural injections the ink particles stained the space with large black tracks and spread outwards through the intervertebral foramina and along the lymphatics to the regional lymph glands

X ray studies of the flow of solutions in the epidural space injected via the lumbar route of living subjects were first carried out by Sicard and Forestier in 1921,[7] using lipiodol In his thesis, Forestier describes the passage of the heavy oil outwards through the intervertebral foramina, and the influence of gravity in determining the direction of spread Farr repeated this work in fresh cadavers, using aqueous sodium iodide as a solution more likely to simulate the behaviour of local anal gesics in the epidural space He found that the whole epidural space was filled by 118 cc injected through the sacral canal, and that 89 cc extended up to the fourth thoracic segment[8]

The exact site of action of epidural analgesics is not clear but three possibilities exist[9] —

1 Diffusion occurs across the dura mater into the subarach noid space and cerebrospinal fluid, effecting a true "spinal" analgesia

2 The drugs act directly on dural-covered nerve roots in the epidural space

3 The nerves are affected distal to their dural sheaths after they have left the intervertebral foramina, producing a paravertebral block

For a long time the experimental evidence seemed to indicate that the last of these possibilities was the most likely, and epidural analgesia was regarded as an efficient way of producing an extensive bilateral paravertebral block[10] This

opinion was based chiefly upon some experiments by Bertocchi demonstrating the poor dialysing power of post mortem dura mater,[11] and the failure to recover any local anaesthetic from the cerebrospinal fluid of a patient under epidural analgesia [12]

More recently, however, it has been shown that during perfusion of the subarachnoid space of live dogs it is possible to recover up to 10 per cent of the dose of analgesic drug placed in the epidural space, and that four minutes after an epidural injection of 2 per cent procaine the concentration of procaine in the cerebrospinal fluid rises to 0 8 mg /ml (a concentration sufficient to depress nervous conduction) [13] Furthermore, the region of the dural cuffs has been shown to be particularly favourable to the passage of particulate matter [14] Indian ink suspensions with particle size of 0 4 - 1 5 μ readily pass out of the subarachnoid space, through this area, into the surrounding epidural tissue, and thence to the regional lymph glands (Fig 6) With colloidal carbon this passage takes less than half an hour [15] It seems reasonable to suppose that if coarse particulate matter can pass out with such ease through the "ink-cuff" area, the relatively tiny crystalloid molecules of a local analgesic solution should be able to find their way in through the same region, in the reverse direction

By using two spinal catheters simultaneously, one in the epidural space and the other in the subarachnoid space, Frumin *et al* found that in man significant concentrations of procaine appeared in the cerebrospinal fluid after epidural injection The rise and fall of procaine concentration in the cerebrospinal fluid was associated with the waxing and waning of clinical analgesia (*see* Fig 7) [16] They found that skin analgesia was present when the concentration of procaine in the cerebrospinal fluid rose above 0 015 per cent, and this figure agrees closely with the findings of Helrich *et al*, who showed that 0 02 per cent is the threshold concentration of procaine for effective subarachnoid analgesia [17] The experimental conditions of this investigation do not completely exclude the possibility of errors arising due to leakage of procaine solution around the subarachnoid catheter, nevertheless the results are highly suggestive, and add strong support to the body of circumstantial evidence in favour of the passage

of epidural solution across the intact dura into the subarachnoid space

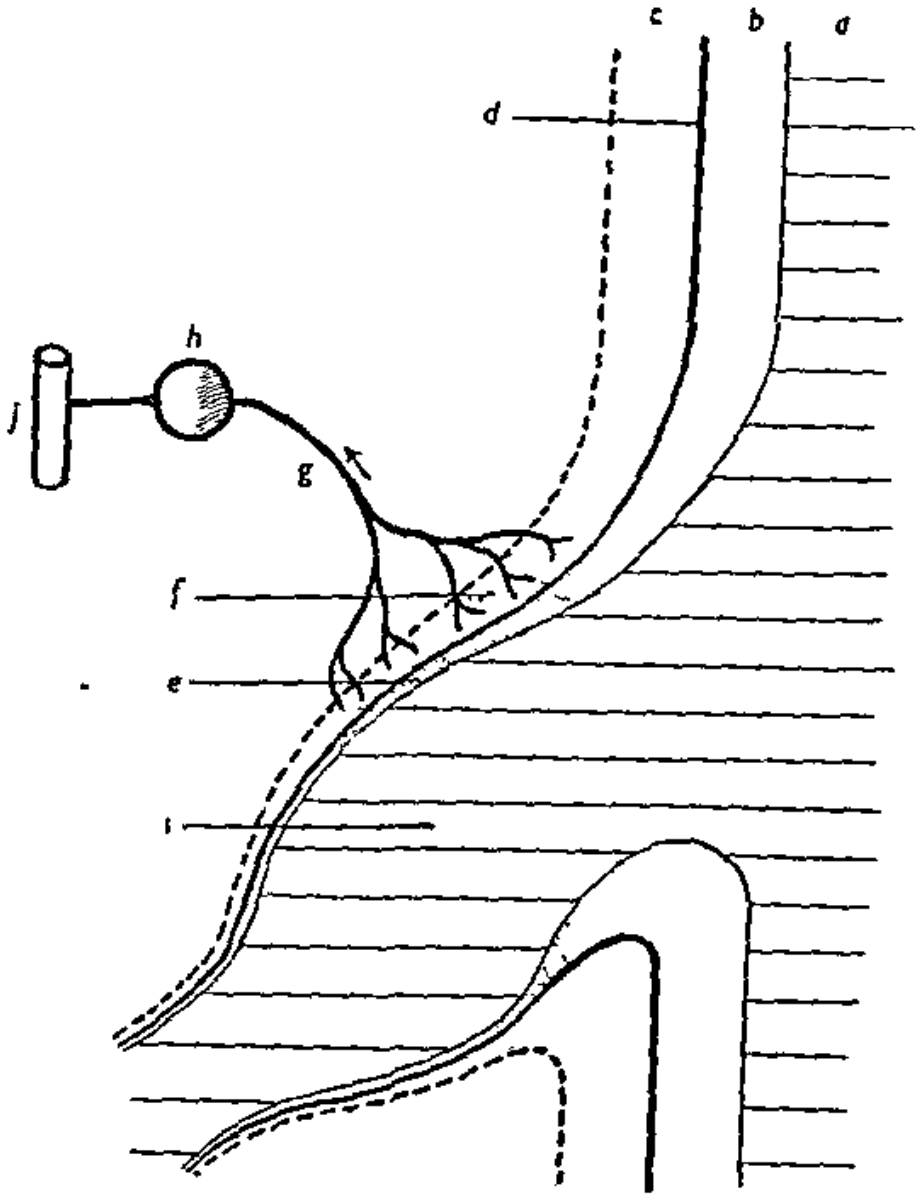

FIGURE 6

Diagram of spinal nerve root (rabbit) and its surrounding "ink-cuff," following the injection of Indian ink into the subarachnoid space

a, spinal cord, b, subarachnoid space, c, epidural connective tissue, d, dura mater, e, ink particles in subarachnoid cul-de-sac; f, ink particles in epidural connective tissue, g fine lymph channels draining epidural tissue, h lymph nodes of body wall, i, spinal nerve, j, longitudinal lymph channel

(Brierley and Field Journal of Anatomy 1919)

My own clinical observations confirm the impression that an epidural injection acts in some way within the spinal canal, and not beyond in the paravertebral spaces. On *page* 81 is

a correlation table for the size of dose required and the age of the patient. It will be seen that there is a strong inverse

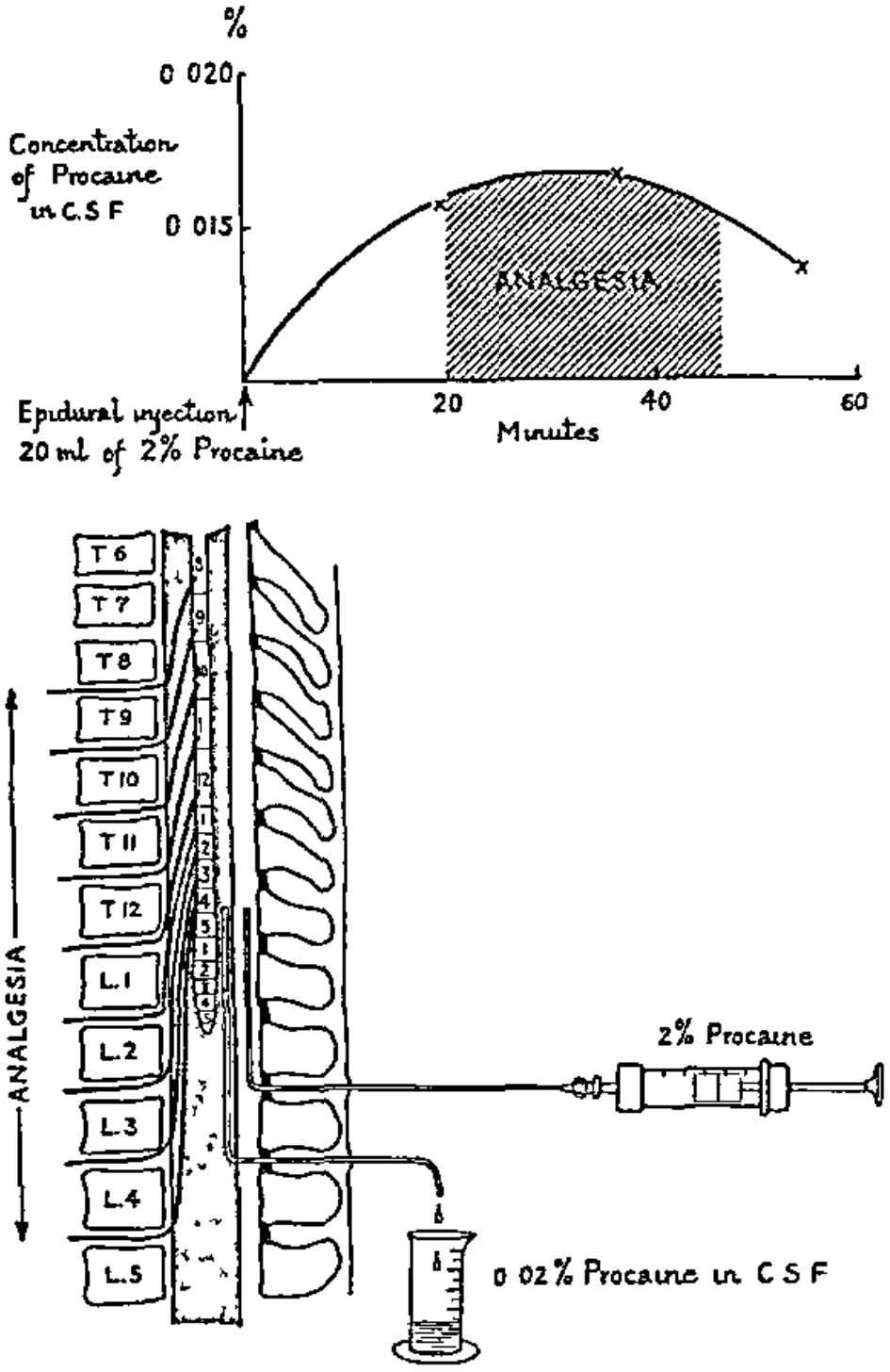

FIGURE 7
Recovery of procaine from the cerebro spinal fluid after epidural injection (*see* text)
(Drawn from data by Frumin et al., Journal of Pharmacology 1953)

relationship between dose and age (the greater the age the smaller the dose). This suggests that with increasing age the

FIGURE 8

Spread of solutions in the epidural space

(a)

Man aged 70 Height 5ft 7in 26 ml of analgesic solution injected between L_1 L_2 at the rate of 0 5 ml /sec fol lowed by 5 5 ml of Neo hydriol (Fluid) Analgesia complete in all segments up to T_2

(b)

Man aged 76 Height 5ft 6in 16 ml of analgesic solution injected between L_2 L_3 at the rate of 0 15 ml /sec., fol lowed by 5 25 ml of Neo-hydriol (Fluid) Analgesia complete in all segments up to T_4

Note that opaque solution does not track out along the intercostal nerves in the mid thoracic region although analgesia is complete in that distribution (X rays taken 1 hour after injection)

intervertebral foramina become less permeable, and so hinder the escape of epidural solutions so that a given volume travels further up the spinal canal and causes a wider area of block In some cases a dose of 27 ml or less has produced a block of all segments below the second or third thoracic segment for a period of three hours (a total of forty to forty two spinal nerves) it is scarcely possible to imagine even the most efficient paravertebral block lasting so long on a dose of less than 0 7 ml per nerve

Radiographs of the spine taken after the epidural injection of radio-opaque material encourage the notion that epidural analgesics act intraspinally rather than in the paravertebral spaces Five or six millilitres of a non viscous opaque oil were injected through the epidural needle immediately after a dose of local analgesic, so that the oil could spread out along the track of the aqueous solution and outline its passage through the intervertebral foramina Radiographs were taken one hour later The results of two such cases are shown in Figure 8 It will be seen that although a considerable amount of trans foraminal spread has taken place in the lumbar and upper thoracic segments, none has occurred in the mid thoracic region and yet in one case analgesia was complete at all levels up to the second thoracic segment and in the other up to the fourth thoracic segment showing that spread into the para vertebral tissues is not a pre requisite of successful epidural analgesia

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CHAPTER III

PHYSIOLOGY

NERVE fibres differ in size, function and anaesthetic susceptibilities Fibres of small diameter have a relatively large absorptive surface area in relation to their volume, and little or no myelin sheath, and so are more susceptible to the effects of local analgesics than larger fibres, since the volume of a nerve increases as the square of its radius, while its absorptive surface-area has a linear relation to the radius Fibres are classified broadly as A, B and C fibres, according to their size and functions, the largest and most heavily myelinated of these being the motor fibres with a diameter of about 20 microns[1 2] Strong analgesic

TABLE I

RELATIONSHIP OF NERVE FIBRE SIZE TO FUNCTION AND ANAESTHETIC REQUIREMENTS

Fibre Group	Diameter in μ	Function: Motor	Touch	Temp	Pain: Somatic	Pain: Visceral	Visc Efferent	Approx. concn of Nupercaine in epidural space to effect blockade
A α	20	+	+					> 1/600
A β	14		+	+	+			
A δ	9			+	+	+		1/600
B	7				+	+		
C	2 or less				+	+	+	1/1500

Blockade required for surgical analgesia

Blockade required for therapeutic purposes

solutions interrupt all varieties of fibre, while progressively weaker solutions spare increasing numbers of the larger nerves in order of size, producing varying degrees of *differential block*, as outlined in Table I

For surgical analgesia the nerve block should include as many pain fibres as possible from the operative field The presence of a motor block is unnecessary since a full afferent

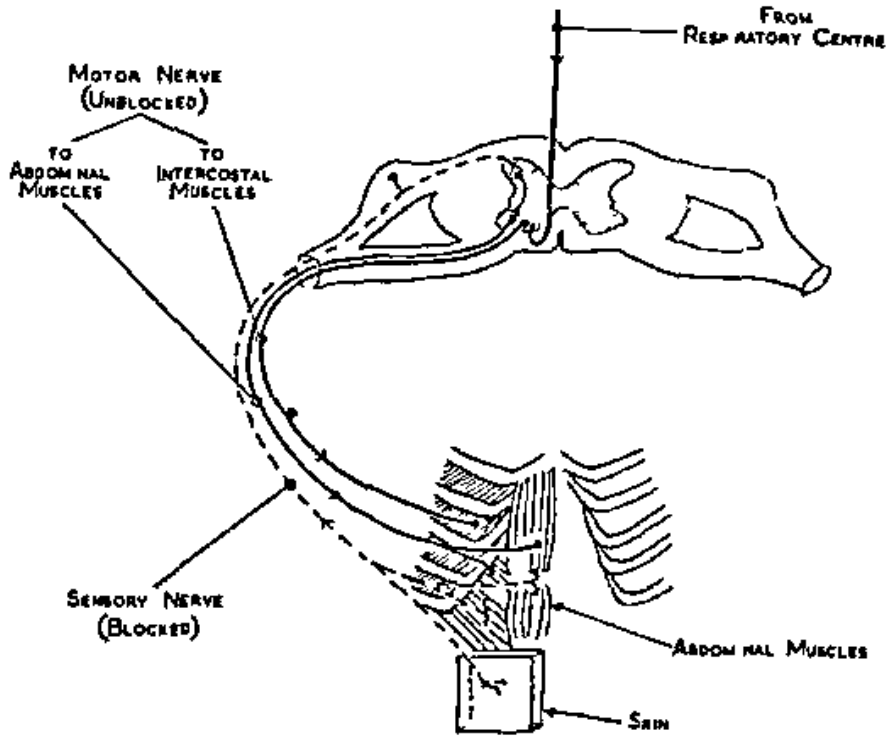

FIGURE 9

Differential neural blockade in the upper abdomen Correctly chosen concentrations of analgesic solutions block the afferent pathways but spare the motor nerves Reflex flaccidity results but the intercostal muscles can still respond to impulses from higher centres

blockade interrupts the reflex arc and produces *reflex relaxation* despite the persistence of an intact and potentially active final common motor pathway In fact, a motor block may be undesirable, for instance, in upper abdominal surgery interruption of motor as well as sensory nerves produces a certain amount of respiratory embarrassment and pulmonary stasis, by eliminating lower intercostal activity, whereas a differential sensory block gives full abdominal relaxation in the presence of a normal tidal exchange, since the respiratory muscles can still function normally in response to stimuli arriving from the respiratory centre (*see* Fig 9) For therapeutic blocks, intended

to control conditions arising from disordered autonomic function, the autonomic afferent B fibres and the smaller C fibres are concerned, and here the patient will be grateful for the minimum amount of numbness caused by the injection as well as being able to retain the power of his limbs, for this purpose weak solutions are chosen, in order to spare all but the B and C fibres

In the absence of motor paralysis, the modifications of physiology which accompany a differential epidural block are all those associated with interruption of autonomic pathways, and the extent of these modifications will depend upon the number of segments anaesthetised The changes which concern the anaesthetist most closely are those of the cardiovascular system

BLOOD PRESSURE

Vascular tone is maintained directly by the vasomotor nerves emerging in the sympathetic outflow between the first thoracic and second lumbar segments, and indirectly through the secretion of adrenal medullary hormones in response to stimuli mediated through the splanchnic nerves It may be expected, therefore, that the interruption of sympathetic nerves produced by an epidural block will cause a fall of blood pressure in proportion to the segmental involvement of the block In the past there has been considerable confusion of thought over this point, and it has been claimed by some authorities that epidural analgesia, unlike subarachnoid analgesia, spared the vasomotor nerves in some way, so that blood pressures were very little altered, even in the presence of a high sensory block[3 4 5 6 7 8] Others, notably Clay Shaw,[9] Abajian[10] and the German writers Denecke,[11] Duttman,[12] and Goepel,[13] observed falls of blood pressure comparable to those found in subarachnoid analgesia, and my own observations have been in accordance with their findings[14]

Figure 10 shows the relationship between the upper limit of skin analgesia and the fall of mean arterial pressure in 120 consecutive cases of lumbar epidural block It will be noticed that there is a linear relationship between the height of the block and the new level of blood pressure, the degree of hypotension depending entirely on the number of segments involved and not on the initial height of the blood pressure

The onset of hypotension is apparent in the falling diastolic pressure before any change in the systolic

These falls of blood pressure may be masked in the conscious patient Page and Taylor have shown experimentally

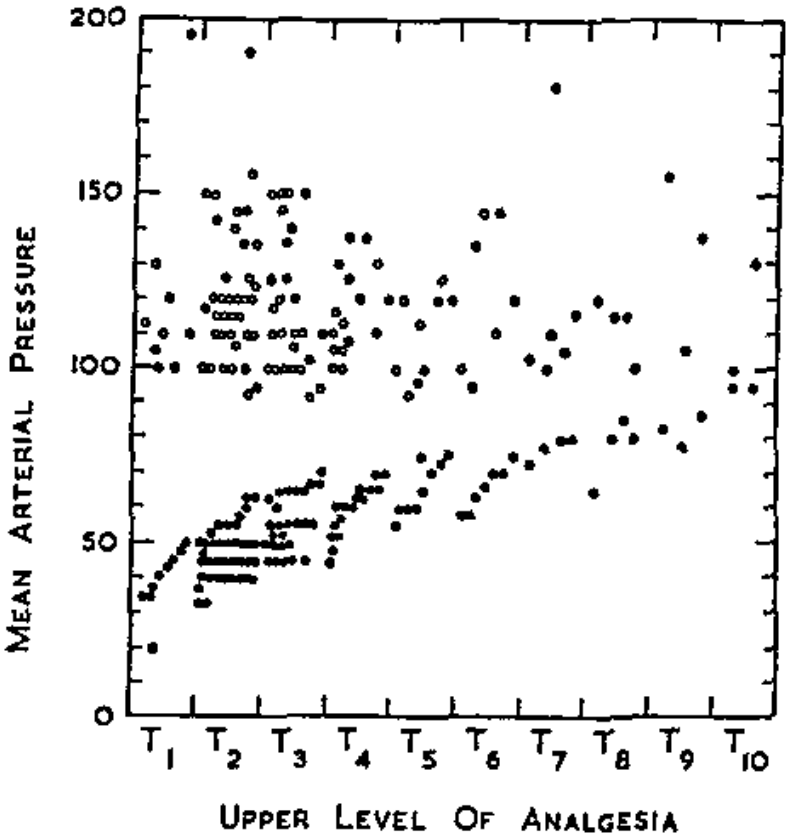

FIGURE 10

Relation between blood pressure and the segmental involvement of the epidural block in 120 patients (Light general anaesthesia used in every case)
The Mean Arterial Blood Pressure is expressed as the arithmetic mean of the systolic and diastolic pressures O=Pre operative resting level ●=Lowest level after induction of epidural analgesia

that the isolated brain can act as a pressor organ [15a, b] and clinically, consciousness alone may have a marked pressor effect In a few cases the blood pressure is sustained at normal levels after a moderately high epidural block, but as soon as light general anaesthesia is induced the mean arterial pressure falls to a level determined by the segmental extent of the block, and rises again immediately the patient awakes (*see* Fig 11) The belief that epidural analgesia does not lower the blood pressure may have arisen from the observation of an unusually high proportion of such cases in centres where it

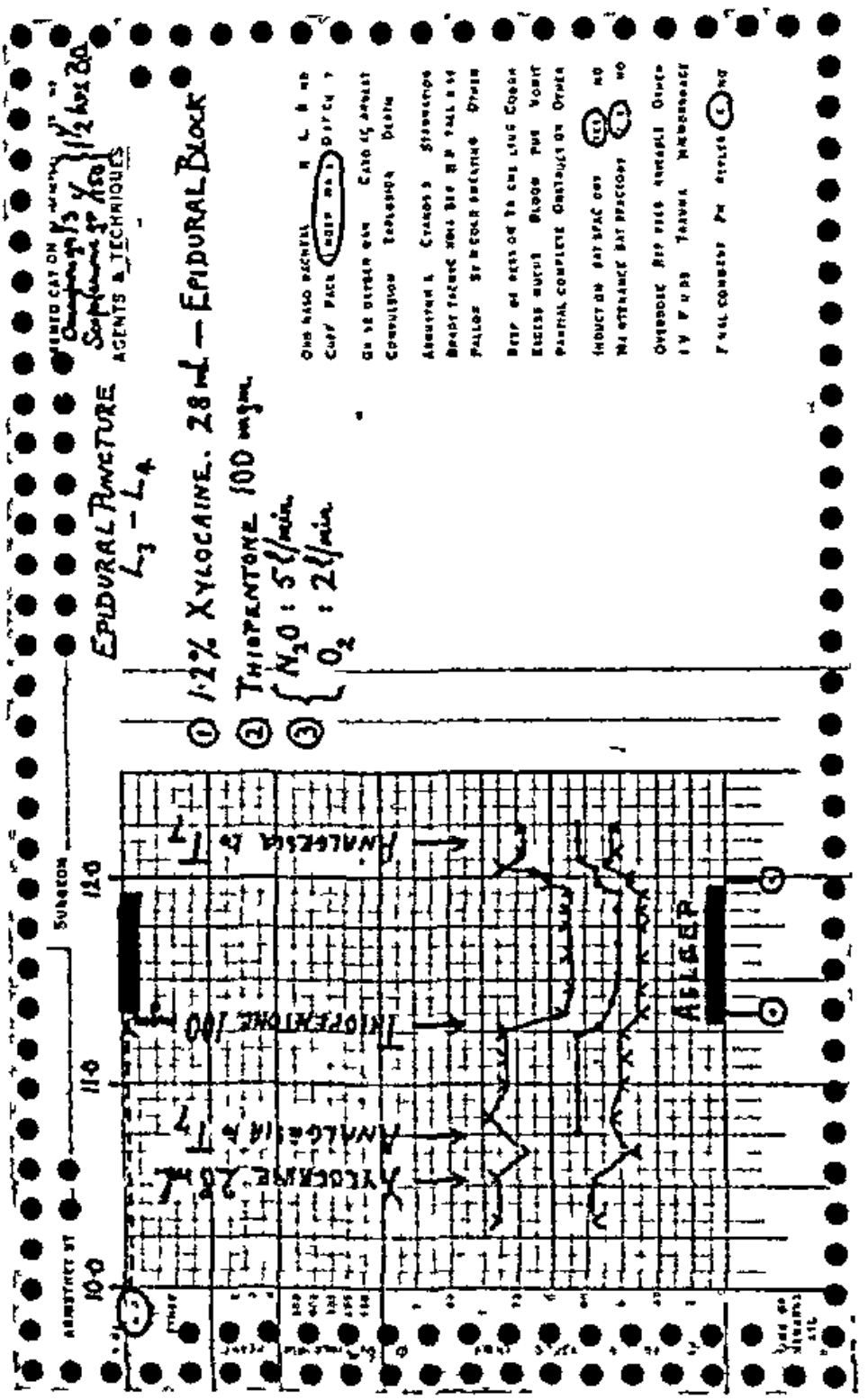

FIGURE 11

Consciousness as a pressor factor

Blood pressure chart of a woman of 56 undergoing vulvectomy. Epidural block to seventh thoracic segment. Note that the blood pressure starts to fall after induction of the epidural block, but a compensatory rise maintains the pressure at an unexpectedly high level. Light sleep, induced with a small dose of thiopentone and a weak nitrous oxide mixture is accompanied by an abrupt fall of blood pressure. An equally abrupt rise occurs on regaining consciousness

is the custom to use epidural analgesia alone without general anaesthesia

Since debasement of the blood pressure is a natural accompaniment of high epidural block, it is necessary to consider the safety, or otherwise, of such falls and the limits that should be put to them, in order to avoid the occurrence of ischaemic anoxia in any important tissues

When Griffiths and Gillies first popularised the practice of controlled vascular hypotension by total spinal block, systolic pressures of 40 - 50 mm Hg were considered safe provided there was adequate ventilation and oxygenation [16] It was argued that the level of systemic arterial pressure is immaterial provided adequate capillary circulation exists this is ensured when the pressure at the arteriolar end of the capillary exceeds the sum of the venous pressure and the colloid osmotic pressure of the plasma, a total of about 32 mm Hg in normal man Arterial pressures in excess of 32 mm are expended solely in overcoming the peripheral resistance, and when this is removed by vasodilatation a systolic pressure a little in excess of 32 mm will suffice for tissue requirements While the main principle involved in Gillies' proposal is still valid, there has been a tendency to adopt a higher value for the lowest permissible level of blood pressure, particularly with regard to the following organs —

Heart.—Reduction of the peripheral resistance opposed to cardiac action reduces the amount of work done by the heart, and so lowers the heart's own demands for blood and oxygen But, in the presence of atheroma, coronary flow may be relatively inefficient, so that a disproportionately high perfusion pressure is required in order to maintain an adequate myocardial circulation, and systolic pressures below 60 - 70 mm Hg may not be safe Osher has shown that in the dog's heart a rapidly increasing disparity between coronary resistance and coronary flow occurs at pressures below 80 mm [17], the additional impedance of atheromatous coronary arteries will increase this disparity still further The anoxaemic test has been recommended as a pre-operative measure to unmask suspected coronary insufficiency [18] A 10 per cent oxygen mixture is breathed for five to ten minutes while electrocardiographic tracings are taken Depression of the S-T segment, exceeding 2 mm in Lead IV, or a total of 3 mm in all leads.

is taken to indicate anoxia of the subendocardial muscle and the presence of coronary insufficiency, although a negative test does not necessarily exclude coronary disease Besides the effect of blood pressure on the myocardium, paralysis of the efferent cardiac sympathetic nerves affects the heart rate

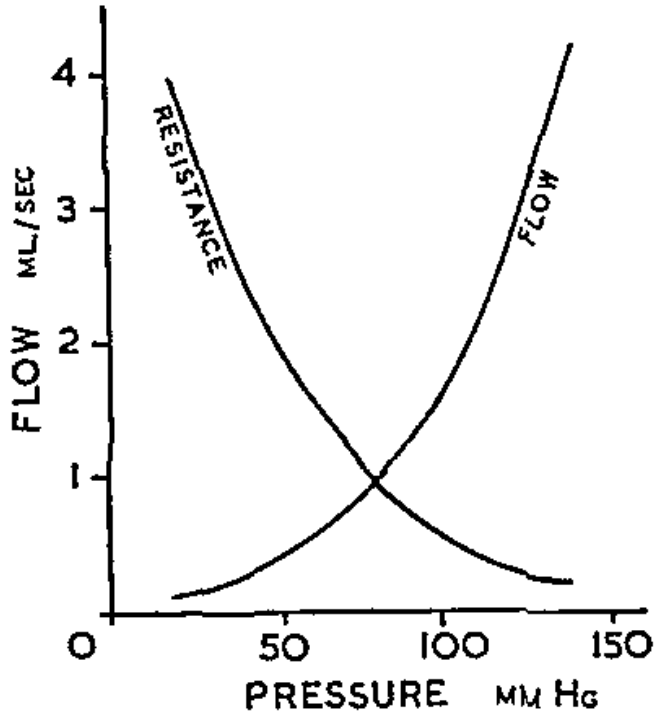

FIGURE 12

Relation between perfusion pressure and coronary resistance and blood flow (dog) Coronary resistance mounts steeply at pressures below 80 mm Hg

(After Ostei American Journal of Physiology 1955)

Cardio accelerator fibres arise from the upper five thoracic segments, and so involvement of these segments results in bradycardia, and pulse rates as low as 60 per minute are commonly found

Brain.—Of all the tissues in the body the brain is the least able to withstand anoxia Electroencephalographic studies in conscious subjects suggest that the limit of tolerance is approached at systolic pressures of 50 - 55 mm Hg in normal subjects, while in arteriosclerotic patients this is higher, at 70 - 80 mm [19] Under barbiturate anaesthesia, however, the safety margin is probably extended, since cerebral metabolism (and hence oxygen demand) is reduced by 30 - 40 per cent under light thiopentone narcosis [20]

Liver.—A large proportion of the hepatic blood supply is second hand *via* the portal vein, with its oxygen supply depleted by the prior claims of the gut When these claims are high (and intestinal movement is active under epidural analgesia), practically the entire oxygen supply to the liver has to be carried in the relatively small amount of blood arriving from the hepatic artery If flow through the hepatic artery becomes inadequate for the total needs of the liver, local tissue anoxia will result, with the production of vaso-depressor material,[21a, b] and a tendency for the vascular hypotension to persist, moreover, lasting liver damage may occur Observations on the liver during laparotomy under epidural analgesia suggest that the critical perfusion pressure for normal livers is in the region of 60 mm Hg systolic, and in the presence of liver disease this threshold is probably higher[22]

Kidney.—The cut end of a ureter has been observed squirting a vigorous stream of urine while the systolic pressure was steady at 75 mm Hg With mean arterial pressures below 50 - 60 mm secretion of urine is diminished and may cease, but normal renal epithelium is apparently unaffected by pressures as low as 40 - 50 mm , and urine secretion recommences when the systolic pressure rises above the filtration level[23]

Eye.—Thrombosis of the central artery of the retina has been reported following the induction of profound hypotension by the methonium drugs in the head up position, but with the horizontal or slightly head-down position used in epidural analgesia this disaster is less likely to occur at comparable levels of blood pressure Here it may be noted that in patients with hypertensive retinopathy, the reduction of blood pressure accompanying high blocks produces a marked change in the appearance of the fundi, arterial spasm and irregularities are relieved, and venous congestion becomes less pronounced For example —

Man of 59 with arteriosclerosis and blood pressure of 170/100 Pre-operative ophthalmoscopy showed severe venous occlusion at arterial crossings, " copper-wiring " and moderate focal constriction of the arteries After induction of epidural anaesthesia the blood pressure fell to 70/50 and the fundi presented the following appearance great reduction of venous nipping and " copper wiring."

although both were still present to a slight extent Complete absence of focal spasm

Body Temperature.—Paralysis of the sympathetic system interferes with the heat regulating mechanisms in three ways Adrenaline secretion falls, so that basal metabolism (and hence heat production) is lowered, and at the same time sudomotor paralysis and cutaneous vasodilatation occur in the segmental distribution of the block Absence of sweating tends to raise the body temperature, while peripheral vasodilatation tends to lower it However, vasodilatation is very much less efficient than sweating as a means of losing heat, and so there is a tendency for heat retention to occur in warm surroundings This is seldom sufficiently marked to cause a noticeable rise of temperature, but in a hot theatre, or in the presence of fever, an additional rise of 1°-2°F may result When keeping a watch for temperature changes, carefully taken axillary readings are adequate for practical purposes A rise to 104°F calls for active cooling measures to prevent cerebral damage from hyperthermia, when ice packs round the neck and upper chest and a fan directed on the head are effective While the necessity for such steps is extremely rare, the possibility should be borne in mind in hot climates

On the other hand, temporary suspension of the peripheral heat regulating machanisms can be exploited to facilitate induction of hypothermia, in cases where a lowered metabolism may help to decrease tissue demands in the face of a depleted supply, for example in oligaemic shock In an ambient tem perature of 68°F the rectal temperature commonly falls to 96°-97°F after a high epidural block, without any active cooling measures beyond removing clothing from the patient's lower limbs Skin temperature readings are unreliable when surface cooling is being carried out, and rectal temperatures should be taken, preferably with an electrical thermometer

Case —Man of 45 in oligaemic shock from repeated massive haematemeses for emergency gastrectomy Pale, sweating Pulse rate 115 per minute' B P 78/? Rectal temperature, 100 2°F Epidural block induced to T_4 T_5 under light thiopentone and nitrous-oxide and oxygen narcosis and the legs exposed Rectal temperature fell to 96 2°F Awoke immediately after operation but did not shiver or complain of feeling cold Uneventful recovery

RESPIRATORY SYSTEM

It has been pointed out that a correctly chosen differential epidural block does not interfere with the muscles of respiration However, the respiratory passages must be considered The bronchial tree is supplied by dilator sympathetic nerves and constrictor parasympathetic nerves so it might be expected that a block involving the sympathetic alone would leave the parasympathetic constrictor action unopposed, causing bronchoconstriction and respiratory impedance during operation, and a tendency to atelectasis afterwards For some reason, which is not at present clear, bronchoconstriction does not occur, in fact there is an opposite tendency for bronchial relaxation to accompany the onset of epidural blockade, and in emphysematous patients with an existing element of bronchoconstriction the change of respiration may be quite dramatic, as in the following case —

Man of 73 for laparotomy, fat, barrel chested and slightly orthopnoeic with a productive morning cough Heart enlarged expiratory rhonchi all over both lung fields blood pressure 155/85 After a slow induction of anaesthesia with 450 mg of thiopentone maintenance was continued with 6 litres of nitrous oxide and 2 litres of oxygen per minute. Despite a clear airway respiration was laboured, with grunting forced expiration and marked subcostal effort Cyanosis was present and the feeble excursions of the anaesthetic bag reflected a poor tidal exchange Lumbar epidural injection was then carried out with 36 ml of procaine nupercaine mixture, between L_1 and L_2 Within 15 minutes the blood pressure had fallen to 68/40, cyanosis had disappeared and respiration changed to a free gentle movement with excursions of the bag approximately doubled 1½ hours later skin analgesia extended up to the third thoracic segment

It was thought that the beneficial effects of epidural block in this type of patient might be explained by the work of Schweitzer and Daly, who showed that vascular hypotension is accompanied by bronchodilatation brought about through baroreceptors in the carotid sinus[a, b, c, d] They showed that falls of perfusion pressure in the carotid sinus released vagal bronchoconstrictor tone, while raising the blood pressure increased bronchial tone Another possibility may lie in the reduction of pressure in abnormal anastomotic channels within the emphysematous lung It has been shown that in emphysema

and bronchiectasis thrombosis of the terminal bronchial arterioles leads to the opening up of anastomoses between the bronchial arteries (arising from aorta) and the pulmonary arteries, so that systemic pressures become transmitted to the lesser circulation, and the pulmonary arterial pressure becomes abnormally high [25, 76] There is an inverse relationship between pulmonary arterial pressure and oxygen uptake from the lung [77] The normal mean pulmonary arterial pressure is about 18 mm Hg, and a rise to 55 mm causes a fall of oxygen uptake of approximately 30 per cent Hence a reduction of systemic arterial pressure will cause a fall of pressure in the bronchial arteries, and in cases with patent broncho pulmonary anastomoses a fall of pulmonary arterial pressure will follow, with an increase of oxygen uptake However, the hypotensive effect of epidural blockade cannot be the sole cause of the improved respiration, since a return of laboured breathing does not follow restoration of the blood pressure For example —

Man of 64, with carcinoma of the prostate "Chronic bronchitis," worse in the winter, narrow, fixed type of chest, blood pressure 120/80 After a slow induction with 500 mg of thiopentone, followed by nitrous oxide and 25 per cent oxygen tidal exchange was poor, with expiratory effort and cyanosis was present Epidural injection of 23 ml of 1 2 per cent xylocaine between L_2 and L_3 was followed by a fall of blood pressure to 85/50 and a change to free rhythmical respiration with increased tidal exchange and an absence of cyanosis 8 mg of "methedrine" were then given intravenously, and the blood pressure rose to 130/75, but despite this respiration remained satisfactory, and there was no return of expiratory effort

Bronchial dilatation might be caused through absorption of the adrenaline in the epidural solution However, examples of increased tidal volume have occurred when there was no adrenaline added to the solution An explanation may lie in the breaking of some vicious circle, through the diminished number of afferent stimuli arriving from the thoracic segments involved in the block But whatever the cause, the effect is both beneficial to the patient and productive of quiet operating conditions

KIDNEY

The effects of blood pressure changes upon the kidney have already been mentioned (*see page* 26)

The experimental work of Trueta Barclay, Franklin, Daniel, and Pritchard presented in their classic work ' Studies of the Renal Circulation," has shown that the arteries of the outer cortex are more irritable than those of the proximal parts of the renal arterial tree, and in certain conditions of stress reflex cortical vasoconstriction occurs, shunting the greater part of the intrarenal circulation through the medulla, thus causing cortical ischaemia [29] Cortical ischaemia causes anuria and if sufficiently intense and prolonged, may lead to death from uraemia and necrosis of cortical tissue This mechanism is claimed to underlie the aetiology of the anurias of traumatic uraemia, septic abortion, concealed accidental haemorrhage, etc The experimental counterpart of these conditions, the cortical vasoconstriction of " tourniquet shock," is prevented by division of the splanchnic nerves, and it is suggested that sympathetic blockade will have a similar protective effect in the clinical manifestations of this reflex phenomenon If this suggestion is correct, sympathetic blockade by the epidural route should be a beneficial prophylactic measure during the operative handling of urogenital structures, as well as a curative factor if instituted early enough in the course of a reflex anuria, before ischaemic tissue damage has occurred in the cortex

UTERUS

The extrinsic motor nerves to the body of the uterus arise from the fifth to tenth thoracic segments, while the sensory fibres enter the cord at the eleventh and twelfth thoracic segments During labour a block of T_{10} will allow vigorous yet painless uterine contractions to proceed Blocks above T_8 will slow the process of labour, although the intrinsic mechanisms of the uterus can still carry the process of labour through to completion, and uterine retraction is not impaired

STRESS

The stress of an abdominal operation causes a marked fall of circulating eosinophils in patients with normal adrenal cortical function [29] When the operation is performed under general anaesthesia the eosinophil fall commences within an hour of the initial incision, and is greatest after the fourth hour

Three groups of patients were tested for their eosinophil response to operation The first was a control group, under general anaesthesia, and these had a typical fall, greatest in the fourth hour The second group had lower abdominal operations conducted under high epidural block and light general anaes thesia In these patients there was no vagal stimulation, since

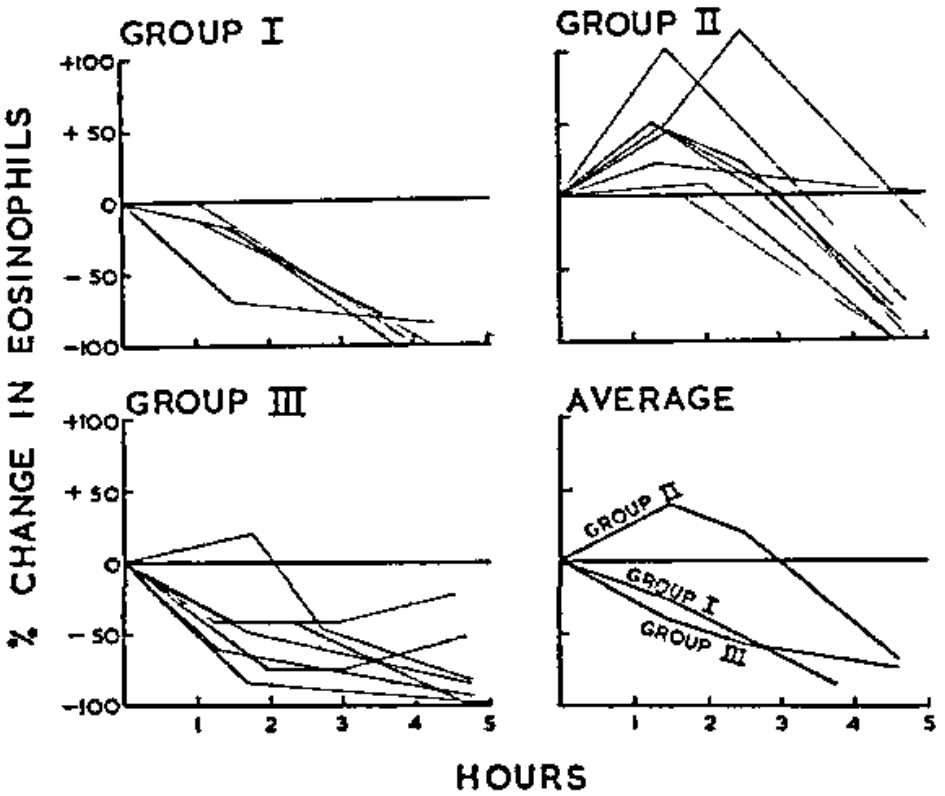

FIGURE 13

Eosinophil responses to laparotomy modified by afferent blockade

Group I Controls Five patients under general anaesthesia Normal eosinopenic response to stress commencing after 1 hour and almost complete after 4 hours

Group II Eight patients Lower laparotomy under epidural block and light general anaesthesia (complete afferent blockade) Note delay in fall of circulating eosinophils until the block wears off

Group III Seven patients Upper laparotomy under epidural block and light general anaesthesia (partial afferent blockade) The eosinophil responses are comparable to those in Group I

manipulations were confined to the lower abdomen, and so the afferent nerve block was complete The eosinophil counts showed a delayed fall so long as the central nervous system was shielded from afferent stimuli by the epidural block, but with the passing of this shield there was a prompt fall of

eosinophils, and one and a half hours after the block had disappeared most of the eosinophils had followed suit (*see* Fig 13) The third group had upper abdominal operations carried out under epidural and light general anaesthesia and in these patients afferent stimuli could reach the central nervous system through the vagi This group showed the same type of response as group 1 * Certain conclusions on the role of afferent stimuli in the mechanism of the stress response can be drawn from these findings, but they do not concern us here As far as practical anaesthesia is concerned these experiments seem to show that a complete afferent block does soften the blow of the stress response, and the body is spared the bombardment of operative stimuli until the strain of surgery is passed, the wound closed, and blood loss at an end This shielding from afferent stimuli is most marked in lower abdominal operations, and others where vagal stimulation does not take place and is reflected by the tranquil yet alert appearance of patients returning to bed after the most extensive procedures

* **Experimental Methods**—Oxalated blood samples for eosinophil counts were taken after induction of anaesthesia (with evipan or thiopentone) and before the start of operation Further samples were taken 1½ hours and 4½ hours after the first incision in most cases an extra sample was taken at 2½ hours Adrenaline was not added to prolong the effects of the epidural solutions since adrenaline itself in amounts of 0 3 mg causes a marked fall in the eosinophil count All cases were done in the afternoon or evening to avoid errors due to the normal diurnal variation of the eosinophil count Half of the eosinophil counts were carried out by a modification of Discombe's eosin-acetone method and the other half by Randolph's phloxine-propylene glycol method

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CHAPTER IV

EPIDURAL PRESSURES

MUCH ink has been spilt in the protracted discussion centred around the problem of pressure differences in the epidural space Janzen stumbled across the problem accidentally in 1926 while undertaking careful manometric measurements of cerebrospinal fluid pressures[1] The manometer in use was filled with a mercuric iodide mixture of high specific gravity, so as to measure pressure changes with relatively little alteration of volume within the apparatus Janzen was surprised to find that during the performance of lumbar puncture his manometer registered a *negative* pressure and then, after overcoming a slight elastic resistance, the negative pressure gave way to the expected positive pressure associated with subarachnoid tap, and cerebrospinal fluid flowed out of the needle Janzen was intrigued by this curious phenomenon, and after investigating it in thirty nine patients and several cadavers he reached the following conclusions —

1 The degree of negative pressure obtainable depended upon the type of spinal needle used Blunt needles gave greater negative pressures than sharp ones, and needles with side openings gave better readings than those with end openings

2 Slow and careful introduction of the needle gave the greatest negative pressures The negative pressure could be increased or diminished by advancing or withdrawing the needle

3 Greater negative pressures were obtainable with low cerebrospinal fluid pressures than with high ones (*i e* when the dura was less distended and resistant

From these facts, and his post mortem dissections, Janzen was satisfied that all his observations could be adequately explained by dimpling of the dura by the needle point, the negative pressure being an artefact arising in the epidural space as the advancing needle point dented a cone of resilient dura within the unyielding walls of the spinal canal (*see* Fig 14)

This careful work, and the logical conclusions drawn from it, passed unnoticed and two years later Heldt and Moloney

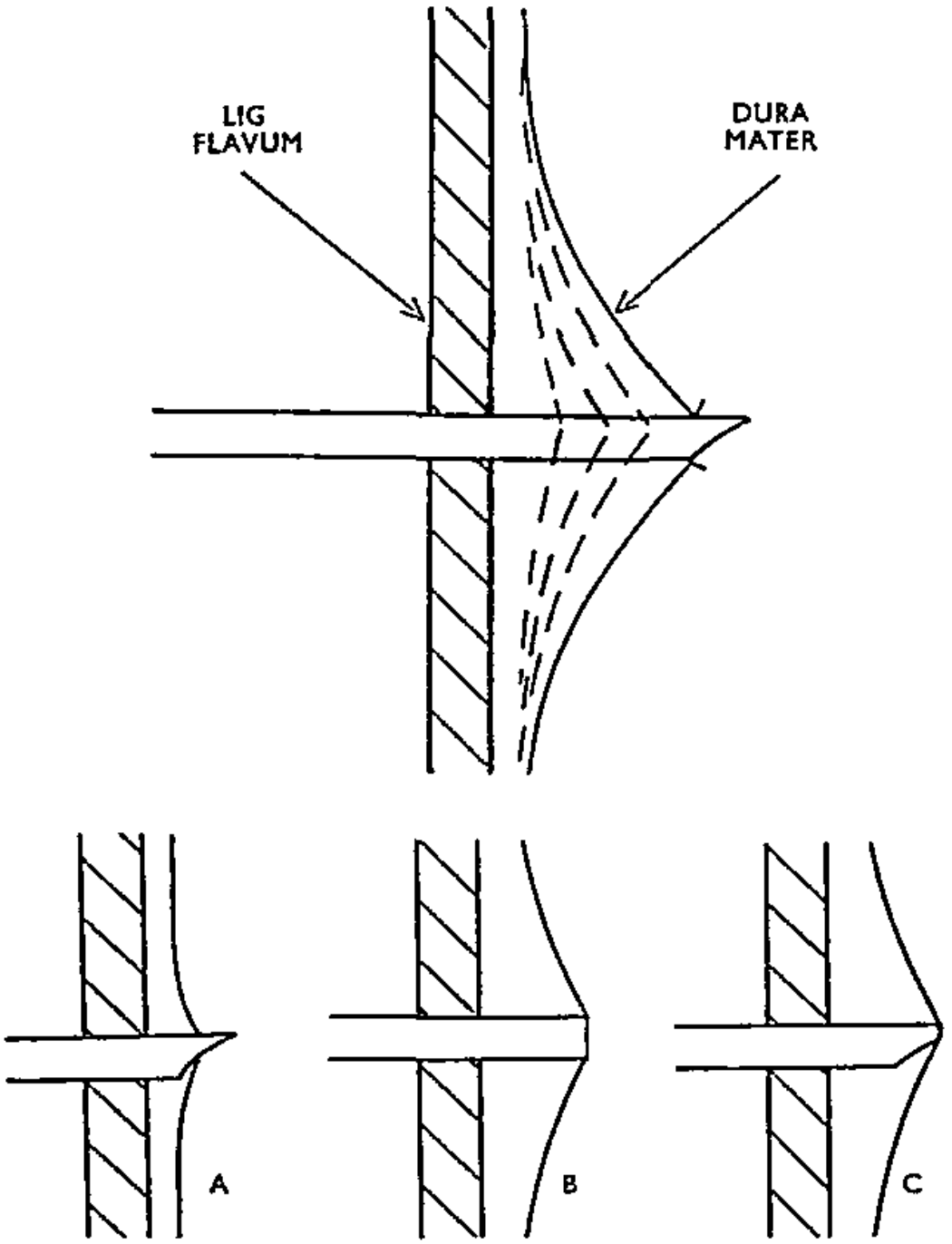

FIGURE 14

Janzen's observations on epidural negative pressures Negative pressure increases as the needle is advanced, until the dura is pierced and c s f flows out A Sharp needles pierce the dura easily and produce little or no negative pressure effects B Blunt end opening canulas cause good coning but do not transmit pressure changes C. Pressure changes are best observed using blunt, oblique-opening needles (*Anaesthesia, 1953*)

rediscovered the phenomenon that Janzen had described.[2] The latter workers thought that two factors were at work in producing the epidural negative pressure. Firstly a "true" and normally existing negative pressure which was somehow supposed to defy Nature's abhorrence of a vacuum and to exist from early foetalhood. They claimed that the 'true' pressure measured between −1 and −18 mm Hg. Secondly, a "spurious' negative pressure was added to this such as Janzen had described, caused by the advancing needle point, and the total negative pressure could amount to anything up to −30 mm Hg, or even higher. It was not made clear how the "true" and "spurious" pressures could be distinguished and there is little doubt that it is impossible to do so. Heldt and Moloney made one significant observation which strongly suggests that the negative pressures they observed arose from small volume sources, such as would be caused by localised indentation of the dura within the spinal canal. By means of a two way tap on the epidural needle they were able to inject liquid into the epidural space and measure epidural pressures at the same time. They found that the injection of small amounts of saline (less than 6 ml.) completely abolished the negative pressure.

Six years after Janzen's description of the creation of an artificial negative pressure in the epidural space, Gutierrez, of Buenos Aires, turned the phenomenon to a practical account by using it as a landmark in performing epidural injections.[3] Instead of a manometer, Gutierrez placed a drop of fluid in the hub of the needle, so that the hanging drop would be sucked in when the space was entered. He called this the "signa de gota" or "sign of the drop," and the test became one of the most popular for identifying the epidural space, despite the admission of its originator that it could be elicited in only 82 per cent. of cases.

Albert Bonniot, of Grenoble (1934), was the next to turn his attention to the question of epidural pressures, and he confirmed Janzen's finding that a decrease of *cerebrospinal* fluid pressure was associated with an increase of recordable negative pressure in the extradural space.[4] These results were obtained when the position of the body was adjusted so that the site of puncture was at a higher level than the rest of the

body For instance, upper thoracic punctures were done in the sitting position, with the neck well flexed, and lumbar injections in the lateral or prone position, with the head low

The matter was not allowed to rest here, and further speculation, innocent of experimental backing but nevertheless quick with creative possibilities, followed In 1936 Zorraquin suggested that the negative pressure observed was not an artefact, but occurred naturally, and was induced by two forces transmitted to the epidural space *via* the intervertebral foramina One, he suggested, was abdominal in origin and constant in nature, produced by the drag of viscera suspended from their mesentery, the other variable and intermittent, produced by the transmitted intrathoracic negative pressure of inspiration[5] In the same year Odom suggested that the negative pressure was created by flexion of the spine[6] He claimed that bowing of the back lengthened the spinal canal and increased its volume, thus causing a temporary negative pressure in the epidural space However, this hypothesis is not in accordance with the facts demonstrated by Reid and Sherrington in 1890 when they showed that flexing of the spines of cadavers produced a considerable diminution, and not increase, in the volume of the spinal canal[7]

The next serious experimental work was done by Eaton of the Mayo Clinic, in 1939, using a water manometer in living subjects[8] Eaton made three observations —

1 The negative pressure increases as the needle advances across the epidural space, until the moment when the dura is punctured

2 If the needle is halted after recording a small negative pressure, and the pressures are then equalised, further advance will produce a further fall in pressure

3 An epidural puncture was done, with a manometer attached, in the 4th lumbar interspace, and then a second epidural puncture was made in the 3rd interspace, and a blunt stilet was passed down the second needle He found that by advancing the stilet, negative pressures up to – 14 cm H_2O could be repeatedly obtained, the pressure returning to zero when the stilet was withdrawn (*see* Fig 15)

Eaton concluded that his observations were in agreement with those of Janzen, confirming that the epidural negative pressure is an artefact

In 1947 one of Zorraquin's suggestions found an echo in some observations by Macintosh and Mushin at Oxford. By injection experiments and dissections they demonstrated the

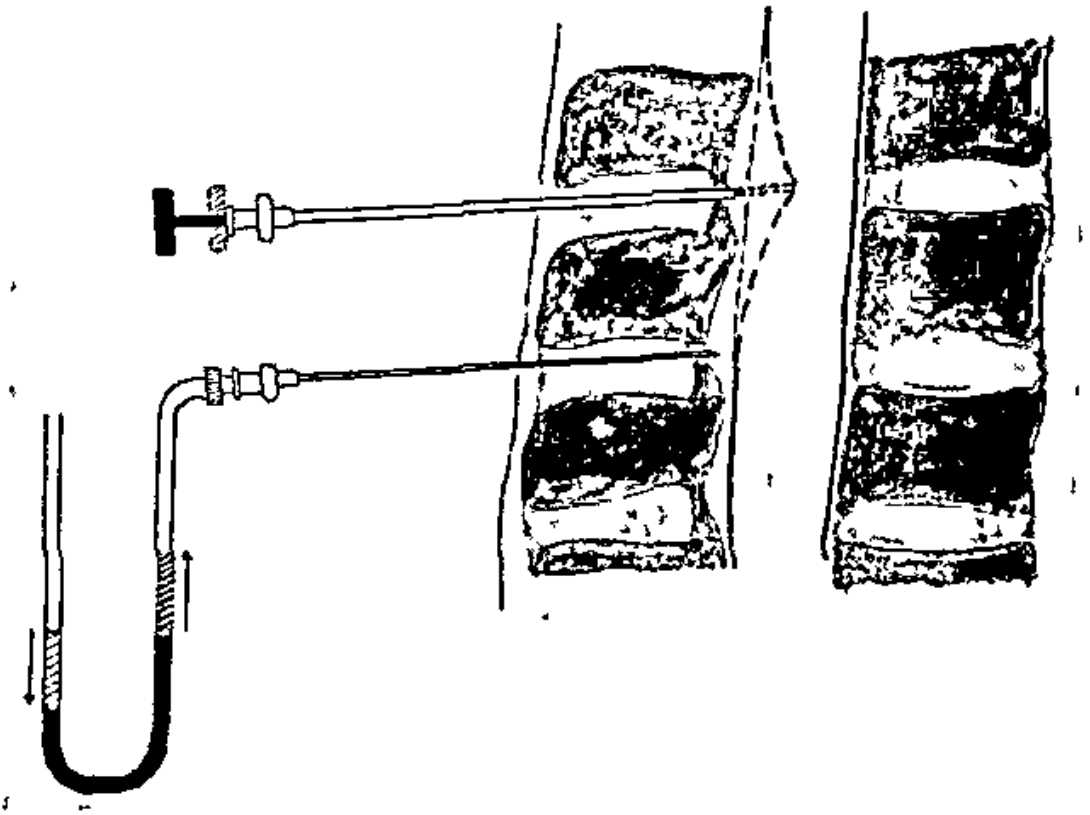

FIGURE 15
Eaton's experiment.
Demonstrating that epidural negative pressures are caused by coning of the dura, and are proportional to the degree of indentation (*see* text)

free connections that exist between adjacent and contralateral paravertebral spaces, *via* the epidural space, and they restated Zorraquin's conclusion that the intermittent thoracic negative pressure of inspiration must therefore be transmitted to the epidural space.[9] They pointed out, however, that this negative pressure would be quickly damped down by the fat and areolar tissue in the extradural space, so that the negative pressure wave would not be transmitted far from its site of origin Later Macintosh (1950) added further confirmation to this, when he showed that after correct placement of the needle in the epidural space, his balloon indicator (*see* Chapter V) could be partially reinflated by asking the patient to cough.[10]

Another Oxford worker, Bryce-Smith, carried out some important manometric observations in the same year.[11] He

TABLE II

EFFECTS OF COUGHING DEEP BREATHING, AND JUGULAR COMPRESSION ON LUMBAR EPIDURAL AND SUBARACHNOID PRESSURES

	At Rest	Coughing	Jugular Com pression	Deep Breathing
	mm H O	mm H_2O	mm H_2O	mm H_2O
Case One				
c s f press	65	+105	+260	No change
epidural press	0	+ 7	+ 8	−4
Case Two				
c s f press	170	+178	—	No change
epidural press	0	+ 3	—	−2
Case Three				
c s f press	25	+ 70	+245	No change
epidural press	0	+ 9	+ 10	−8
Case Four				
c s f press	75	+ 85	+210	No change
epidural press	0	+ 3	+ 2	−2

(From Bryce Smith, 1950 *Anaesthesia*)

TABLE III

PUBLISHED FIGURES FOR EXTRADURAL NEGATIVE PRESSURES

Observer	Negative Pressure produced by Deep Inspiration (in mm H_2O)	Total Recorded Negative Pressure (in mm H_2O)	Type of Manometer used
Janzen (1926)	—	0 −400	Mercuric Iodide Sp Gr 3 2
Heldt & Moloney (1928)	—	−10 - −408	Mercury Sp Gr 13 6
Bonniot (1934)	—	−60 - −160	Water
Eaton (1939)	—	0 - −140	Water
Lawrence (1948)[12]	—	−20 - −170 (Depending on bluntness of needle)	Water
Bryce Smith (1950)	−2 - −8	0 - −110	Water

took simultaneous manometer readings from two needles placed in the subarachnoid and epidural spaces at the same intervertebral level in the lumbar region and found that although coughing and jugular compression raised both c s f and extradural pressures, deep inspiration lowered the epidural pressure without change of c s f pressure (*see* Table II)

Having dealt with the manometric findings of several workers, it is helpful to review them together, and a glance at Table III reveals two interesting facts

Firstly, it will be noticed that the " Total Recorded Negative Pressures " can be arranged in two groups those around 400 mm H_2O making one group, and those between 110 and 170 mm H_2O falling into the other The lower group of readings were obtained with water filled manometers (specific gravity = 1 0), while the manometers used in the higher group contained liquids of relatively high specific gravity The latter type of manometer undergoes less volume change at a given pressure than the former, so that it is more suitable for recording true changes of pressure from small volume sources This suggests that the pressure changes being measured do in fact arise from a small volume source, such as would be created by local dimpling of the resilient dura within the rigid walls of the spinal canal

Secondly, if we look at Bryce-Smith's figures for pressure changes associated with deep inspiration, it will be seen that the values obtained are insignificant when compared with the " Total Recorded Negative Pressures " And so, even if the " hanging drop " test did depend upon puncturing the epidural space in phase with a *deep* inspiration (an unlikely event in practice), the amount of negative pressure obtained by respiratory movements would be slight and of little account compared with the negative pressure arising from coming of the dura

Some observations of my own support this view Epidural punctures were attempted in sixteen patients, using the hanging-drop technique, with needles of varying sharpness (*see* Chapter V) The patients were sitting up for four to five minutes beforehand, so that the full hydrostatic effect of the column of cerebrospinal fluid would distend the dura as much as possible The spine was kept as straight as was compatible

with performing a lumbar puncture The needle was introduced in the 2nd or 3rd lumbar interspace, and advanced only during the expiratory phase of respiration, so that intrathoracic pressure would be positive rather than negative at the moment of entry into the epidural space Despite the unfavourable conditions, a vigorous positive "drop" sign was obtained in ten of the cases Moreover, after eliciting a positive sign, the needle was halted and the empty hub recharged with a second drop, and then a further advance made In eight of the cases the hanging-drop sign was positive a second time, and in one of these (using a moderately sharp needle) the sign was positive eight times in succession before the needle point finally perforated the dura and cerebrospinal fluid flowed out [13] There can be little doubt that in these cases the negative pressure effects were caused solely by dimpling of the dura

That a positive drop sign need not be an infallible index of correct extradural location but may arise falsely from muscular movements, is shown by the following case —

A man of 76 was very restless during the insertion of a spinal needle on which a hanging drop had been placed for demonstration purposes During advance of the needle the patient moved continually and could not be induced to remain still Suddenly the drop was sucked in with considerable vigour and this was demonstrated to the onlookers as a sure sign that the epidural space had been entered But further advance towards the subarachnoid space was blocked by bony resistance and on reinserting the needle it was evident that the first insertion had been arrested at a relatively shallow level by the dorsal surface of a vertebral lamina and the epidural space had not in fact been entered

Figueiredo reports that this false negative pressure sign is relatively frequent [14]

To summarise, it may be concluded that although respiratory movements can cause a negative pressure in the *lumbar* epidural space, they do so only when the inspiratory effort is great, and even then their effect is small In practice, during quiet respiration nearly all negative pressure effects in the lumbar region are due to coning of the dura by the advancing needle point

In the *thoracic region* on the other hand respiratory negative pressures are probably transmitted effectively to the local epidural space, and this may explain why a positive

drop-sign is obtained more frequently by high thoracic puncture than in the lumbar region[14] (*see* Chapter V)

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CHAPTER V

IDENTIFICATION OF THE EPIDURAL SPACE

GENERAL REMARKS

TO the beginner the idea of passing a needle through one and a-quarter to two and a half inches of tissue and halting the point accurately in a narrow space a few millimetres wide, is discouraging And so it is as well to begin by saying that, given care, the procedure is much less difficult than it seems But a steady hand and a certain amount of care and attention to detail is essential for success if the anaesthetist is neither able nor willing to supply these it is better not to attempt the technique It is easy for an otherwise admirable technique to become discredited by careless practice

The epidural space is a region of loosely bound tissue, presenting little resistance to the propagation of hydrostatic pressure changes enclosed in tissues which are highly resistant to the transmission of these changes Methods of identifying the epidural space depend, in one way or another, upon the recognition of the passage of the needle tip from tissues of high resistance to those of low resistance

The lumbar approach to the epidural space was tried by Cathelin[1] and by Tuffier[2] at the beginning of the century, and was abandoned as unreliable In 1921 Fidel Pagés[3] re examined the problem and proposed certain methods for the accurate recognition of the space His chief sign was purely tactile in nature, depending on the sense of " give " that is felt by the operator when the point of the needle escapes from the tough ligamentum flavum into the epidural space He recommended making the puncture laterally, 1 to 1½ cm from the midline, with the bevel of the needle directed medially In this way the bevel of the needle, the ligaments to be pierced, and the surface of the dura mater are all parallel, and Pages claimed that recognition of the ligamentum flavum was facilitated, and puncture of the dura avoided, by the increased resistance presented by the flat of the bevel However, it will be noted that the epidural space is much narrower in its lateral

parts than medially moreover the vertebral veins running in the antero lateral parts of the epidural space are more liable to damage in the lateral than in the medial approach Once the needle was in place and no cerebrospinal fluid ran out

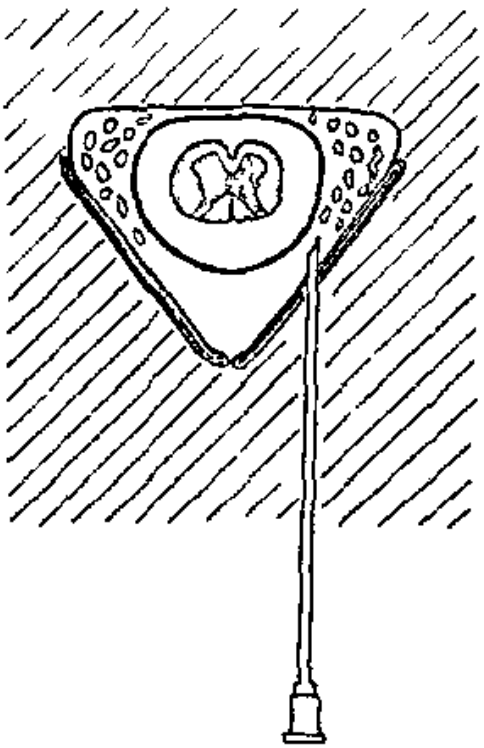

FIGURE 16
Pagés approach
The needle is introduced 1 1½ cm from the midl ne with the bevel fac ng the med an plane parallel to the ligamentum flavum and the surface of the dura Note that the ep dural space is narrow at th s po nt and the ep dural veins are l able to injury

the position was confirmed by attaching a syringe of fluid and attempting injection A lack of resistance indicated that the point of the needle was correctly placed and clear of the dense ligamentum flavum

Pagés' confirmatory sign of lack of resistance to injection was later developed by others In 1921 Sicard and Forestier[4] applied epidural injections of radiopaque substances to the diagnosis of spinal canal abnormalities They identified the epidural space by attaching a syringe of fluid to the needle and attempting injection continuously while advancing the needle through the ligaments (*i e before* the ligamentum

flavum was pierced) Dr Jacques Forestier in his thesis of 1922, describes the sign thus —" On peut deduire que la pointe de l'aiguille est bien placee si l'injection de la solution de cocaine a la seringue qui etait penible devenit aussi aisee que si l'aiguille etait dans la cavite sous arachnoidienne "*

Another method of identifying the epidural space, and which is mentioned only to be condemned, is that of puncturing the dura and then withdrawing the needle into the space until no more cerebrospinal fluid flows Cathelin first attempted this technique in 1901, and abandoned it as unreliable Later the method found its way into works by Pages Giordanengo[7] and Dogliotti, all of whom condone it on the ground that the pressure gradient is from the cerebrospinal fluid outwards into the epidural space so that substances in the latter are unlikely to find their way against the stream through a small dural puncture wound, which in any event quickly seals itself off Bonniot[8] and Gutierrez[9] are very outspoken in their condemnation of this method and there is little doubt that they are right There is nothing to suggest that dural puncture wounds do seal quickly, in fact all the evidence *points to a slow repair over a period of days*[10] *and the local* rise of pressure in the epidural space may temporarily exceed that of the cerebrospinal fluid, and so force a dangerous amount of analgesic fluid into the subarachnoid space, producing a total spinal block

I recall a case where this occurred during an attempted caudal block The theca extended to an abnormally low position, and cerebrospinal fluid was tapped after the caudal needle had been introduced only two centimetres The needle was withdrawn until cerebrospinal fluid ceased to flow (the point was then only just within the sacrococcygeal membrane), and 25 ml of 1 500 amethocaine solution was injected slowly without a preliminary test dose All the signs of a total spinal block followed but after treatment with a pressor drug and

* (*Translation* It can be deduced that the needle point is well placed if injection of cocaine solution in the syringe which was difficult becomes as easy as if the needle were in the subarachnoid space ') The solution under pressure was functioning both as an indicator to the operator and as an atraumatic instrument to push the dura away from the advancing needle point aptly described by Dr Sicard as un mandrin liquide (i e "fluid trocar) The test was later popularised by Dogl otti in 1933 * and is known as the loss of res stance test " It will be considered in greater detail later in the chapter

inflation with oxygen for half an hour the patient made an uneventful recovery

It may happen that the dura is punctured accidentally during the induction of an epidural block In that case if epidural analgesia is particularly preferred to a subarachnoid block, it may be justifiable to persist in attempting epidural block, provided the second puncture is performed one or two spaces away from the unsuccessful site and injection is made very slowly at the rate of 10 ml per minute In this way an excess of pressure will be avoided in the immediate vicinity of the dural wound, and will be less likely to cause the passage of analgesic solution into the cerebrospinal fluid However, it is probably wiser to abandon the procedure altogether, or convert the injection to a subarachnoid spinal anaesthetic

The existence of a real or apparent negative pressure in the epidural space has already been discussed (*see* Chapter IV) Gutierrez[11] and Soresi[17] were the first to apply internal pressure differences to the identification of the space, and they devised the "hanging-drop sign" This simple test involves placing a drop of liquid in the open hub of the spinal needle during its introduction As soon as the needle pierces the ligamentum flavum and enters the epidural space the drop of liquid is sucked in When seen for the first time this sign is very startling and convincing, but it is said to be present in less than 85 per cent of cases when the lumbar approach is used, and therefore lacks reliability However, this sign appears to be positive more frequently in the upper thoracic region when the favourable type of blunt wide bore needle is used This is a fortunate tendency as the thinness of the interspinous and yellow ligaments in the upper thoracic region makes the "loss-of resistance" test extremely difficult A number of developments of the simple "drop" test have been made, and they will be considered under details of "Technique'

TECHNIQUE

PRELIMINARY PREPARATIONS

Scrupulous asepsis is essential because dural puncture is a possible hazard of the technique

The anaesthetist should "scrub up," and don sterile gown and gloves, as for a surgical operation An autoclaved epidural

drum (*see* Chapter VI) is then opened by an assistant, and the anaesthetist lays out his own trolley with a covering of sterile macintosh and towel from the drum, thus avoiding the use of Cheattle's forceps, and the assistant pours some 1 per cent iodine in spirit into the gallipot

The patient is then placed in the lateral position and the thighs flexed on the trunk, and the full length of the back exposed After swabbing a generous area of skin with iodine, the anaesthetist marks the site of puncture with his thumb nail, and scrubs the site over with a second iodine swab

GUTIERREZ'S HANGING DROP TEST

The skin at the site of injection is pierced with a Size introducer, or a straight cutting needle The epidural needle, with stilet in place, is then introduced strictly in the midline, and in the sagittal plane, as for a subarachnoid puncture, to a depth of about 1½ cm The stilet is then withdrawn, and a drop of analgesic solution placed in the hub of the needle The needle is now advanced very carefully and gradually through the liga ments, held by the forefinger and thumb of both hands, while the little fingers and hypothenar eminences are steadied against the patient's back In this way the operator can resist any tendency of the needle to jerk forward after piercing the tough ligamentum flavum (*see* Fig 17)

Since inspiratory movements do transmit an increment of negative pressure to the epidural space, albeit a small one, it is as well to take advantage of the fact, and advance the needle only during the inspiratory phase of respiration, watching the hanging-drop keenly all the time There is no need to distract one's gaze from the drop in order to watch the respiration, for the respiratory movements are clearly felt by the operator's hands braced against the patient's back As soon as the blunt needle point escapes from the resistant liga mentum flavum into the epidural space, a sudden sense of "give" is felt, and the hanging-drop disappears into the shaft of the needle It is of the greatest importance to check the advance of the needle instantly, as soon as these positive signs of epidural puncture are manifest, lest the momentum of sudden release from resistant tissues should drive the needle onwards through the dura, into the subarachnoid space

Gutierrez s test has the cardinal virtue of simplicity the necessary equipment being reduced to the basic essentials of a spinal needle and syringe Various refinements of this test involving accessory apparatus have been recommended

FIGURE 17
The hanging drop sign of Gutierrez

Janzen and Bonniot used liquid manometers while Ontenadı favoured an aneroid because of its more constant volume Zorraquin[13] used a spherical glass indicator containing a drop of liquid and bubble of air attached to the hub of the needle The most practical of these accessories is Odom s indicator[14] This is a small length of glass capillary tubing ground to fit the hub of the spinal needle (*see* Fig 18) A drop of liquid placed in the lumen of the tubing gives a very sensitive indication of pressure changes encountered by the needle point However, a badly fitting indicator is worse than useless since it may admit air around the taper joint and so fail to register any change of pressure when the epidural space is entered

LOSS-OF RESISTANCE TEST OF SICARD AND FORESTIER AND DOGLIOTTI

Since this test depends upon the recognition of a sudden release of resistance accompanying passage from the tough

ligamentum flavum into the epidural space, the change is more readily experienced with a large bore needle of low internal resistance, than with a fine bore needle of high internal resistance A short bevelled 18 or 19 B W G (1 25 or 1 10 mm diameter) spinal needle is used If care and local analgesia are used, needles of this calibre cause no discomfort to the conscious patient, while finer needles with a higher internal resistance of their own increase the technical difficulties by giving a less exact end point to the test

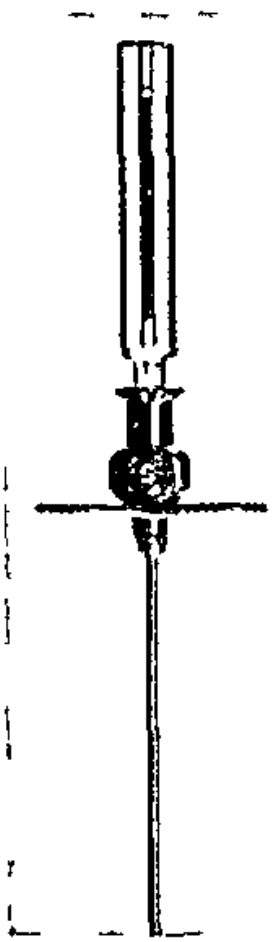

FIGURE 18
Odom's indicator (using a drop of saline coloured with indigo-carmine)

The needle is introduced to a depth of 1 1½ cm , as described in the "hanging drop" test, and the stilet removed A 10 ml or 20 ml syringe is filled with water normal saline, or analgesic solution and attached firmly to the hub of the needle Personally, I use the contents of a 20 ml ampoule of 1 1500 nupercaine then if the patient is conscious, a little of this solution can be used to anaesthetise the skin and deep fascia Pressure is now exerted on the plunger of the syringe, and syringe and needle advanced together So long as the needle point is in the ligaments there is a relative or absolute resistance to injection, but as the point emerges from the ligaments into the epidural space, the plunger surges forward as resistance disappears, and injection becomes as easy as discharging the syringe into an empty space A large syringe is easier than a small one for this purpose If a 2 ml syringe is used, and the ligaments are diffuse, moderate pressure on the plunger may discharge the contents of the syringe before the ligamentum flavum is reached, making repeated refills necessary

A firm, braced grip on the needle, and a slow, controlled advance are the most essential conditions of this technique All jerky movements must be avoided, and the needle halted instantly the epidural space is entered For this, stance and the position of the operator's hands are important, and different

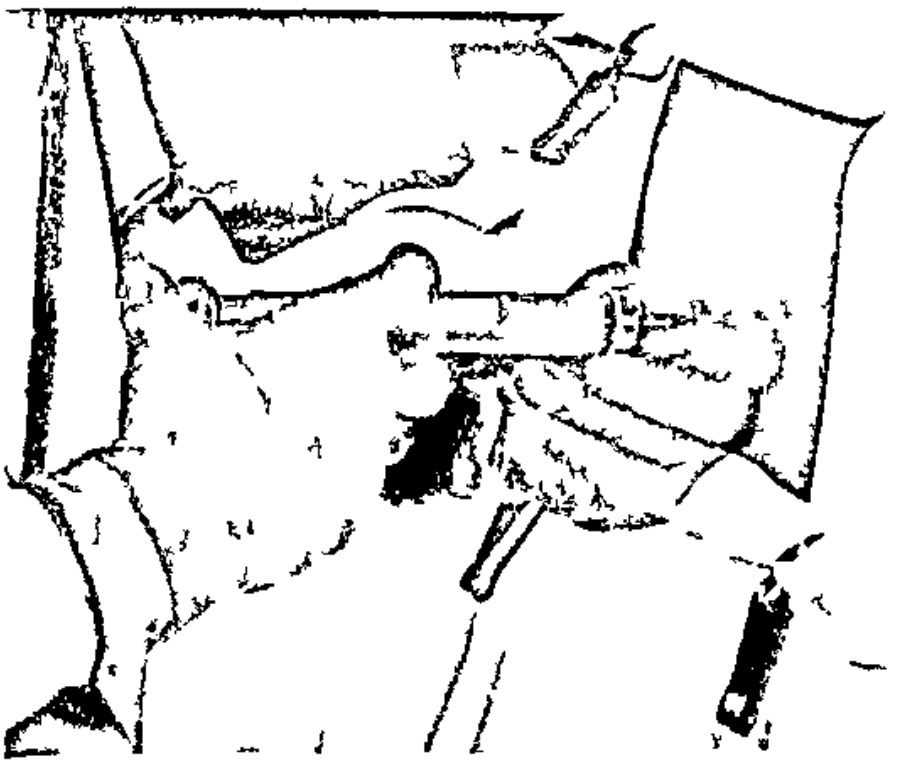

FIGURE 19
The loss of res stance test lateral view (r ght hand d gr p)

FIGURE 20
The loss of resistance test from above (r ght handed grip)

from those adopted for ordinary lumbar puncture or the "hanging-drop" technique Although the procedure can be carried out adequately from the sitting position, the standing position is preferable, adopting the stance of a riveter at work, with the head and eyes *over* the work, rather than behind it The needle is firmly grasped between thumb and forefinger, at the junction of hub and shaft, with the hand supinated and the back of the wrist and hand braced against the patient's back (*see* Figs 19 and 20) This hand must be rock steady to supply both a gradual, controlled, forward movement to the needle, and an instantaneous braking force as soon as the epidural space is entered The other hand holds the syringe and the thumb exerts continuous firm pressure on the plunger sensing the different resistances encountered during the needle's advance This hand is almost entirely concerned with supporting the syringe and interpreting the significance of changes in resistance to injection, the slight forward motion that it imparts to the needle is counterbalanced by the other hand braced against the patient's back Once the space is entered, the syringe is disconnected from the needle by a gentle rotary movement, and confirmatory tests carried out

The depth at which the epidural space is encountered varies considerably Gutierrez kept extensive records of the distance between the skin and the epidural space in 3,200 cases, and Figure 21 is a histogram drawn from his results My own, much more limited figures, accord with this distribution the distance between skin and epidural space being greater in the lower lumbar than in the upper lumbar region

The resistance encountered during the needle's advance differs somewhat from patient to patient, but the variations fall into roughly three groups —

1 The commonest, where resistance to injection appears complete through all the ligaments

2 Resistance in the interspinous ligament is moderate, but quite unmistakably present, becoming greater when the ligamentum flavum is reached

3 In some lithe and muscular subjects, after a fairly marked initial resistance, injection becomes easier at an unexpectedly shallow depth, presumably due to a thinning of the ligamentous tissues in the neighbourhood of hypertrophic muscles This diminution of resistance is only relative, and quite different

in character from the vacuous sensation imparted by a true epidural puncture If injection of the full analgesic dose is made at this stage, fluid under pressure in the tissues tends to drip back when the syringe is disconnected and the patient will probably suffer from backache the next day If the needle

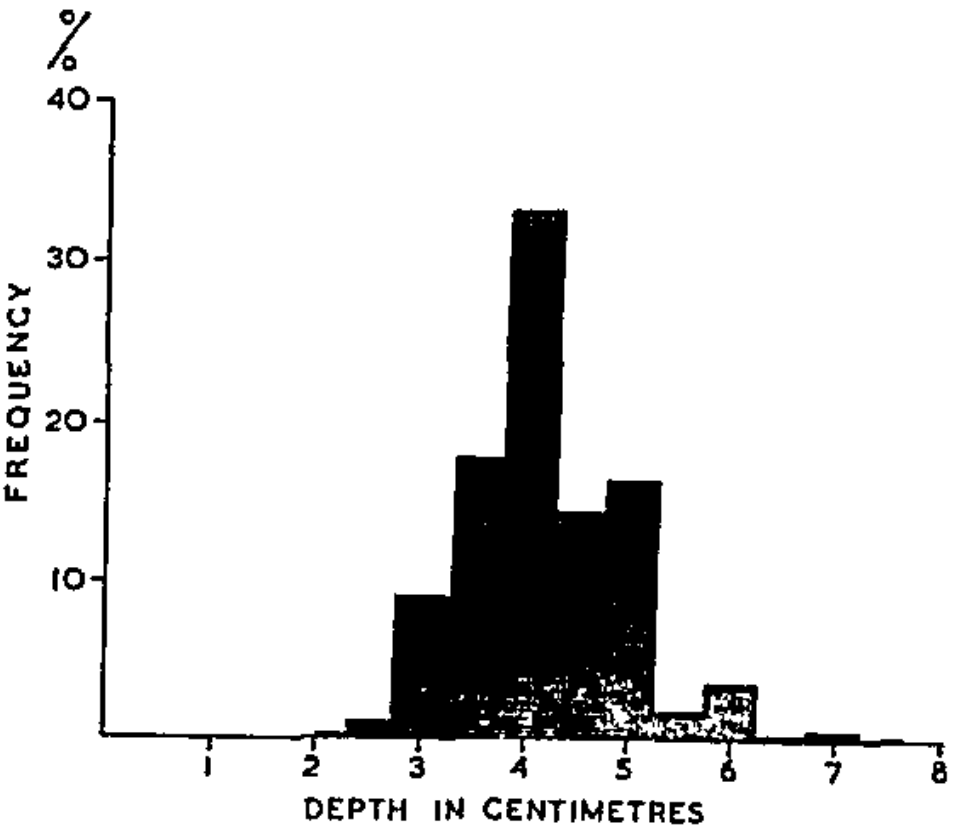

FIGURE 21
Frequency distribution of the distance between the skin and epidural space in the lumbar region (Based on Gutierrez's figures obtained from 3 200 cases)

is advanced a little deeper, resistance increases as the ligamentum flavum is encountered, and then disappears suddenly when the epidural space is entered This difficulty of pseudo-loss-of resistance is not frequently met, but it can be confusing when it does arise, particularly if fine bore needles are used With wide-bore needles differences of resistance are more readily appreciated, and identification of the epidural space can be made with much greater confidence

MECHANICAL AIDS

In 1922 Sicard used a blunt cannula within the epidural needle, in order to diminish the risk of injuring the dura Once

the epidural space was identified by the loss-of-resistance test, the sharp needle was withdrawn and the cannula advanced a further 1 - 2 mm to ensure that its opening lay well within the space. Forestier, who worked with the late Dr. Sicard, also

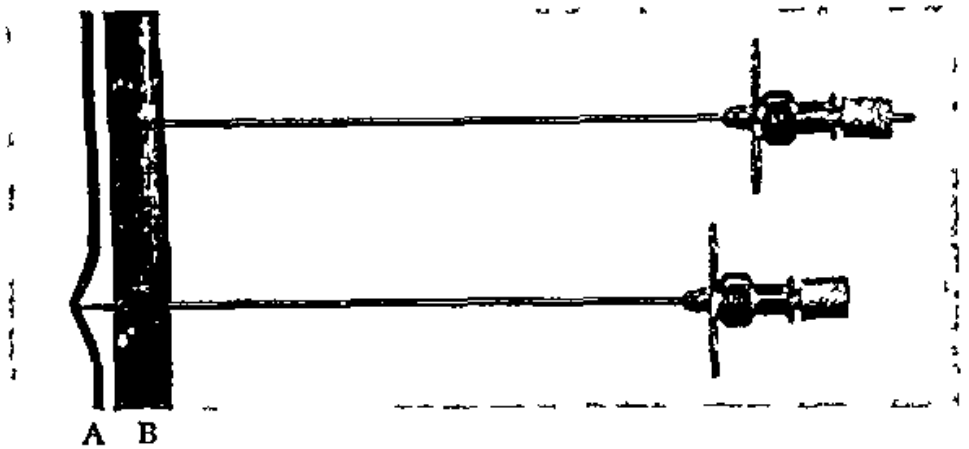

FIGURE 22A
The Macintosh needle
A blunt spring loaded indicator-stilet is impelled forward when the point of the needle passes from resistant ligaments into the epidural space A Dura mater B Lig flavum

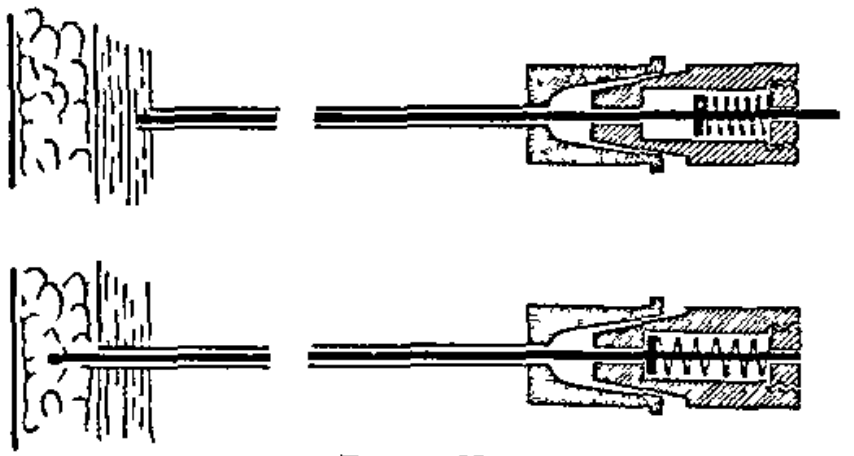

FIGURE 22B
Drawing of internal construction of Macintosh needle
(British Medical Journal)

used the same principle, but preferred to have the needle inside the cannula, so that he was left with a larger cannula in the epidural space after the needle was withdrawn.[4]

In 1932 this principle was adapted by Ontenada His cannula was about half a centimetre longer than the needle, and needle and cannula were advanced together, with pressure applied to the cannula. As soon as the needle point pierces the ligamentum flavum, the cannula, freed of resistance, jumps forward into the epidural space. Being blunt the cannula pushes the dura away

without piercing it [16] Although this is an ingenious method it must be regarded as a retrogression rather than an advance on Sicard's original technique for the bland ' mandrin liquide " or " liquid stilet " formed by the stream of fluid in the loss-of resistance test has been replaced by a traumatic shaft of steel, which although blunt may yet injure the dura

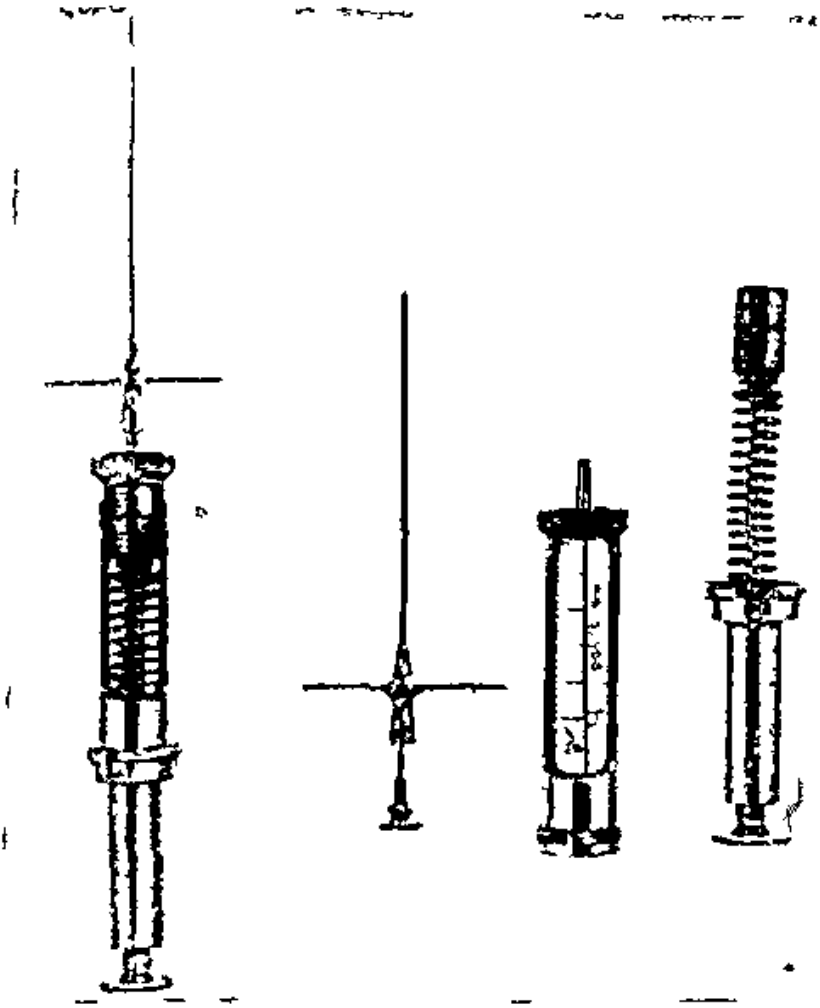

FIGURE 23
The Ilké syring-
(*Schweiz med Wschr*)

Macintosh's extradural space indicator (*see* FIG 22) is a further refinement of Ontenada's method With this instru ment the outer needle is held by the winged fingergrips and *the blunt indicator-stilet impelled forward by the action* of a small spring when the epidural space is entered [17] In patients with well-defined ligaments this gives a very pretty indication of correct epidural puncture, but in others, where the ligaments vary in density, slight inward movements of the stilet may cause

confusion, and tempt the anaesthetist to halt the needle at too shallow a depth

Goepel[18] uses a graduated blunt stilet to palpate the dura in difficult cases, whenever a reflux of injected solution raises doubts that the dura may have been pierced This graduated sound has a blunt rounded end and being delicately held between finger and thumb, is probably a safe and effective means of confirming that the dura is intact

Brunner and Ilké[19] have devised a spring loaded syringe for use in the loss-of resistance test, pressure being applied to the piston of the syringe by a spring, instead of by the operator's hand (*see* Fig 23) The syringe discharges automatically when the needle enters the epidural space In their paper describing this instrument they report two failures in 105 cases (certainly no improvement on the 1 - 1½ per cent failure rate to be expected after a little experience with the Sicard Dogliotti method) For those who care for simplicity, a light and effective substitute for the Ilké syringe is made by stretching an elastic band over the end of the piston handle of an ordinary syringe

Macintosh's balloon indicator[20] employs a small air filled balloon to signal entry into the epidural space The balloon is mounted on a Luer or Record adaptor, and has a thick walled neck and a thin body The epidural needle is placed in the spinal ligaments, and the balloon attached and inflated by injecting 2 ml of air through the thick part of the wall with a fine needle On entering the epidural space the balloon deflates (*see* Fig 24)

With the exception of Goepel's sound, each of these devices has its own particular disadvantage, and they all have the cardinal fault of substituting complexity for simplicity of technique, and a predetermined mechanical force for the delicacy of the human touch With the Sicard Dogliotti method, on the contrary, a clear interpretation of the needle's position can be made as slight changes of resistance in different parts of the ligaments are transmitted to the thumb pressing on the plunger of the syringe The operator feels the plunger surge forward, and sees it move, and thus the sensation is tactile as well as visual, and carries greater conviction than purely visual signals received from insentient apparatus

CONFIRMATORY TESTS OF EPIDURAL PUNCTURE

Having placed the needle correctly in the epidural space its position must be confirmed by carrying out one or more of the following tests —

1 Aspiration with a 2 ml syringe (suction is greater with a small syringe than with a large one and therefore more likely

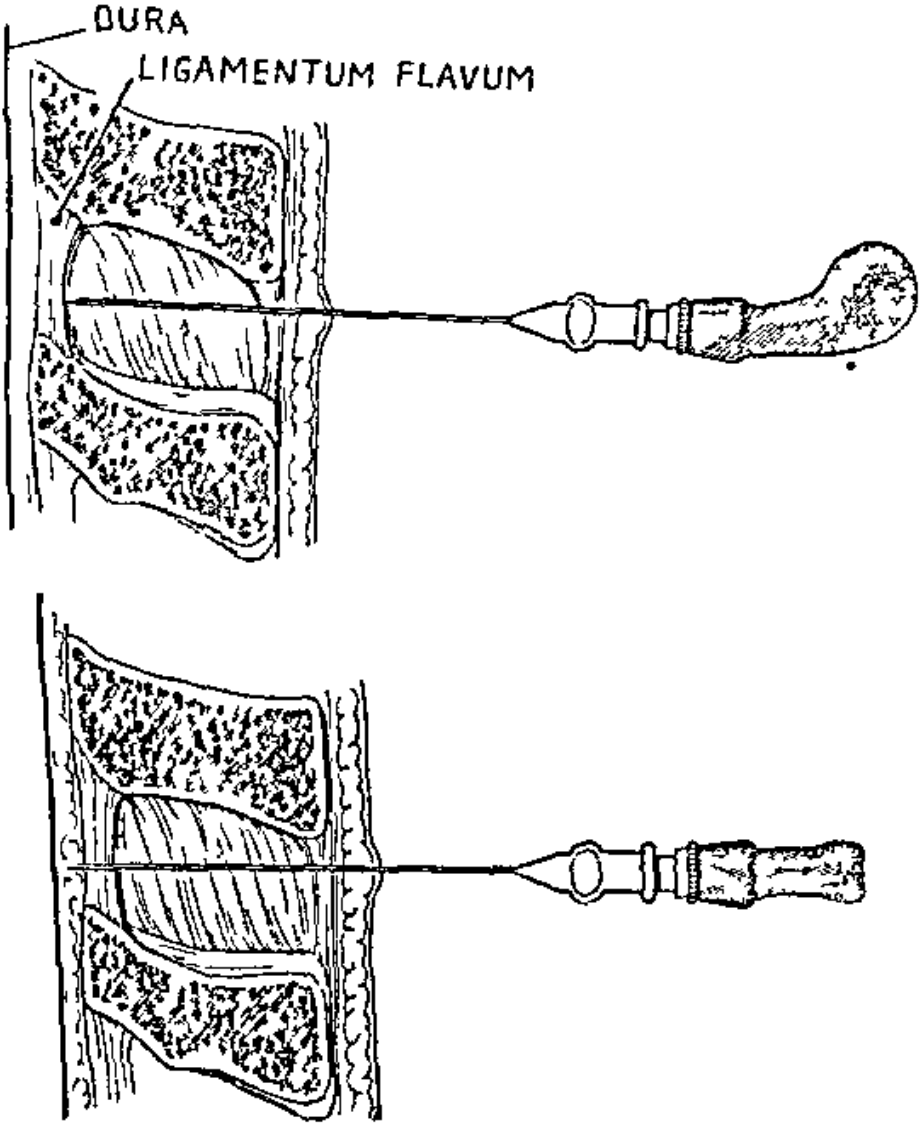

FIGURE 24
Macintosh's balloon indicator
(*Anæsthesia*)

to aspirate c s f or blood if the dura or a vein have been punctured)

2 Inject 1-2 ml of air through the syringe, and again aspirate The air should go in easily, but nothing should return on aspiration

3 **The Test Dose.**—It is recommended that a small amount of analgesic solution should be injected, and the patient observed for the following five to ten minutes If subarachnoid puncture has inadvertently occurred, injection of 5 - 10 ml of 1 600 nupercaine will cause spinal analgesia, and the patient will soon be unable to move his feet On the other hand if no motor or sensory paralysis is present after five to ten minutes, it is safe to proceed with the injection of the full quantity of epidural solution This test requires that the patient should be conscious while epidural puncture is performed But in many ways it is preferable to induce general anaesthesia before puncture rather than after it The performance of epidural puncture is quicker under general anaesthesia, since no infiltration with local analgesic is necessary, and the operator is untroubled by movements of the patient, or fear of inflicting pain or distress (although when carefully done, the procedure is painless in the conscious patient) The test dose can still be carried out on the unconscious patient by testing for falls of blood pressure instead of using motor or sensory paralysis as an indication of high spinal block Any marked fall of blood pressure occurring within five minutes of injection indicates a subarachnoid block This test, however, requires the assistance of a second person who can be relied upon to take accurate blood pressure readings, and such help may not be available Alternatively, the presence of an active knee jerk can be used as a sign that subarachnoid block has not taken place [21]

In other writings on epidural technique the test dose has become entrenched as a reliable safety measure, but it would be a pity if it were to be accepted as such and so induce a false sense of security in the anaesthetist, encouraging him to relax his caution and gentleness once the test-dose had been carried out Careless handling of the needle while attaching or detaching of the syringe during the final epidural injection may thrust the needle point onwards through the dura, and so cause a subarachnoid block after all tests for correct positioning of the needle have proved satisfactory

While extremely hesitant in recommending others to abandon the use of the test-dose, I must confess that I gave up using it after a very short acquaintance with the technique,

and since then in over 1 000 administrations I have not had cause to regret doing so There have been no accidental intra thecal injections, the patients could be anaesthetised before the block was performed, and the saving of time has been very considerable But omission of the test-dose is safe only if obtuse bevelled and wide bore needles and unremitting care are used With fine, long bevelled needles, the tip may penetrate the dura, and although the point is not advanced far enough to allow aspiration of c s f, some epidural solution may be forced through the small puncture wound into the subarachnoid space during injection

If the worst should happen, and a large part of the epidural dose should accidentally find its way into the subarachnoid space, all is not lost, and the outlook although potentially fatal, should give no great cause for alarm, if the case is handled properly In the event of massive subarachnoid injection a total spinal block results, with profound vascular hypotension, and paralytic apnoea *Cardiac arrest from medullary inhibition does not occur*, but will follow from stagnant and anoxaemic anoxia unless the vascular and respiratory paralyses are treated Therefore, artificial respiration, and restoration of blood pressure with pressor drugs is all that is required, until the effects of the massive dose of spinal analgesic become reversed by the normal venous excretion of substance from the spinal theca,[*] a process that is aided by the maintenance of a normal blood pressure

"Drip-Back" Tests.—Occasionally, after injection of 10 - 15 ml of epidural solution, a few drops of fluid drip back from the needle, despite a negative aspiration test The fluid may come from one of three sources —

1 The subarachnoid space has been entered, and the fluid is c s f

2 The needle has deviated from the midline into the extensor muscles of the spine, and a relative loss of resistance has been mistaken for the more marked loss of resistance of the epidural space The solution has pooled under pressure between tissue planes and is dripping back from there

3 The epidural space has been entered correctly, but injection has been too rapid in relation to the distensibility of the

epidural space This has caused a temporary build up of local epidural pressure, and back flow of solution

In order to decide the origin of the dripping fluid two tests are described —

1 Allow the drops to fall on the back of the bared wrist Cerebrospinal fluid is warm, injected analgesic solution at room temperature will be cold

2 *Chemical Tests* The drops can be collected in a test tube containing a reagent which will give a specific colour change when the analgesic solution used is added to it A colour change in the reagent then indicates that the liquid dripping back is undiluted epidural solution, and not cerebrospinal fluid

For example, procaine can be detected by means of the diazo reaction because it contains an aromatic amine group A solution of nitrous acid (produced by mixing sodium nitrite with hydrochloric acid) and β naphthol changes from yellow to red on the addition of procaine

In practice, the simpler test of Gutierrez of allowing the drops to fall on the bared wrist is quite adequate, and does not require any extra assistance

As already mentioned, Goepel's dural sound may be used to confirm that the dura is intact The sound is marked at intervals and after passing it to the exact length of the needle it is carefully advanced a few millimetres further, with the lightest touch, until it can be gently "bounced" against the resilient dura

If dural puncture has been excluded, and the cause of the reflux of solution lies between a misplaced intramuscular injection, and too rapid epidural injection, the puncture should be repeated in the same interspinous space in the following way The depth of the needle is noted, and the needle is withdrawn until the point lies in the subcutaneous tissues The shaft is then carefully re aligned in relation to the sagittal plane, and re inserted A fresh loss of resistance at the same depth as before confirms correct placement in the epidural space

INJECTION OF SOLUTION

There is a considerable rise of pressure in the epidural space during injection of solutions, and this pressure change is transmitted to the cerebrospinal fluid within the dural sac [23 24]

Unless injection is made slowly, uncomfortable feelings of vertigo and fulness in the head are caused in the conscious patient Even with slow injections at the rate of 0 5 ml /sec , or less slight dizziness lasting a minute or so may occur and the patient should be warned of this so that he will not be alarmed The presence of fluid tracking round the spinal roots also gives rise to paraesthesiae in the legs the patient experiencing a sensation of warmth, or of water running down the legs If the likelihood of these sensations are explained to the patient beforehand, they will cause him no worry if they do arise, and moreover they will confirm his confidence in the knowledge that the anaesthetist has insight into his experiences and is " with him all the way "

Even in the anaesthetised patient a slow injection is preferable to a rapid one With rapid injections fluid is dispersed widely but thinly throughout the epidural space, so that although the resulting block is extensive, it lacks body and is of short duration With slow injections there is time for the solution to pool evenly in larger amounts in any given area, with the result that the block tends to be more localised, but longer lasting, since there is a greater volume of solution to be absorbed from a more limited region of the epidural space It follows that, provided injection is made slowly, the period of analgesia will be related to the volume of solution injected since large volumes will provide a greater depot of drug from which analgesic absorption can continue

SITE OF PUNCTURE

Many works on epidural analgesia attach considerable importance to the choice of injection level, in order that the dose of analgesic should be kept small, and the area of analgesia limited to the field of operation Thus, puncture between C_7 and T_1 is recommended for upper thoracic operations, between T_4 and T_{10} for upper abdominal work, and T_{10} to L_1 for lower abdominal and lower limb operations In my opinion this distinction of injection sites is unnecessary, with the possible exception of high puncture for upper thoracic work

Injection in the lower thoracic and lumbar regions is easy and certain owing to the favourable inclinations of the vertebral spines, and thickness of the interspinous ligaments in that

area, while the block can be carried up to any metameric level by increasing the volume of analgesic solution The quantities of solution necessary for high blocks *via* the lumbar route are well within the toxic range and there is little virtue in limiting analgesia to an area beyond which the surgeon's hands may stray, for any abdominal operation is likely to become an exploration of the whole abdominal contents It is true that a localised block will involve less sympathetic rami and so cause less fall of blood pressure than an extensive one, but a fall of blood pressure may be desirable in itself (*see* " Controlled Hypotension," Chapter VII), and in any case such falls are easily controllable by the use of pressor drugs More over, mid thoracic puncture is difficult and uncertain, owing to the slope and overlap of the vertebral spines, and anything that adds to the difficulty of the method must be rigorously avoided, for if epidural analgesia is to merit a place in routine practice the failure rate must be extremely low, in order to justify its advantages and compete with the highly efficient intravenous relaxant techniques

For these reasons puncture is best performed between T_{12} and L_1, and only rarely do indications exist for using the upper thoracic approach between C_7 and T_3 Severe scoliosis or kypho scoliosis cause spinal deformities which may deter the anaesthetist from attempting epidural puncture However, these cases present no real difficulty if the site is chosen correctly The point at which transition takes place from the primary to the secondary curvature is usually between the twelfth thoracic and first lumbar vertebrae, and at this point, where angulation and rotation of the vertebral bodies is minimal, epidural puncture is no more difficult than in a normal spine

Raised cerebrospinal fluid pressure distends the dura and narrows the epidural space, therefore the position of the patient should be such that the site of puncture is above, rather than below, the main bulk of c s f , in order to take tension off the dura, and allow it to be displaced more readily However, this must not be carried to excess, for if accidental dural puncture should occur, and if the cerebrospinal fluid pressure is low enough at that point, a " dry tap " may result, thus encouraging

the operator to place the full dose of his epidural solution within the subarachnoid space

For the lumbar approach the patient should be lying on his side with knees drawn up and back flexed in order to open up the interspinous spaces and facilitate entry of the spinal needle The table is tilted so that the line of the vertebral

FIGURE 25

The sitting position for upper thoracic puncture The neck is flexed with the head tucked under the assistant's chin and the shoulders firmly gripped Puncture is being carried out in the first thoracic interspace Odom's indicator is in use as the loss-of resistance test is difficult in this situation

column shows a slight head-down inclination, thus avoiding excessive cerebrospinal fluid pressure at the site of injection, more tilt is needed for broad shouldered men than for broad hipped women This procedure allows the dural envelope to fall away easily from the walls of the spinal canal when the needle point enters the epidural space, and at the same time sufficient local c s f pressure remains to make subarachnoid puncture obvious should it occur accidentally

For upper thoracic punctures the patient should be sitting up and securely supported by an assistant, with the neck flexed, in order to bring the injection site to the highest point (*see* Fig 25)

The orientation of the needle bevel is of no consequence in the lumbar region, since the needle is introduced almost at right angles to the long axis of the spine But in the upper

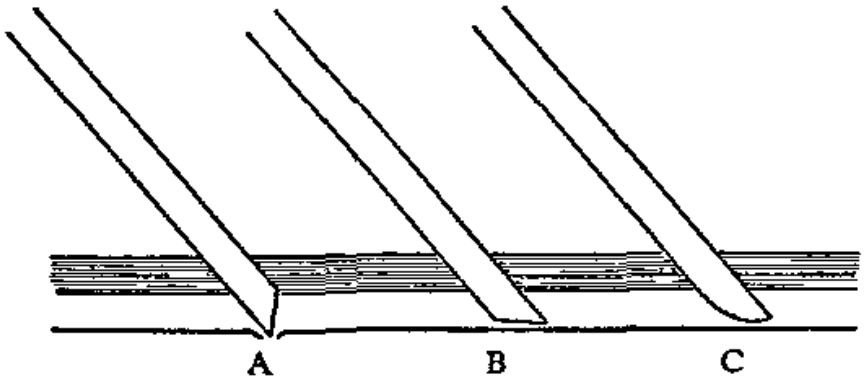

FIGURE 26

Relation of bevel to dura when needle is inserted at an angle

A Incorrect The bevel faces upwards and the point is liable to pierce the dura B Correct The bevel faces inwards parallel to the surface of the dura C Tuohy needle correctly orientated so that the curved shoulder lies towards the dura

thoracic region, where the slope of the vertebral spines makes it necessary to introduce the needle at an angle, it is important to direct the bevel towards the dura, so that the point is discouraged from piercing it With the Tuohy needle (*see* Chapter VIII), on the contrary, the rounded shoulder is placed next to the dura, so that it can function like a ski during its advance, and slide harmlessly over the surface of the meninges (*see* Fig 26)

Conclusion.—Puncture is safest in the lumbar region Successful puncture in this situation is most likely if the patient is in a horizontal, or slightly head-down position, and if the loss-of resistance test is used

High thoracic puncture calls for extreme care, since the spinal cord is so vulnerable Puncture between C_7 and T_1 is best carried out with the patient in the sitting position, one of the negative pressure signs should be used, as the loss-of resistance test is difficult in this region

Mid thoracic puncture is difficult and should be avoided

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CHAPTER VI

DRUGS AND EQUIPMENT

1. DRUGS

THE ideal analgesic agent for the single-dose method of epidural injection should be quick acting, sure in effect, and sufficiently long lasting to outlive the most protracted surgery With the indwelling catheter technique the last of these is unnecessary, since repeated injections through the catheter can prolong analgesia indefinitely It should be possible to autoclave the solution used or the solute and solvent separately, without loss of potency and the *p*H and tonicity of the injected solution should be sufficiently near that of the body fluids to avoid nerve damage in the event of accidental subarachnoid injection

PROCAINE, Novocaine, Planocaine (p aminobenzoyl diethylaminoethanol) The crystals, but not solution, may be autoclaved

Of all the analgesic drugs in common use this is the least powerful and has the shortest duration of action The duration of action, even when prolonged by the use of a vaso constrictor, does not exceed one to one and a half hours It must be injected as a 2 per cent or stronger solution when used by itself, and it has the disadvantage that its molecule contains a p amino benzoic acid group and so antagonises the action of sulphonamide drugs When used by the single-dose technique its only value is to hasten the onset and deepen the intensity of analgesia of a slower-acting but more persistent drug such as nupercaine, by mixing the two together, for this purpose a solution of about 1 5 per cent is effective (a 1 gram ampoule of procaine crystals with two 30-ml ampoules of nupercaine makes a 1 6 per cent solution of procaine in nupercaine) Otherwise the use of procaine is confined to the indwelling catheter technique, but even then it seems more rational to use more powerful and longer acting drugs Procaine is a primary aromatic amine, and so gives the diazo

reaction Gutierrez made use of this fact as a confirmatory sign of correct epidural injection (*see page* 59)

AMETHOCAINE, Pontocaine Pantocaine Decicaine, Tetracaine (p butylaminobenzoyl diethylaminoethanol) The crystals, but not solutions, may be autoclaved

This is a more satisfactory drug than procaine being more powerful and considerably longer acting The 1 500 solution is satisfactory for surgical analgesia, and lasts for about two to three hours The drug is supplied in 100 mg ampoules, and can be autoclaved, and the crystals are readily soluble in water or saline, and so the solution can be prepared conveniently on the spot by adding 100 mg of crystals to 50 ml of saline

XYLOCAINE, Lignocaine, Lidocaine (w-diethylamino 2 6-dimethylacetanilide) Very stable Solutions may be autoclaved [1]

If xylocaine had a longer action it would be the ideal drug for epidural use It has the swiftest action of all analgesic drugs, producing effective analgesia within six to twelve minutes of epidural injection, and the quality of analgesia is intense As with other analgesics, duration of action is dependent upon concentration, and Figure 27, based upon data published by Crawford, shows how these two factors are related for xylocaine [2] It is useful for operations that are likely to take less than two and a half hours, and it is the drug of choice for operations carried out in the conscious patient, for instance, caesarean section Solutions stronger than 1 25 per cent cause increasing degrees of motor paralysis, and so a concentration of about this amount should be chosen in order to obtain the full benefits of a differential block A 1 2 per cent solution appears to be ideal, and this is readily prepared by mixing the contents of a 30-ml ampoule of 2 per cent xylocaine with a 20-ml ampoule of water or saline

NUPERCAINE, Cinchocaine, Percaine (butyl-oxycinchoninic acid diethyl-ethylenediamide) Stable, solutions can be autoclaved. This is the longest acting analgesic available for epidural use, with a duration of three to four and a half hours A solution of 1 600 is widely used, but this is barely strong enough to give complete sensory analgesia in all cases The block obtained with this concentration gives quite adequate reflex relaxation and quiet operating conditions, when

combined with light general anaesthesia, but if the patient is to remain conscious xylocaine is preferable since the latter gives a more intense analgesia The analgesic effects of 1 600 nupercaine can be augmented by adding procaine or amethocaine to the solution, but the limits of safety may easily be exceeded by giving two toxic drugs simultaneously because their toxic effects may summate, and it is wiser to avoid such mixtures altogether

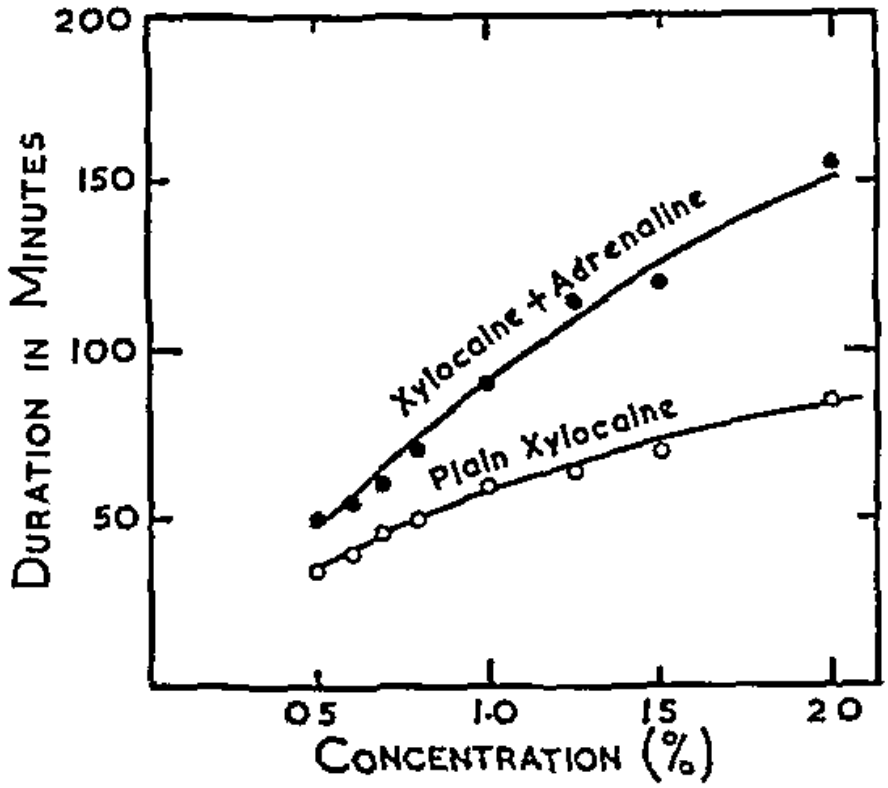

FIGURE 27
Relation between duration of analgesia and concentration of xylocaine with and without the addition of 1 100 000 adrenaline
(From data by O B Crawford Anaesthesiology 1953)

When an epidural catheter is in place (*see* Chapter VIII), it is possible to compare the degree of spread and duration of action of different drugs in the same patient Comparisons by this method show that xylocaine spreads less predictably, and tends to produce a more widespread block than nupercaine

To summarise (*see* Table IV) For swiftness of effect, and intensity of analgesia, xylocaine is the drug of choice, but its effects do not last more than one-and three-quarters to two and a half hours, and so it cannot be used for long operations unless an epidural catheter is inserted For long operations

nupercaine is preferable, but the dose required is usually larger than that for xylocaine When covered by light general anaesthesia the 1 600 solution is sufficient by itself, but xylocaine is preferable in conscious patients

TABLE IV

COMPARISON OF CONCENTRATIONS AND EFFECTS OF DRUGS IN THE EPIDURAL SPACE

Drug	Concentrations for Sensory Block	Concentrations for Sympathetic Block	Speed of Onset (Minutes)	Duration of Action (Hours)
Procaine	2·0 - 3·0%	0·5 1·0%	15 25	1 1½
Amethocaine	0·2% (1 500)	0·066% (1 1500)	15 25	2 3
Xylocaine	1·0 - 1·5%	0·25 0·75%	6 12	1½ 2½
Nupercaine	1 600 1 500	1 1500 1 1000	20 30	3 4½

The Induction and Duration times are those obtained with the stronger range of concentrations and with the addition of adrenaline 1 200 000 1 150 000

PROLONGATION OF EFFECT

Increased duration of action will result from any measure which tends to retain a depot of analgesic drug in the epidural space and, as mentioned in the preceding chapter, the injection of large volumes is one way of doing this, although the resulting spread of analgesia is unnecessarily wide The measures to be considered now are those which aim at slowing the rate of removal of the injected drugs

1. Local Vasoconstriction.—Addition of a vasoconstrictor drug to the analgesic solution constricts the epidural vessels, and reduces the quantity of blood flowing through the epidural space, and this reduces blood stream absorption The pure vasoconstrictor effect of noradrenaline might make it *appear the most suitable drug for this purpose* However, noradrenaline is destroyed extremely rapidly by amine oxidase and so its effects as a local vasoconstrictor are very evanescent Adrenaline is destroyed more slowly, and its effects are more lasting Ampoules of adrenaline hydrochloride may be sterilised by autoclaving, with only negligible loss of potency, thus

EFFECTS OF THREE HOURS HEAT ON POTENCY OF ADRENALINE AMPOULES*

(*p*H 4·2 solution containing 0·1% pot. metabisulphite)

After 3 hours at 100° potency is 95%
" " " 115° " " 94%
" " " 120° " " 85%

A strength of 1 : 200,000 to 1 : 150,000 (0·3 - 0·4 ml. of 1 : 1000 solution in 60 ml.) is effective, and prolongs the duration of anaesthesia approximately 25 to 50 per cent. For laminectomy, where it is desirable to have the maximum vasoconstriction and haemostasis in the epidural space itself, the strength may be increased to 1 : 100,000 to 1 : 85,000 (0·6 - 0·7 ml. in 60 ml. of solution).

2. Vascular Hypotension.—It is reasonable to suppose that a reduced blood flow, consequent upon a low blood pressure will delay absorption from the epidural space. A strong clinical impression that this does occur is based on a number of cases where unexpectedly long periods of analgesia (up to five hours) have been associated with long periods of hypotension in the region of 60 - 75 mm. Hg. systolic.

3. Viscous Solutions.—The low viscosity of water allows aqueous solutions to disperse widely throughout the epidural space, while solutions with a high viscosity might be expected to travel more slowly, and so provide a more localised and segmental form of anaesthesia. Denecke was the first to apply this idea in 1937, using serum, and later 5 per cent. gelatine, as the viscous agent.[4] Since the block was to be a strictly localised one, confined to six or seven segments in all, it did not matter greatly from the respiratory point of view if paralysis was complete in those few segments. Accordingly, the concentration of local anaesthetic in the mixture was increased to very strong proportions, strengths of 0·3 per cent. and 0·4 per cent. amethocaine being used. With this concentration, and doses of up to 15 ml., Denecke obtained analgesia lasting five to seven hours and limited in extent to three segments on each side of the injection site.

In 1941 German chemists synthesised the macromolecular polymer "Periston" (polyvinylpyrrolidone) as a plasma substitute in wound shock, and Duttmann made use of this substance instead of gelatine, since it was more easily stored and

sterilised and gelatine was in short supply Duttmann s results were similar to those of Denecke, *a dose of 14 20 ml of* a 0 3 per cent solution of amethocaine providing segmental analgesia for five to six hours [5] Further modifications of the technique were made by other workers Goepel increased the concentration of amethocaine to 0 5 per cent in a 6 per cent solution of " Periston," and reduced the dosage to 6 - 12 ml [6] Buchholz and Lesse preceded the injection of viscous solution (or " plombe," as the Germans call it) with a larger volume of saline, in order to open up the tissue spaces in the epidural cavity ahead of the viscous mass [7]

The total experience of these writers and others using similar viscous solutions, runs into many thousands of cases,[8 9 10] and so their findings demand considerable respect but nevertheless the principles involved deserve careful scrutiny The use of highly concentrated viscous solutions is based on the assumption that small quantities, injected very slowly, will remain localised at a given spinal level and so produce a very limited area of intense analgesia for a long time This would be acceptable if one could be sure that the dose would remain localised, but as the epidural space is so variable it is impossible to guarantee that a comparatively small dose will not spread much more widely than expected If very concentrated solutions are used, and spread does occur, undesirable motor paralysis will follow in a corresponding area with a resulting depression of respiratory function For this reason it has seemed to me preferable to adopt a more cautious approach and employ concentrations within the range used for simple aqueous solutions Moreover, Denecke's technique demands the performance of a mid-dorsal puncture for upper abdominal operations in order to localise the " plombe " to the segmental nerve roots involved This is difficult and since failures are more likely to occur, it is an undesirable technique In order to ensure the maximum success rate, injection should be confined to the region where it is easy, namely, the lower thoracic and lumbar region Larger volumes than those used by Denecke are necessary when injection is made at a distance from the segmental level at which the block is desired, in fact the volume required approaches the amount needed for simple aqueous solutions

With these points in mind, I have used a solution of 1·4 per cent xylocaine and 1 100,000 - 1 150,000 adrenaline, with 7·5 per cent polyvinylpyrrolidone. This concentration of viscous solution is greater than that used by the German workers, in order to leave no doubt about its effectiveness. The injection was made very slowly, as recommended by Buchholz and Lesse, at the rate of six seconds per millilitre, and in many cases an even longer period was taken over the injection. The following conclusions emerged —

Spread of Analgesia —This was slowed, but the ultimate spread did not appear to be limited in extent.

Speed of Onset of Analgesia —This was also slowed. Using xylocaine, analgesia took ten to twenty-five minutes to become fully developed, instead of the usual six to twelve minutes with plain aqueous solutions.

Duration of Analgesia —This was prolonged, but not to the extent observed by the German workers with their concentrated solutions. The greatest prolongation appeared to be about 15 to 30 per cent. of the average duration observed with aqueous solutions.

Some case notes may help to illustrate these points —

Case 1 —Woman of 51, height 5 ft. 4 in., 16 ml. of viscous solution injected between spines of L_2 - L_3. Injection was made very slowly in the horizontal position, at the rate of 7 seconds per millilitre, with a pause of 2 minutes after the first 10 ml. 8 minutes after completing the injection analgesia extended up to the tenth thoracic segment, and after 20 minutes analgesia had spread to the seventh thoracic segment. Analgesia persisted for only 2½ hours.

Case 2 —Man of 27, height 5 ft. 8 in., 39 ml. of viscous solution injected between T_{12} - L_1, at the rate of 6 seconds per millilitre. At the end of operation, 2½ hours later, analgesia was present up to the fourth thoracic segment. Total duration of analgesia 3½ hours.

Case 3 —Woman of 82, height 5 ft. 1 in., 15 ml. of viscous solution injected between L_4 - L_5, at the rate of 6½ seconds per millilitre. Analgesia extended up to the second thoracic segment, and persisted for 3 hours.

Thus, it is doubtful whether the use of viscous solutions is worthwhile when normal concentrations of analgesics are employed. The individual anaesthetist must decide whether the slight prolongation of effect justifies spending a longer time

over the injection and waiting for the delayed onset of analgesia

EQUIPMENT

Take trouble and trouble will not take you It is a wise plan to adopt the pessimistic view that an intended epidural injection is a potential subarachnoid puncture and prepare accordingly, with all the care that would be used for an elective

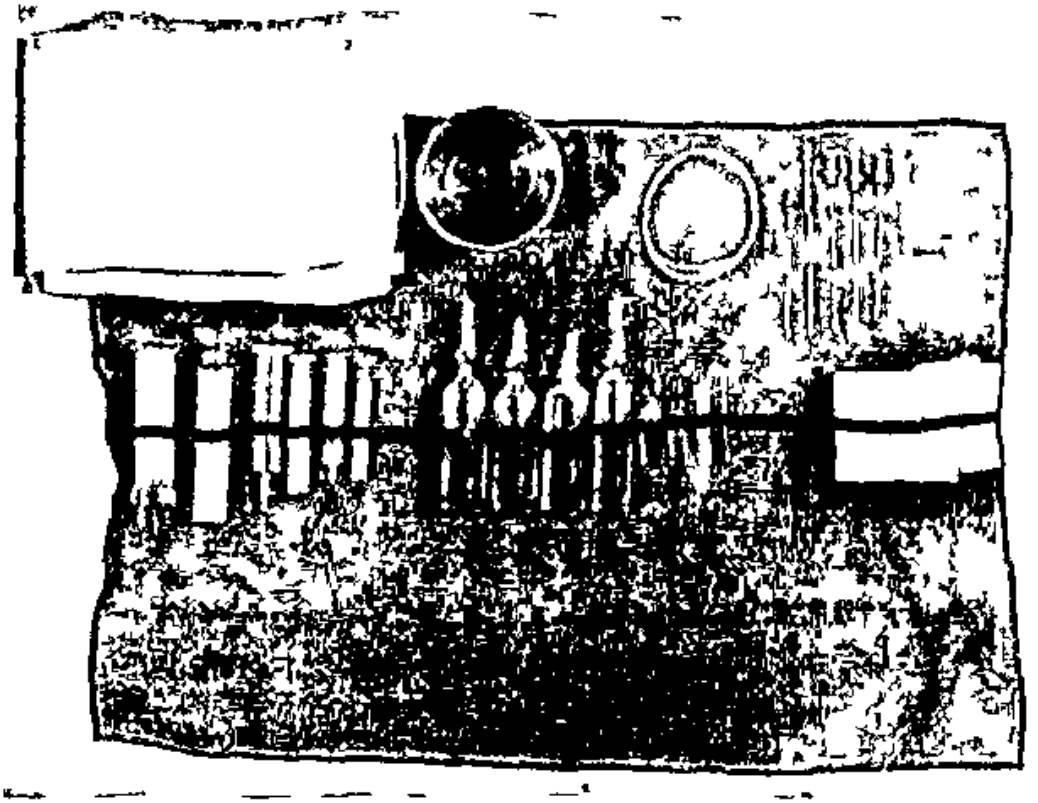

FIGURE 28
Contents of ep dural drum ready for use
(*Medicine Illustrated*)

intrathecal block In order to keep asepsis as fully controlled as possible, all materials for use should be autoclaved together in a single drum, at a pressure of 20 lb per square inch for twenty minutes There is some doubt whether detergents should be used to clean syringes and needles before sterilisation if subarachnoid blocks are to be done, since cases of myelitis have been reported which may possibly be due to traces of detergent remaining in the syringes [11]

After the drum has been opened by an assistant, the anaesthetist, scrubbed up, and gowned and gloved as for a surgical operation, can lay out his own injection trolley without fear

of contamination from carelessly used Cheattle's forceps The drum should be packed so that on opening it the following articles appear in this order —

Mackintosh sheet and towel, to cover injection trolley

Three or four towels and towel clips or one window towel to drape the patient (with careful technique these may be dispensed with)

Gallipot, for 1 per cent iodine in-spirit, to sterilise the skin

Injection pack, containing swabs, syringes, ampoules and needles, etc

Figure 28 shows an injection pack unrolled and ready for use The contents may be varied to suit the anaesthetist's individual preferences, Odom's indicator, Macintosh needles etc , being added as required The pack shown is suitable for epidural or subarachnoid blocks, and contains —

1 20 ml Record syringe
2 5 ml Luer syringe, for use with Luer fitting Tuohy needle
3 2 ml Luer syringe
4 Luer Record syringe adaptor
5 2 × 30-ml ampoules of 1 600 nupercaine
6 1 × 30 ml ampoules of 2 per cent xylocaine (plain)
7 1 × 3 ml ampoule of 1 200 nupercaine, in case a " heavy spinal " subarachnoid block is decided upon
8 1 × 20-ml ampoule of 1 1500 nupercaine, to anaesthetise the skin, and for use as a seeker solution in the Sicard Dogliotti loss-of resistance test
9 1 × 1 ml ampoule of 1 1000 adrenaline hydrochloride
10 2 ampoule files
11 Gauze swabs for painting iodine on the patient's skin
12 Assorted needles An intradermal needle to raise the skin wheal, and anaesthetise the subcutaneous tissues Two filling needles A blunt epidural needle A sharp, fine, Howard Jones spinal needle, for subarachnoid blocks A Tuohy needle for passing epidural catheters (*see* Fig 29)
13 36 inches of vinyl plastic tubing for use in the continuous epidural technique

DOSAGE

There are many variables in the anatomy of the extradural space which make it impossible to prejudge the upper level of

the block so accurately as in a subarachnoid injection and so it is as well to consider the range of analgesia and the limits of accuracy required

In most cases in which epidural analgesia is indicated (*i e* major surgery below the diaphragm) it is desirable to carry the level of analgesia up to or beyond the mid thoracic region By this means the whole abdominal wall is rendered insensitive and a proportion of the sympathetic outflow is interrupted, so that controlled hypotension can be used if required It does not matter if an excess of solution is injected carrying the block into the upper thoracic, or even the cervical region, for the concentrations of drugs are chosen to produce an autonomic and sensory block while allowing the motor fibres to escape, so that respiratory paralysis is impossible however far the solution travels Thus, in most cases the anaesthetist aims to produce a block up to the mid thoracic region, and his margin of permissible error lies from there upwards

There are two important anatomical factors which determine the height to which a block will travel (1) the volume of the epidural space, and (2) the size of the escape routes from it

The volume of the epidural space is greater in a tall man than in a short one and so a given volume of solution will have less effect in the former than in the latter Fluids escape from the space by way of the intervertebral foramina (and more slowly by venous absorption), so that small volumes of solution will travel relatively farther in patients whose intervertebral foraminae are stenosed by the calcifying processes of age or arthritis than in the young and supple

The extrinsic variables under the control of the anaesthetist are —

1 The level of injection

2 The volume of injected solution Large volumes will travel farther and remain *in situ* longer than small volumes,

3 The speed of injection Rapid injection forces the solution farther upwards and downwards in the epidural space, but spreads it out more thinly than after slow injection Thus a given volume injected rapidly will produce a more extensive area of analgesia than the same volume injected slowly, although the duration of analgesia will be shorter, since the volume of solution is widely dispersed and more quickly

removed by venous absorption In the conscious patient, slow injection causes few subjective sensations beyond occasional paraesthesiae, or feelings of warmth or cold in the legs whereas rapid injection gives rise to unpleasant symptoms The rapidly increased epidural pressure displaces the dura, and causes a temporary rise of c s f pressure, with sensations of vertigo and fulness in the head In the unconscious subject rapid injection causes a momentary tachypnoea

4 Gravity Sicard and Forestier noticed the marked effect that gravity exerts on lipiodol solutions in the epidural space and to a lesser extent lighter solutions are influenced in the same way A steep head-down tilt helps to carry the solution towards the head, while the sitting position tends to limit the upward spread

Three of the extrinsic variables can be standardised —

1 Epidural puncture is easiest between the second and third or third and fourth lumbar spines and one of these spaces should be chosen routinely, unless a special condition such as scoliosis indicates the choice of a different level

2 The speed of injection should be slow and steady at the rate of about 0 5 1 0 ml per second for aqueous solutions and 0 2 ml per second for viscous ones

3 On most occasions a slight head-down tilt of 5° is satisfactory This reduces the pressure in the lumbar portion of the dural sac, and so makes dural puncture less likely during introduction of the needle, but is not steep enough to cause any gravitational effects

The volume of epidural solution is the only remaining extrinsic variable, and this must be chosen to suit the probable intrinsic conditions to be found in a patient of that particular size and age The factor of probability arising from individual variations in epidural structure must be reiterated, for it is this that makes dosage a matter of approximation, rather than the subject for hard and fast dosage-tables Nevertheless this limitation is of little practical importance, provided there is a clear understanding of the principles involved

The volumes of solution commonly used vary between 15 ml and 50 ml A few illustrative cases will serve to show how dosage varies in different patients —

1 A large young man, 6 ft 2 in tall for partial gastrectomy It was expected that the epidural space would be large and

the escape routes freely patent, requiring a large dose of solution 48 ml were injected between T_{12} and L_1 Analgesia to T_4

2 Frail old woman of 80 for Judet's operation to hip Height 5 ft 2in At this age, and in the presence of arthritis, the intervertebral foramina would probably be considerably stenosed, preventing leakage of solution from the epidural space 24 ml were injected between T_{12} and L_1 Analgesia to T_2

3 Heavily built man of 73, for retropubic prostatectomy Height 5 ft 4 in This man was active for his age, and his intervertebral foramina probably patent to a considerable degree 32 ml injected between L_1 and L_2 Analgesia to T_4

Some statistics of age, height and dosage in 116 surgical cases will show how these factors are related The speed of injection, the drug used (nupercaine), and the viscosity of the solution were the same in every case The degree of spread was found by testing for the upper level of analgesia immediately after the operation was completed

The ratio

$$\frac{\text{The amount of solution injected}}{\text{The number of segments involved, above the site of injection}}$$

gives an arbitrary expression of dosage in terms of ml litres per spinal segment affected above the site of injection The patients were unselected, except that operations lasting for more than two-and a half hours were excluded from the series, on the assumption that a significant regression of the level of analgesia might occur after that time

Table VI, correlating height and dosage, and Table VII, correlating age and dosage, have been compiled from the preceding observations, and they reveal the following facts —

Height and Dosage (Table VI) —Inspection alone shows that although there are wide limits for dosage in any one class of height, there is a *definite tendency for greater dosage* requirements in the taller classes The correlation coefficient, calculated from Table V, is 0 33, and this is three times the standard error of the coefficient (S E = 0 11), showing that there is a significant association between height and increased dosage

TABLE V
EPIDURAL DOSAGE

Case No	Age	Height	Level of Injection	Dose in ml	Height of Analg	No of Segments from Site of Injection	Dose in ml per Segment
1	62	5′ 2″	L_3 - L_4	35	T_4	10	3 5
2	48	6′ 0″	L_1 - L_2	46	T_2	11	4 2
3.	51	5′ 11″	L_2 - L_3	37	T_3	9	4 1
4	44	5 4″	T_{12} - L_1	41	T_4	8	5 1
5	43	5′ 9″	T_{12} - L_1	46	T_2	10	4 6
6	41	5′ 4″	T_{12} - L_1	41	T_4	8	5 1
7.	67	5 5″	T_{12} - L_1	37	T_4	8	4 6
8	61	5′ 6″	T_{12} - L_1	40	T_3	9	4 4
9.	48	5′ 11″	T_{12} - L_1	45	T_2	10	4 5
10	49	5′ 5″	T_{12} - L_1	44	T_2	10	4 4
11.	52	5′ 10″	T_{12} L_1	45	T_2	10	4 5
12.	51	5 7″	T_{11} - T_{12}	43	T_2	9	4 7
13	41	5 9″	T_{11} - T_{12}	42	T_3	8	5 2
14	49	5′ 11″	T_{12} - L_1	42	T_2	10	4 2
15	42	5′ 7″	T_{12} - L_1	43	T_2	10	4 3
16.	73	5′ 10″	T_{12} - L_1	38	T_2	10	3 8
17.	53	5′ 4″	T_{12} - L_1	43	T_1	11	3·9
18	49	5′ 7″	T_{12} - L_1	42	T_4	8	5 2
19.	69	5′ 5″	L_2 - L_3	38	T_2	12	3 1
20	39	6′ 0″	L_1 - L_2	48	T_4	9	5 6
21.	26	5′ 7″	L_1 - L_2	42	T_3	8	5 2
22.	36	5′ 10″	T_{11} - T_{12}	42	T_1	10	4 2
23	52	5′ 6″	T_{12} - L_1	40	T_4	8	5 0
24	27	5 7″	L_1 - L_2	45	T_4	7	6 4
25	36	5 11″	T_{12} L_1	46	T_3	9	5 1
26	59	5′ 8″	L_2 - L_3	40	T_4	10	4 0
27.	40	5′ 2″	T_{12} - L_1	39	T_1	11	3 55
28.	50	5′ 3″	T_{12} - L_1	40	T_1	10	4 0
29	65	5′ 10″	L_1 - L_2	38	T_2	11	3 45
30	34	5′ 9″	T_{11} - T_{12}	45	T_3	8	5 6
31	42	5′ 9″	T_{12} - L_1	41	T_4	8	5 1
32	31	5′ 11″	L_1 - L_2	40	T_2	10	4 0
33	30	5′ 1″	T_{12} - L_1	40	T_3	9	4 4
34	70	5′ 8″	L_2 - L_3	39	T_4	10	3 9
35.	26	5′ 10″	L_1 - L_2	46	T_2	8	5 75
36	48	5′ 1″	T_{12} - L_1	40	T_2	10	4 0
37.	64	5′ 4″	L_3 - L_4	37	T_4	8	4 5
38.	49	5′ 10″	L_2 - L_3	42	T_3	9	4 6
39	38	4′ 11″	T_{12} - L_1	37	T_4	8	4 5
40	73	6′ 0″	T_{12} - L_1	38	T_2	10	3 8

EPIDURAL DOSAGE (*continued*)

Case No	Age	Height	Level of Injection	Dose in ml	Height of Analg	No of Segments from Site of Injection	Dose in ml per Segment
41	56	5 10″	T_{12} L_1	43	T_7	9	4 7
42	65	5 9″	L_1 - L_2	35	T_8	8	4 37
43	65	5 3″	L_1 - L_2	39	T_2	11	3 54
44	55	6 0″	L_1 L_2	48	T_4	10	4 8
45	53	5′ 9″	L_1 L_2	42	T_5	10	4 2
46	58	5 1″	L_1 - L_2	35	T_5	10	3 5
47	44	5 5″	L_1 - L_2	39	T_2	11	3 54
48	55	5′ 7″	L_1 - L_2	39	T_2	11	3 54
49	45	5 4″	L_1 - L_2	25	T_7	8	3 2
50	65	5′ 9″	L_1 - L_2	25	T_9	6	4 1
51	49	5′ 2″	L_1 - L_2	26	T_9	8	3 25
52	61	5 0″	L_1 L_2	35	T_3	12	2 9
53	60	6′ 2″	L_1 - L_2	30	T_5	6	5·0
54	57	5′ 9″	L_1 - L_2	40	T_3	12	3 33
55	64	5′ 8½″	L_1 - L_2	30	T_5	9	3 33
56	46	5′ 3″	L_1 - L_2	44	T_3	11	4·0
57	42	5 6″	L_1 - L_2	39	T_5	9	4 3
58	42	5′ 7″	L_1 L_2	43	T_6	8	5 4
59	51	5 7″	L_1 - L_2	40	T_7	10	4·0
60	51	5′ 8″	T_{12} - L_1	43	T_7	10	4 3
61	50	5′ 4″	T_{12} - L_1	40	T_7	10	4 0
62	45	5′ 4″	L_1 - L_2	40	T_7	10	4 0
63	80	5′ 4″	T_{12} L_1	24	T_8	10	2 4
64	60	5′ 2″	L_1 - L_2	30	T_7	12	2 5
65	59	6′ 0″	T_{12} L_1	45	T_6	10	4 5
66	67	5 10″	T_{12} L_1	38	T_1	11	3 45
67.	58	6 3″	L_1 - L_2	50	T_7	12	4 1
68	85	5 6″	T_{12} - L_1	29	T_8	10	2·9
69	83	5′ 5″	L_1 - L_2	27	T_6	8	3 37
70	65	5 11″	L_1 - L_2	39	T_7	10	3 9
71	44	5 1″	T_{12} - L_1	42	T_1	11	3 8
72	50	5′ 3″	L_1 - L_2	38	T_2	12	3 1
73	70	5′ 11″	L_1 - L_2	37	T_4	11	3 36
74	36	6 1″	T_{12} - T_{12}	45	T_5	9	5 0
75	70	5′ 7″	L_1 - L_2	26	T_5	13	2·0
76	27	5 8″	L_1 - L_2	39	T_5	12	3 25
77	36	5 0″	L_1 - L_2	35	T_6	10	3 5
78	42		T_{12} - L_1	32	T_5	9	1 55
79	38		L_1 - L_2	42	T_6	7	6 0
80	61		T_{11} - T_{12}	40	T_1	10	4·0

EPIDURAL DOSAGE (*continued*)

Case No	Age	Height	Level of Injection	Dose in ml	Height of Analg	No of Segments from Site of Injection	Dose in ml per Segment
81	50		L_1 L_2	40	T	11	3 6
82	38		T T_2	44	T	10	4 4
83	74		L_1 L	30	T_4	10	3 0
84	70		L_2 L_3	37	T	12	3 1
85	73		L_2 L_3	27	T_3	12	2 25
86	48		L_1 L_2	39	T_2	11	3 54
87	39		L_2 L_3	42	T_4	10	4 2
88	23		T_2 L	40	T_2	10	4·0
89	44		T_2 L	40	T_3	10	4 0
90	34		L_2 L_3	42	T_5	8	5 25
91	57		L_1 L	44	T_2	12	3 66
92	62		L L_2	37	T_3	11	3 35
93	78		L L_2	32	T_2	11	2 9
94	83		L L_2	27	T_3	10	2 7
95	75		L L_2	38	T	11	3 4
96	67		L_2 L_3	35	T_4	8	4 3
97	51		T_{12} L	38	T_2	10	3 8
98	68		L_2 L_3	39	T_2	12	3 25
99	44		L L_2	38	T_2	11	3 47
100	30		T_2 L_1	40	T_2	10	4·0
101	52		L_1 L_2	37	T_3	10	3 7
102.	36		L_1 L_2	42	T_3	10	4 2
103	44		L_2 L	40	T_2	12	3 3
104	43		T_{12} L	40	T_4	8	5·0
105	48		T_2 L_1	38	T_2	10	3 8
106	47		L L_2	40	T	11	3 55
107	37		L_1 L_2	39	T_4	9	4 3
108	52		L_2 L_3	38	T_2	11	3 45
109	61		L_1 L_2	42	T_3	10	4 2
110	51		L L_2	39	T_2	11	3 55
111	78		L_2 L_3	32	T_4	11	2·9
112	60		L_2 L	30	T_2	12	2 5
113	48		L L_2	35	T_4	9	3 9
114	63		T_{12} L_1	30	T_2	10	3·0
115	43		L L	46	T_2	10	4 6
116	79		L L_2	40	T_1	13	3·0

TABLE VI
CORRELATION OF HEIGHT AND EPIDURAL DOSAGE IN 77 CASES
(Analgesic Solution—1 600 Nupercaine)

Height	Dosage in ml per Spinal Segment above the Site of Injection									Total
	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	
6 5" / 6 3"					1					1
6 2" / 6 0"				1	1	2	2	1		7
5 11" / 5 9"			4	2	7	5	3	2		23
5 8" / 5 6"	1	1	2	2	6	1	4		1	18
5 5" / 5 3"	1		4	3	5	2	2			17
5 2" / 5 0"		2	1	5	2					10
4 11" / 4 9"						1				1
TOTAL	2	3	11	13	22	11	11	3	1	77

Age and Dosage (Table VII) —It is evident that the degree of association between age and dosage, shown in Table VII, is much stronger than between height and dosage in Table VI Every patient under the age of sixty needed more than 3 0 ml per segment (above the site of injection) and every patient over eighty needed less than 3 5 ml per segment

The calculated correlation coefficient for age and dosage is 0 56 (*i e*, six times the standard error of the coefficient S E =0 09) Therefore, there is a very significant inverse relationship between age and dosage, and age is much more important than height in determining the dose required

TABLE VII
CORRELATION OF AGE AND EPIDURAL DOSAGE IN 116 CASES
(Analgesic Solution—1 600 Nupercaine)

Age	Dosage in ml per Spinal Segment above the Site of Injection									Total
	20	25	30	35	40	45	50	55	60	
80 - 89	1	2	1							4
70 79	1	3	5	3	6	2	1			11
60 69		3	7	3	6	2	1			22
50 - 59			3	8	8	5	1			25
40 - 49			4	8	9	4	7			32
30 39				1	8	1	3	2	1	16
20 29			1		1		1	1	1	5
TOTAL	2	8	21	23	32	12	13	3	2	116

Formula for Dosage.—An approximate working formula for dosage (for nupercaine) can be calculated from the seventy seven cases in which both height and age were measured The multiple correlation coefficient for Dosage (D), with Age (A), Height (H), and the number of analgesic segments above the vertebral level of injection (S), is 0 698, which is significant, this means that D can be calculated from A, H, and S, within a reasonable margin of error The regression equation for calculating D is —

$$D = -46\,619 - 0\,312A + 1\,102H + 2\,922S^{*}$$

or, more simply,

$$\text{Dosage, in ml of 1/600 nupercaine} = \left[\begin{array}{l}\text{(Height in inches} + 10\%) + (3 \text{ times the}\\ \text{number of spinal segments to be blocked}\\ \text{above the vertebral level of injection)}\end{array}\right] - \left[\frac{\text{Age in years}}{3} + 47\right]$$

It will be appreciated that one of the components of this formula, (S), is an arbitrary, hybrid measurement, being a

* I am indebted to Mr Nigel Cridland D M , D O (Oxon) for the calculation of this equation

figure derived from two points on different reference systems, namely, a spinal segment and a surface landmark on the vertebral column Nevertheless, when injection is made in the lumbar region, the calculation gives a rough practical guide to the expected dose of 1/600 nupercaine, to within, perhaps, four or five millilitres As mentioned earlier, xylocaine tends to produce a more widespread block than nupercaine, and although the extent of analgesia obtained with xylocaine often follows the calculated dosage for nupercaine, in many cases the block extends 20 - 40 per cent farther than expected

Examples —

1 Fat woman of 60 Height 5 ft 2 in It was intended to block all segments below the third or fourth thoracic segment Epidural injection with 1/600 nupercaine was made between the second and third lumbar spines (therefore S, the number of spinal segments to be blocked above the site of injection = 11)

The expected dose of nupercaine = (68 + 33) - (20 + 47) = 34 ml 36 ml of 1/600 nupercaine were injected and analgesia reached to the intended level

2. Lean youth of 19 Height 6 ft 1 in The upper limit of analgesia was required to lie between the ninth and tenth thoracic segments Injection of 1 2 per cent xylocaine was made between the third and fourth lumbar spines (*i e*, S = 6 segments)

The calculated dose (on the basis of the formula for nupercaine) = (80 - 18) - (6 - 47) = 45 ml In fact, only 34 ml of 1 2 per cent xylocaine were injected, and yet analgesia reached the intended level

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CHAPTER VII

THE BLOOD PRESSURE

IN Chapter III it was shown that epidural analgesia is accompanied by a fall of blood pressure in proportion to the number of vasomotor segments involved with high blocks, the anaesthetist must decide whether to exploit or correct the induced vascular hypotension according to the nature of the case It is impractical to make hard and fast rules for all types of patient, but broadly speaking three courses of action are open (1) The blood pressure may be kept elevated at normal levels throughout the operation (2) A moderate degree of hypotension may be allowed, to a level of 80 - 100 mm Hg systolic (3) Full hypotension may be actively sought to the lowest safe level of 60 - 65 mm Hg systolic, for the purpose of producing an ischaemic surgical field[1] It must be constantly remembered that tolerance to anoxia is less at low pressures than at normal levels of blood pressure Therefore, if the pressure is allowed to fall, a clear airway must be guaranteed at all times, and all upper abdominal cases should have an endotracheal tube passed, to avoid the danger of anoxia from laryngeal spasm, and on no account must a head up tilt be allowed, or a dangerous degree of cerebral anaemia may result

If the blood pressure is run at reduced levels sharp fluctuations should be avoided as far as possible, and a gradual return to normal be allowed to follow the slow segmental regression of analgesia The careless use of pressor drugs leads to sudden gusts of hypertension which are apt to disturb early clot formation, and cause unnecessary oozing from cut surfaces

Absolute Contraindications to Vascular Hypotension.—1 PREGNANCY.—Foetal oxygenation may be jeopardised by low levels of maternal blood pressure Patients for caesarean section *under epidural analgesia should always receive* a pressor drug early on before the blood pressure has fallen This does not apply to cases of eclampsia, where an epidural block may be induced with the specific intention of reducing an abnormally high blood pressure to normal levels

2 Loss of Whole Blood, or Blood Constituents — Patients in a state of compensatory vasoconstriction, as in haemorrhage from a bleeding gastric ulcer, should not be allowed to suffer any further fall of blood pressure It is arguable that anaesthetic methods involving sympathetic blockade should not be used at all in these cases However, I have employed epidural analgesia in a number of severely ill patients for emergency gastrectomy for haemorrhage, where the surgeon took up to three hours over the operation, and the results were equally good, if not better, than would have been expected by using other anaesthetic techniques

3 Compensatory Vasoconstriction in the presence of a Fixed Cardiac Output —For instance, in chronic constrictive pericarditis a high venous pressure helps to maintain the restricted cardiac output If sudden vasodilatation occurs cardiac diastolic filling may become inadequate, and cardiac failure result This sequence of events is thought to underlie the cause of sudden death that sometimes occurs in cases of constrictive pericarditis during induction of anaesthesia with thiopentone However, the vasodilatation that follows an epidural block is less hazardous, since it is less precipitate and gives more time for vascular adjustments to take place

Indications for Checking the Hypotension at Moderate Levels (80 - 100 mm. Hg systolic).—These apply to a large group of patients and include the majority of cases for major surgery below the diaphragm A moderate degree of vascular hypotension diminishes oozing and blood loss, while a sufficient head of pressure remains to ensure that bleeding from vessels of any consequence is adequate to attract the surgeon's attention I have not seen any harm come to patients of all grades of physical condition between the ages of sixteen and ninety two years when the systolic pressure has been confined within these limits, and the need for blood replacement has been much less than would have been expected at normal levels of blood pressure Therapeutic blocks for hypertensive cardiac failure, or dissecting aneurysm of the aorta fall into this class (*see* Chapter IX)

No matter what complicating conditions exist, this level of blood pressure seems to be perfectly adequate for all cases

patients can safely be taken to even lower levels 80 mm Hg systolic should be regarded as the lowest permissible level of blood pressure if any vascular or parenchymatous abnormalities are present I am aware that some anaesthetists with wide experience in the technique of controlled hypotension may consider this a high limit particularly when metabolic demands are lowered by barbiturate anaesthesia but it allows a safe margin without detracting from the merits of the technique

Indications for Full Controlled Vascular Hypotension down *to 60 75 mm Hg systolic* —This group is confined to cases where the surgeon requires an unusually dry operative field and where the patient s condition does not contraindicate such low levels of hypotension 60 mm Hg systolic should be taken as the lowest permissible level for there is some evidence that hepatic vascular insufficiency occurs below this point (*see* Chapter III) In order to ensure an adequate cerebral circulation a horizontal or slight head-down position should be observed and it must be re-emphasised that on no account should the patient s head be raised while the pressure is low either during operation or afterwards in the ward Failure to instruct the nursing staff on this point may result in postural syncope and dangerous cerebral anaemia if the patient is propped up in bed immediately after operation

It is my impression that at any given level of blood pressure surgical bleeding is less under epidural analgesia than when the methonium drugs are used as the hypotensive agent and since an epidural block lasts longer than a subarachnoid injection I would give it first place in the list of effective hypotensive measures

PRESSOR AGENTS

Hypotension which cannot be restored to normal levels at will is uncontrolled and dangerous If the blood pressure is allowed to fall means must be at hand to raise it again instantly for this posture and vasopressor drugs are used

Posture —In the absence of vasoconstrictor tone a limb will become emptied of blood if it is raised and filled when it is lowered Hence raising the legs or the adoption of a head down tilt will drain blood from the legs into the rest of the body causing a sort of autotransfusion and an elevation of

blood pressure The rise of pressure obtainable by this method is not great, seldom exceeding 5 - 15 mm Hg systolic for a 10° - 20° tilt A corresponding fall takes place when the horizontal position is resumed and so a very careful watch should be kept on the blood pressure when the patient is straightened out from the lithotomy or Trendelenburg positions, lest an undue fall should occur at these times

Vasoconstrictor Drugs.—These are the chief means of stabilising the blood pressure at required levels Many pressor drugs are available, but the anaesthetist is well advised to become familiar with one or two well chosen drugs, rather than confuse himself with a variety of pressor agents of different potency and selection should be made in favour of those which do not give rise to tachyphylaxis on repeated injection In the presence of hypotension absorption from subcutaneous or intramuscular injection sites is capricious and delayed, and so, for a quick and reliable effect, the intravenous route should be used

When the patient is unconscious and the greater part of the sympathetic system interrupted, most of the normal compensatory vascular mechanisms are abolished and a great augmentation of response to vasoactive drugs occurs" [3] Hence only very small quantities of vasopressors are necessary, and this diminishes the tendency to the development of drug tolerance [4]

Ephedrine.—Dose 5 mg - 60 mg Ephedrine has a central cardiac action as well as a peripheral vasoconstrictive effect and it also has a slight cerebral stimulating effect Tolerance and reversal of effect tend to follow repeated injection

Methedrine, (d methyl amphetamine, d-desoxyephedrine "Pervitin") Dose 5 mg - 50 mg As with ephedrine there is a cardiac action as well as a peripheral effect, and the cerebral stimulating effect is marked, but there is much less tendency to develop tolerance As with other pressor drugs, the individual response varies widely, but on an average, 5 mg produces a 25 mm Hg elevation of the systolic pressure within two-and a half minutes and the pressure then gradually declines to its previous level, or a little above it, after twenty minutes When used in small doses, the cerebral stimulating effects do not appear to be a disadvantage either during or after anaesthesia If the operation is unexpectedly short, and

the blood pressure still low when the surgeon has finished, the final intravenous injection may be combined with a larger intramuscular dose, so that on return to the ward the more slowly absorbed intramuscular depot will tide the patient over a potentially hypotensive period

There are numerous other effective sympathetic mimetic drugs obtainable, and the reader should refer to the appropriate pharmocological works if he wishes to explore this field further In practice, methedrine gives very satisfactory results as a long acting pressor agent

Adrenaline and Noradrenaline.—Many synthetic pressor drugs do not show a pure peripheral vasoconstrictor action, but in addition have a stimulating effect on the heart itself Since the fall of blood pressure in spinal block is due to peripheral vasodilatation it is logical to use a drug which has a pure vasoconstrictive action, without any direct effect on the heart Noradrenaline is such a drug Noradrenaline, natural product of the adrenal medulla and physiological transmitter of adrenergic nerve action, is a powerful and very transient vasoconstrictor,[5] without any of the cardiac or metabolic stimulating effects of adrenaline Owing to its evanescent action it is necessary to give the drug in a continuous saline drip The manufacturers recommend a strength of 4 ml of the 1 1000 solution in 1 litre of saline, making a solution containing four micrograms per millilitre However, this is too strong for most purposes and it is very difficult to run the drip slowly enough to keep the blood pressure within reasonable limits A concentration of one or two micrograms per millilitre is more manageable and quite adequate

The intravenous adrenaline drip, in a concentration of 1 · 250,000, and popularised by Frankis Evans,[6] has played a useful part in the past, but has now been supplanted by noradrenaline, since the powerful metabolic and cardiac effects of adrenaline are unwanted, and perhaps even harmful, in a purely hypotensive situation

For practical purposes, methedrine, or some other long-acting sympathomimetic such as neosynephrine or pholedrine, given as required in repeated small doses, is the most convenient type of agent to use in most cases, and the slight disadvantage of their side effects, which in many ways is more

academic than practical, does not outweigh their convenience and ease of administration The noradrenaline drip is best reserved as a powerful but rather fussy trump card for use in the occasional methedrine resistant patient or the bad risk case where very accurate control of the blood pressure is necessary at the outset

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CHAPTER VIII

CONTINUOUS EPIDURAL ANALGESIA

HAVING shot his bolt with a single epidural injection, the anaesthetist creates a zone of analgesia lasting for three to four and a half hours, and no more, and if the surgical task extends beyond this period general anaesthesia and relaxants must be used as required, to allow completion of the operation It is obviously undesirable to change techniques during the course of an operation, and so it is preferable to keep the duration of analgesia under continuous control when unusually difficult and lengthy procedures are planned This can be done by placing a plastic catheter in the epidural space[1] Then continuous analgesia can be prolonged for as long as necessary by intermittent injections through the catheter For therapeutic blocks, where the duration of the blockade must be measured in days rather than hours, the catheter may be left in place for a week or more, so that the patient is spared the discomfort of repeated injections

TECHNIQUE

With the caudal approach to the epidural space, *via* the sacral hiatus, the long distance between the sacral membrane and the dura allows a straight needle to be used, but in the lumbar region the epidural space is so narrow that a semi-stiff catheter thrust across it impinges on the dura at right angles with little chance of gliding harmlessly to one side, and so may injure the dura The Tuohy needle with curved directional Huber point overcomes this difficulty (*see* Fig 29)[2] A sufficient change of direction is imparted to the catheter to allow it to slide off the dura and travel up or down the epidural space according to the way the tip is orientated

Catheters are made thirty six to forty inches long by cutting from lengths of 1 mm bore vinyl plastic tubing* This plastic material is eminently suitable for the job, being tough, pliable, of strictly uniform thickness, and unaltered by steam steriliza-

* Made by Becton Dickinson and Company Rutherford New Jersey U.S A

tion Polyethylene tubing is unsatisfactory for epidural use since its calibre is altered by heat sterilization, and the catheter becomes too thick to pass down the needle Moreover, many antiseptic solutions make polyethylene very brittle, so that if the catheters are sterilized in these solutions breakages may occur within the epidural space Vinyl plastic tubing softens with heat but is moderately hard when cold, and so in order to make

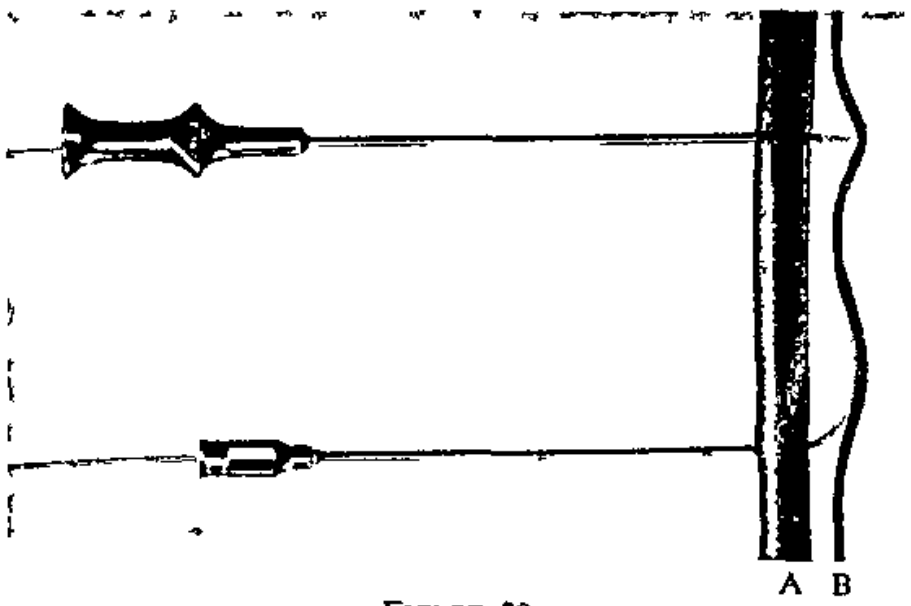


FIGURE 29
Epidural catheters introduced through straight and curve pointed needles Note the gentle curve imparted to the catheter by the curve pointed Tuohy needle A Dura B Lig flavum

the end of the catheter as atraumatic as possible it is as well to smoothe off the square cut ends on a piece of emery paper before sterilizing The catheter is coiled, tied loosely with tape and placed in the epidural pack, along with the other instruments for autoclaving

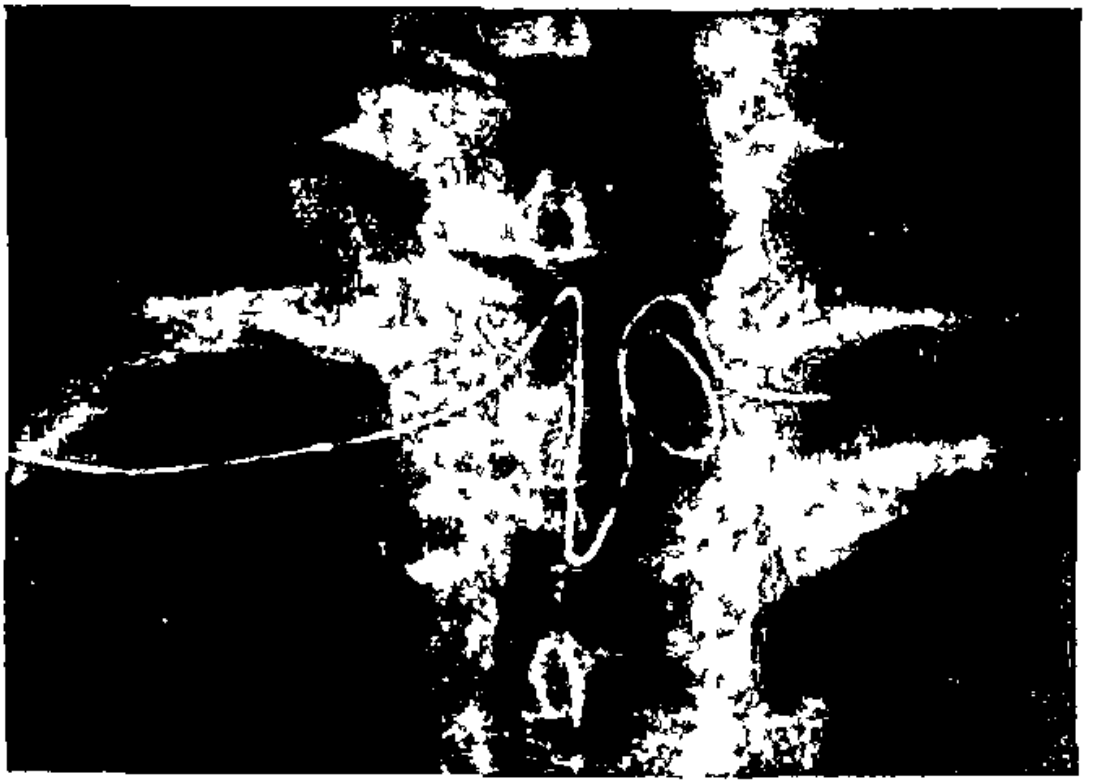
If the catheter is tied too tightly kinks may result, which prove troublesome when threading the catheter through the Tuohy needle A better way of packing the catheter is as follows [3]

The plastic catheter is stiffened by threading through it a fine wire stilet from a child's ureteric catheter Catheter and stilet are then threaded through a length of latex rubber tubing of the size used for intravenous drips, and an inch or so left protruding at each end The stilet is then withdrawn, and the catheter and rubber tubing coiled round the inside of the

epidural drum, taking care that the rubber is not kinked in any part of its course After autoclaving, when the catheter is taken out of its rubber splint, it will be straight, unkinked, and easy to handle

The Tuohy needle is introduced in exactly the same way as for a single-dose injection and once the tip has reached the epidural space the needle is gently rotated until the bevel points upwards or downwards, according to the direction that the catheter is to travel In the upper thoracic region, where there is more obliquity of the spines than in the lumbar region, it is better to introduce the needle with the opening pointing upwards (so that the rounded shoulder of the Huber point can slide over the dura), and leave the opening pointing head wards, otherwise rotation of the point through 180° might scratch or perforate the dura. Catheters will often continue for a short way in the direction in which they are started but they tend to be deflected by the many blood vessels and nerve roots that lie in their path, curling up or doubling back in the reverse direction to that intended, and sometimes even passing out through an intervertebral foramen (Fig 30) In an endeavour to pass the catheter tip up or down to any desired segmental level, wire stilets have been used, in order to impart the necessary rigidity to the catheter[4] But the idea of a rigid catheter blundering its way blindly through the delicate labyrinth of epidural vessels is not an attractive one, court ng as it does the likelihood of epidural haematoma, and the intravenous absorption of injected local analgesic solution through the open ends of torn blood vessels Post mortem examination of the epidural space in patients who have had catheters in place at the time of death shows that some slight venous damage is not uncommon, and the use of a stiffening stilet to force the catheter in any given direction is likely to make this damage much worse

Ideally, it is desirable to be able to place the catheter tip opposite any predetermined segment, so that the zone of blockade can be restricted to the essential minimum This is particularly the case for some localised therapeutic blocks (for instance, the pain relief of acute pancreatitis involving thoracic segments 7, 8 and 9) But to do this the catheter must either be inserted at a high spinal level or forced upwards for long



A

B

FIGURE 30

Transforaminal passage of the epidural catheter a cause of failure Radiograph of nylon catheter introduced between the first and second thoracic spines 0·2 ml of "Neohydriol (Fluid)" injected, in order to outline the catheter A. Catheter curled up in the epidural space with the tip protruding under the first rib B Catheter has been withdrawn 3½ inches The tip is now lying in the epidural space

distances from a lower level in the lumbar region Puncture in the mid thoracic region (T_7 T_8) is difficult owing to the obliquity and overlap of the vertebral spines and laminae, and so should not be attempted In the upper thoracic region, between C_7 and T_3, the interspinous spaces can be opened widely by acute flexion of the neck and successful puncture is relatively easy, provided the " hanging-drop " technique is used and the patient is sitting up, as explained in an earlier chapter the ligaments are too lax and diffuse in the upper thoracic spine to provide a reliable loss-of resistance test Buckingham and his associates claim that the drop sign should be present in every case at this level, if careful technique and blunt wide bore needles are used [5 6] But in my experience this is not so, and I do not consider the site to be safe enough for routine use The cord is very vulnerable at this level, and a careless movement, or too deep advance of the needle in the absence of a positive drop-sign, might cause irreparable damage and paraplegia The alternative, of placing an unstiffened catheter in the lumbar region, is easy and safe, and from there any spinal segment can be blocked by merely increasing the dose of local analgesic In the interests of safety and success therefore, the ideal of localised placement should be sacrificed and the lumbar route used as a routine, and the occurrence of a widespread block should be accepted as an unfortunate necessity in cases where high spinal segments are attacked

Once the Tuohy needle is in place (Fig 31), and the usual confirmatory tests for correct placement have been made the catheter is inspected for absence of kinks and occlusions (Fig 32), and then gently threaded through the needle with one hand while the other steadies the shaft of the needle (Fig 33) As the catheter tip passes from the bevel of the needle into the epidural space there may be a slight resistance owing to the bevel being insufficiently advanced into the space and partially occluded by the inner margin of the ligamentum flavum, but a gentle rotation of the catheter overcomes this, and from then on, further advance is unimpeded During this manoeuvre the conscious patient may complain of paraesthesiae as the tip of the catheter slides past the dural-covered nerve roots When using a plain unmarked plastic catheter it is often difficult to judge exactly how much of the tubing

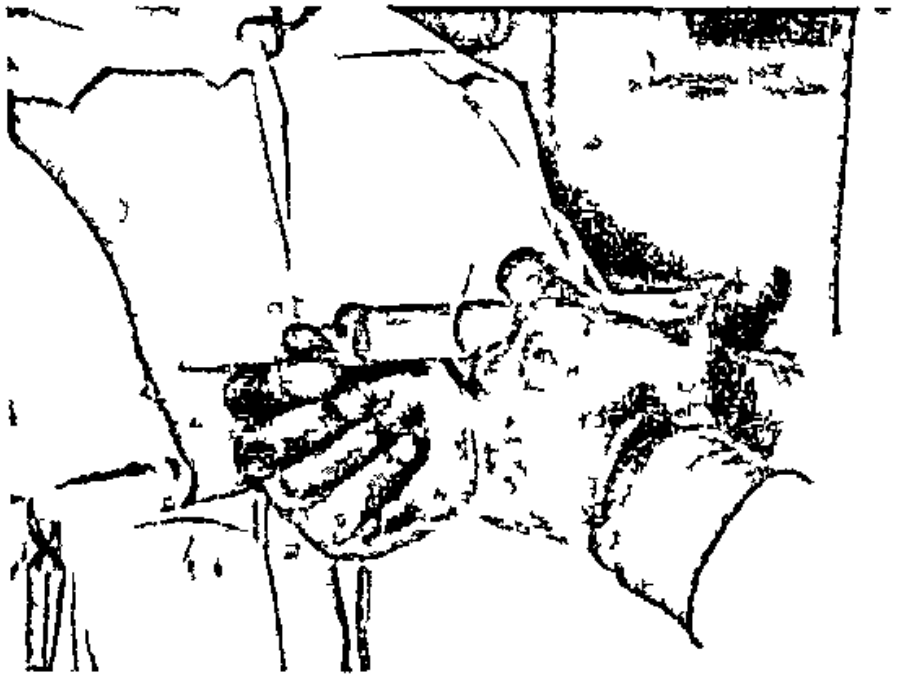


FIGURE 31
Introducing a Tuohy needle in the lumbar region using the loss of resistance test (left handed grip)

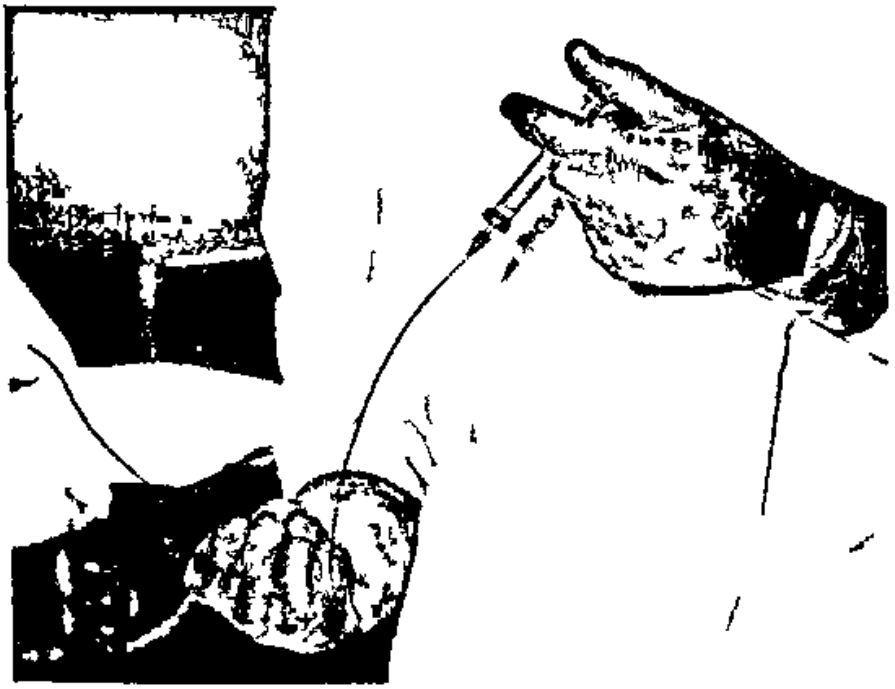


FIGURE 32
Testing the epidural catheter to exclude blockages

has been threaded up the needle It is helpful to slide a small sterile rubber marker along the tubing (a diaphragm from a Gordh needle, pierced in the centre, does well), to a point about eight inches from the end that is to be inserted, then when the catheter has been passed until the marker reaches the hub of the needle one can be certain that an adequate length of tubing lies within the spinal canal, (*see* Fig 34).

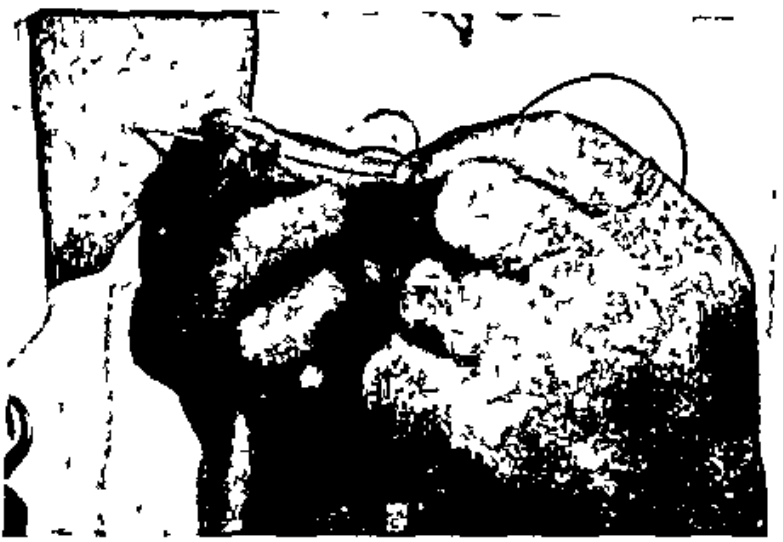


FIGURE 33
Threading the catheter through the Tuohy needle

Aspiration and injection tests are made down the catheter before the Tuohy needle is withdrawn, (Fig. 35). In order to do this a syringe adaptor of some kind must be fitted to the distal end of the catheter; the Tuohy-Borst adaptor has been designed for this purpose, but it tends to twist and strangulate the catheter lumen. A well-fitting hypodermic needle is simpler and equally effective. Two or three millilitres of local analgesic solution are injected as a test dose and to ensure that the catheter is not blocked in any part of its course, and aspiration is carried out to check that blood or cerebrospinal fluid does not flow back from either venous or dural puncture. The syringe adaptor is then temporarily removed from the end of the catheter, and the Tuohy needle carefully withdrawn with one hand while the catheter is steadied with the other (Fig. 36). The patient is then tested for absence of subarachnoid block. If awake, he is asked to move his legs, and if unconscious, blood pressure recordings are taken by an assistant to check for the absence of hypotension from sympathetic blockade and the

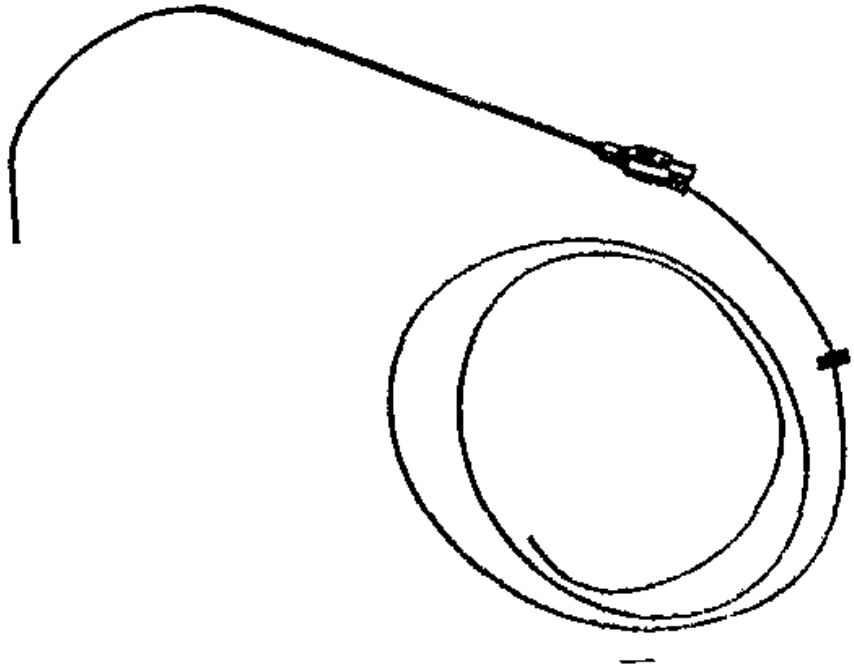


FIGURE 34
Epidural catheter with rubber marker placed 8 inches from the tip

FIGURE 35
Injection of a test dose while the needle is still in place

FIGURE 36
Withdrawing the Tuohy needle

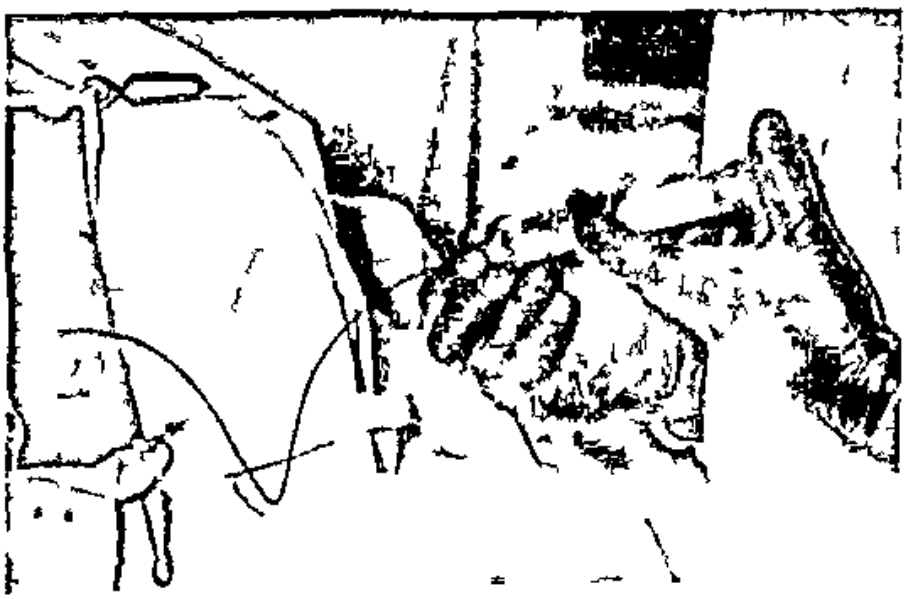


FIGURE 37
Injection of the main dose after the needle has been withdrawn

knee jerks are tested If there is no evidence of subarachnoid puncture, the syringe adaptor is replaced and the initial epidural dose injected up the catheter (Fig 37) The adaptor is then sealed with a sterile blocker (made by sealing the lumen of a male intravenous drip connection with solder), and held in place in a sterile test tube with a plug of sterile cotton wool The point of entry of the catheter is now covered with a sterile dressing, and the catheter and dressing securely strapped in place with several lengths of adhesive tape, the adaptor and test tube being brought out above the patient's shoulder, so that the anaesthetist can have easy access to them during operation If, for any reason, it should be considered necessary to withdraw the catheter at a stage before the Tuohy needle has been removed, *needle and catheter must be removed together* for if the catheter is withdrawn while the needle is still in place the sharp chisel like upper edge of the bevel may very likely slice through the catheter and leave a portion sequestered in the epidural space

The amount and frequency of subsequent injections will depend on the local analgesic used, and the nature of the condition for which the block has been performed If a long abdominal operation is in progress injections must be made frequently enough to ensure a continuous level of analgesia up to and above the operation site In the unconscious patient the level of blood pressure is a good guide to the segmental level of analgesia, a steadily rising level of blood pressure indicating a steadily falling level of analgesia, while each injection of local analgesic is followed by a sharp fall of tension (Fig 38) With 1 600 nupercaine the intervals between injections is about forty five minutes to one hour, and with 1 2 per cent xylocaine about thirty to forty five minutes Alternatively, a slow drip of local analgesic solution may be connected to the catheter, and the flow turned on or off as required If the catheter has been introduced for therapeutic purposes, the block need not be intense enough to produce full skin analgesia, since in most cases only the small sympathetic fibres are concerned, and concentrations of 0 5 - 0 75 per cent xylocaine, or 1/1500 - 1/1000 nupercaine, are sufficient There is no set rule for the frequency of injection in therapeutic blocks, the intervals between doses depending

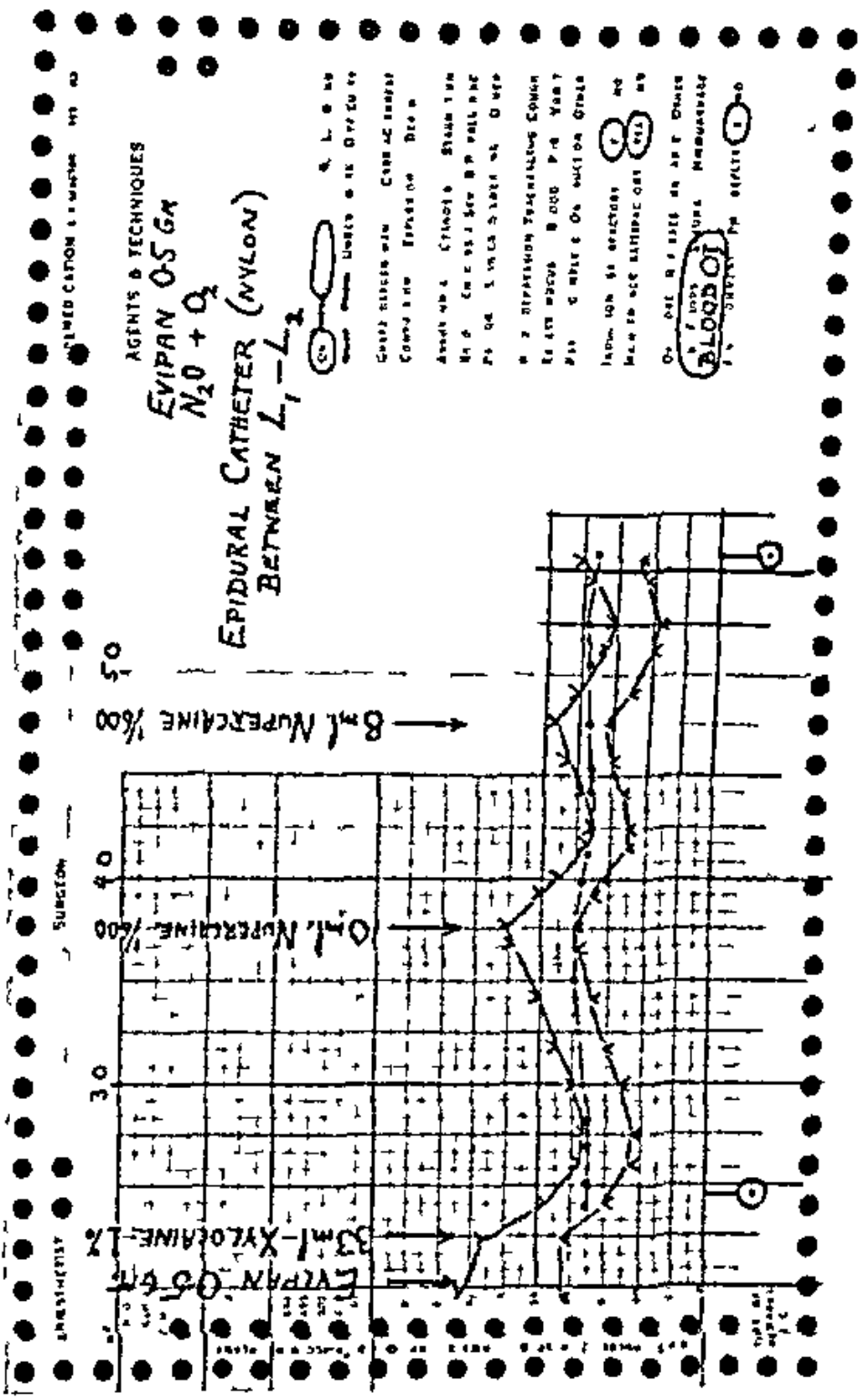


FIGURE 38
Continuous epidural analgesia combined with light general anaesthesia. Blood pressure and pulse chart of a patient undergoing gastrectomy. A rising blood pressure indicates regression of the block, and the need for further increments of local analgesic

on the strength and quantity of local analgesic injected, and the nature of the malady under treatment For instance, in chronic and painless conditions injections can be given four or six hourly, but in acutely painful conditions it is important to maintain pain relief without intermission, and injections must be made more frequently at two, three, or four hour intervals depending on the individual response Table VIII gives a broad guide to the doses required

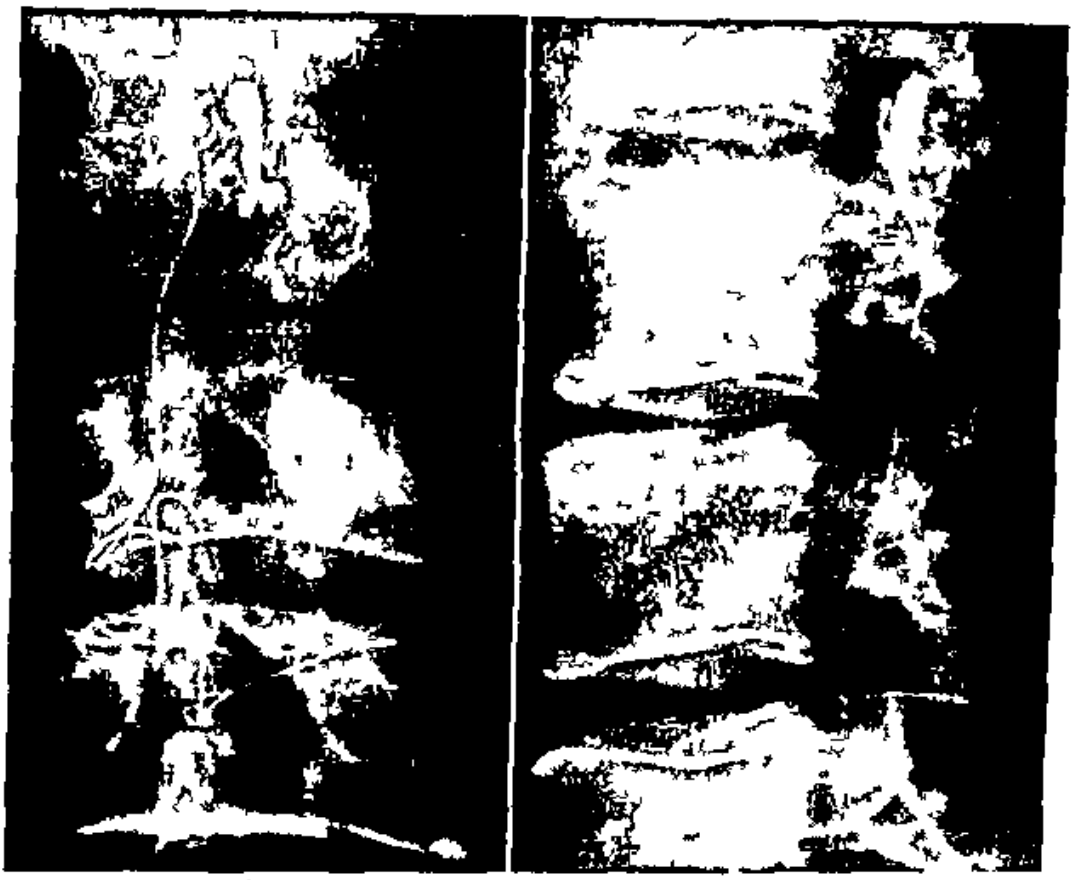
TABLE VIII
THERAPEUTIC EPIDURAL BLOCK EXAMPLES OF DOSAGE REQUIREMENTS

Type of Complaint	Example	Frequency of Injection		
		2 3 hourly	3-4 hourly	4 6 hourly
Acute	Acute pancreatitis	0 5-0 75% xylocaine or 1/1500-1/1000 nupercaine		
	Dissecting aneurysm of aorta	10 15 ml	15 25 ml	
Chronic	Causalgia Vasospasm of legs *Hypertensive* cardiac failure			10 20 ml of — 0 5% xylocaine *or* 1/1500 nupercaine

Each injection must be carried out with full aseptic precautions, and blood pressure readings should be taken before and fifteen to twenty minutes after, so that any marked fall of tension can be corrected with a vasopressor drug If the treatment is to be protracted and the catheter has to remain in place for a long period, it is wise to administer a systemic course of antibiotics as an added precaution against epidural infection Also the position of the catheter should be checked by X rays to confirm that the tip is lying cleanly within the epidural space (Fig 39), and not beyond in the paravertebral tissues, where injection is ineffective (Fig 30) 0 2 ml of radio-opaque oil is sufficient to outline the catheter

Finally, a word of caution against the use of an epidural catheter when anticoagulants are being administered As mentioned earlier, a slight amount of vascular damage is almost inevitable during the insertion of a catheter, and

normally this is of no consequence, but in the presence of anticoagulants a slight ooze may continue indefinitely leading to a large haematoma formation, and possible compression of the cord and paraplegia For example —



(a) Antero posterior

(b) Lateral

FIGURE 39

Radiographs of catheter inserted between third and fourth lumbar spines and correctly placed in the epidural space 0·4 ml of Neohydriol (Fluid) used as opaque medium (Sixty six year old man with massive venous thrombosis of the leg)

A man of 72 had his left femoral artery explored following a femoral embolism The operation was carried out under epidural block, and an epidural catheter was inserted so that a continuous sympathetic block could be maintained in the legs for some days in order to promote the formation of a collateral circulation The patient was heparinised to avoid further clot formation in the femoral artery Thirty six hours after operation the patient died from a massive haemorrhage into the left leg At post mortem a large haematoma was present in the epidural space

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CHAPTER IX

INDICATIONS AND CONTRAINDICATIONS

OPERATIVE ANALGESIA

EPIDURAL analgesia has its greatest application in major surgery below the diaphragm The diminished bleeding, quiet operating conditions and absence of interference with respiration are all of benefit during operation and the early recovery of the patient and period of post operative analgesia make for easy nursing on return to the ward Epidural block is to be preferred in all cases where subarachnoid spinal analgesia might otherwise have been considered, since the avoidance of dural puncture eliminates all possibility of " spinal headache " or subarachnoid infection, and the greater duration of epidural injections provides for longer operating time Operations for large abdominal tumours under spinal analgesia may give rise to some anxiety on account of the respiratory embarrassment caused by a combination of diaphragmatic immobility from the distended abdomen and intercostal paralysis from the spinal block Under epidural analgesia, if the strength of solution is chosen correctly, this danger is very much less since there is minimal intercostal paralysis This point is particularly relevant in caesarean section, where epidural block is indicated if the mother has expressed a wish to be awake at the birth of her child Vaginal delivery can also be carried out under this type of block

In some centres a considerable amount of thoracic work is done under high epidural analgesia injection being made in the upper thoracic region between the seventh cervical and third thoracic spines [1] [2] For thoracoplastic operations this is *claimed to be ideal, providing intense* analgesia without any respiratory depression [3] But in my experience epidural analgesia is not completely satisfactory in this sphere, for two reasons Firstly, the interspinous and yellow ligaments are very attenuated in the upper thoracic region, making the loss-of resistance test difficult or impossible, so that reliance

has to be placed on the drop sign or Odom's indicator, methods which are more prone than the loss-of resistance test to result in perforation of the dura, and are not without danger in the upper reaches of the spine where the cord is so vulnerable If the safe lumbar approach is used large volumes of solution have to be employed to carry the block up to the cervical region, and a careful control has to be kept on the blood pressure, since vascular hypotension is undesirable in patients already on the brink of anoxaemic anoxia both from their disease and from operative interference with the mechanisms of respiration Secondly, the haemostasis is inferior to that obtained by an efficient combination of paravertebral and local infiltration and this reason alone should discount the method in a situation where absence of bleeding is of such assistance to the surgeon In difficult cases, where the anaesthetist is doubtful about the accurate placement of his paravertebral injections, and where some form of regional analgesia is preferred to general anaesthesia, an epidural injection may be given as an additional measure to cover any deficiencies in the paravertebral and local injections Epidural block is also useful in some septic cases where infection of the subscapular space contraindicates infiltration methods Apart from this epidural block has little place in thoracic surgery, for in thoracotomy absolute control of the lung is essential, and there the intravenous relaxants combined with controlled respiration are undeniably the method of choice

In laminectomy and explorations of the spinal cord a preliminary epidural block provides excellent operating conditions If the adrenaline content is made rather stronger than usual (1 100,000 or 1 80 000 instead of 1 200 000 or 1 150 000) marked local vasoconstriction occurs within the epidural space, and diminishes the troublesome bleeding that so often hampers the surgeon's work there Some anaesthetists use high epidural analgesia for the production of hypotension in cranial surgery I have no personal experience of this application of the technique, but at least it would appear to be as effective and no more dangerous, than other methods of producing hypotension for the same purpose

Extreme youth would seem to be a contraindication to the method, at any rate in conscious patients since children do

not as a rule regard injections kindly, nor remain still long enough to allow completion of the procedure with safety However, in at least one German clinic the method is widely used on quite young children and babies, and the results are acclaimed enthusiastically [4]

Absolute contraindications to the method are few —

1. Sepsis in the region of the proposed injection Infection might be carried down to the epidural space and so produce a peridural cellulitis or abscess Or worse still, if the dura were accidentally punctured, meningitis might follow

2. Severe Shock, since the disturbance of autonomic tone produced by the block might not be adequately corrected by vasoconstrictor drugs

That is the cautious orthodox view, but one which is becoming modified in the minds of many anaesthetists since the introduction of noradrenaline The powerful and certain action of this drug allows complete control of arteriolar tone (provided the patient has not already passed into the phase of irreversible shock), and despite total paralysis of compensatory vasoconstrictor mechanisms the blood pressure can be kept at any desired level by merely adjusting the flow rate of an intravenous noradrenaline drip And so there is no logical reason why an epidural block should not be used in shock states, provided that an intravenous drip is running at the time, and noradrenaline can be turned on at a moment's notice Then, if the systolic pressure should fall below 75 - 70 mm Hg, noradrenaline can be run in, and the blood pressure stabilised at any desired level The author has anaesthetised a number of patients in oligaemic shock by this method, chiefly for emergency gastrectomy for haematemesis, and the results have been most gratifying The presence of complete relaxation, without respiratory depression, frees the anaesthetist from the duty of ventilating an apnoeic patient, and allows him to devote his entire attention to the problems of maintaining an adequate circulation Moreover, the patients do not appear to deteriorate during a long operation under these conditions, and the surgeon can feel free to take up to three or four hours if necessary, without fearing that slow surgery will jeopardise the chances of recovery

Relative contraindications are —

1. Existing Neurological Disease. As in subarachnoid anal gesia, it is probably wise to avoid the method in cases with disease of the central nervous system, such as disseminated sclerosis or spinal syphilis For although it is difficult to see how an epidural block could have an adverse effect on these conditions, the anaesthetist will avoid the possibility of becoming involved in a " *post hoc ergo propter hoc* " litigation claim should a natural exacerbation of the disease develop after the operation

2. Spinal Deformities, if exceptionally severe, may prevent a successful puncture Severe scoliosis does not present an insuperable difficulty, if care and imagination are used to envisage the rotation of the vertebrae and the correct path of the needle

THERAPEUTIC ANALGESIA

The ability of a differential epidural block to produce wide spread sympathetic paralysis has numerous applications in the treatment of disabling and painful disorders of the thoracic and sacral autonomic outflows The epidural route is prefer able to subarachnoid and paravertebral blocks in this sphere because it is safer than the former, and technically more certain than the latter, besides being more easily managed as a continuous technique (by the indwelling catheter method) if treatment has to be extended over a long period A broad outline of the scope of the method, with a few illustrative case histories, will serve to show how it may be applied usefully in the individual case

HEADACHE FOLLOWING LUMBAR PUNCTURE

The main cause of spinal headache appears to be an excessive leak of cerebrospinal fluid, leading to subarachnoid hypotension Restoration of normal c s f pressure relieves the headache Besides encouraging the formation of cerebrospinal fluid by liberal drinking, relief can be obtained by bolstering up the c s f pressure from without by epidural injections of 30 100 ml of saline [5]

ACUTE PAIN POORLY RELIEVED BY OTHER METHODS

If the pain is of visceral origin, diagnosis must be absolutely certain before deciding to treat the pain and mask the symptoms of a condition that might require urgent laparotomy For example —

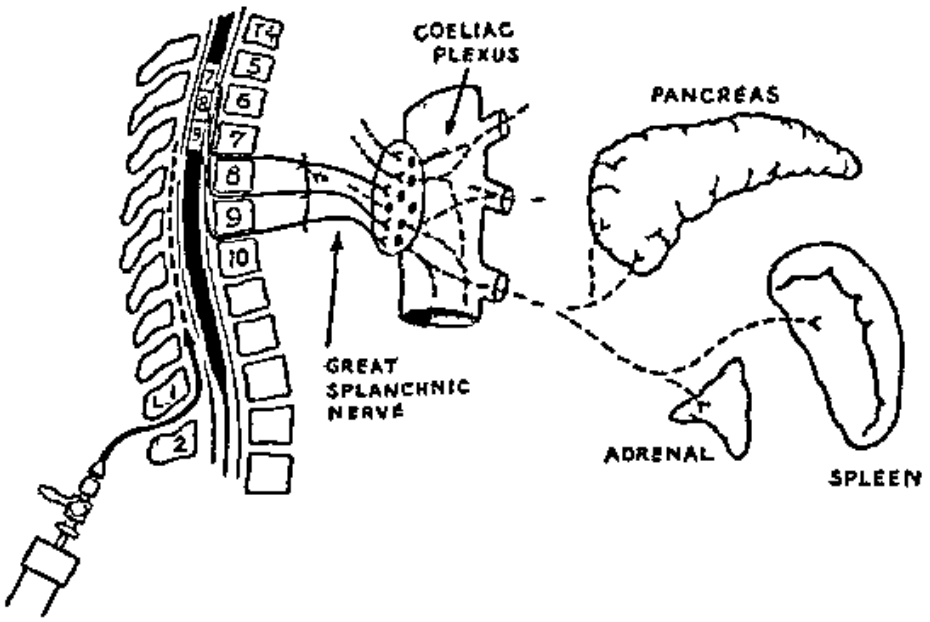

FIGURE 40
The pain of acute pancreatitis Diagram showing the nerve pathways involved
(After Orr and Warren Lahey Clin Bull)

Acute Pancreatitis.—As a direct development of the work of Marion and Mallet Guy at Lyons, the continuous epidural technique of splanchnic blockade has proved an effective method of treating the severe pain of acute pancreatitis [6, 8] The spinal segments concerned are the seventh, eighth and ninth thoracic (*see* Fig 40)

Case —A thin man of 64 was admitted complaining of sudden onset of acute lancinating pain in the epigastrium radiating through to the back and down into the groins On examination the patient was distressed, the pulse rate was 70 per minute, the temperature 98 6°, and the blood pressure 120/80 The abdomen was rigid in the upper quadrants and the point of maximum tenderness was just above and to the left of the umbilicus Bowel sounds were absent, but liver dulness was normal A radiograph of the abdomen showed that there was no free gas under the diaphragm The W B C was 14 000 per cu mm , and the serum

amylase 400 units per 100 ml A diagnosis of acute pancreatitis was made, and treatment started with analgesics and antibiotics *Pethidine in normal doses failed to relieve the pain, and so an epi* dural catheter was inserted between the first and second lumbar spines and 26 ml of 1 0 per cent xylocaine injected Analgesia extended up to the fourth thoracic segment, and the blood pressure fell steeply, but was stabilised at 120/80 with intravenous methe drine Bowel sounds returned within a few hours Analgesia was maintained with 10 ml of 1 1500 nupercaine every three hours but as these injections gave relief for only two hours the dose was increased to 14 ml three hourly, with satisfactory results The patient made an uninterrupted recovery, and the catheter was withdrawn on the fifth day

The ganglion blocking drugs, such as the halides of hexa methonium, also relieve the pain of acute pancreatitis, and at first sight their use would seem more rational than an epidural block, since they interrupt vagal as well as sympathetic impulses, and so diminish the nervous secretion of pancreatic juice However, the methonium drugs reduce intestinal motility, and so tend to aggravate the ileus which accompanies acute pancreatitis, and the analgesia they afford is not so complete as the relief of pain which follows an epidural block

Dissecting Aneurysm of the Aorta.—Although often painless, these splitting aneurysms can give rise to the most agonising and intractable pain that it is possible to suffer An epidural block is indicated in this condition, for three reasons —

1 Relief of pain

2 Vascular hypotension, which reduces the force of the blood " wedge " splitting the coats of the aorta, and so tends to limit the disaster

3 Prevention of renal vasoconstriction, and subsequent anuria, which often accompanies dissecting abdominal aneurysms

Case —An arteriosclerotic cowman of 62 was admitted following the sudden onset of excruciating knife like pain in the back radiating to the left flank and abdomen Fourteen months previously an abdominal aortic aneurysm had been found at laparotomy and had been strengthened with tantalum gauze, at that time his blood pressure had been 210/100 The patient was restless and in the sweat of agony The abdomen was board like, and the blood pressure 160/110 The pain was untouched by intravenous morphia

and a diagnosis of dissecting aneurysm of the aorta was made A single epidural injection between the first and second lumbar spines with 40 ml of 1/1000 nupercaine produced immediate and complete relief of pain and the blood pressure fell to 75/60 after twenty minutes Five hours later the pain returned but less severely than before and the blood pressure rose to 170/110 A second epidural the next day gave relief of pain for five or six hours and the following day a catheter was inserted between the second

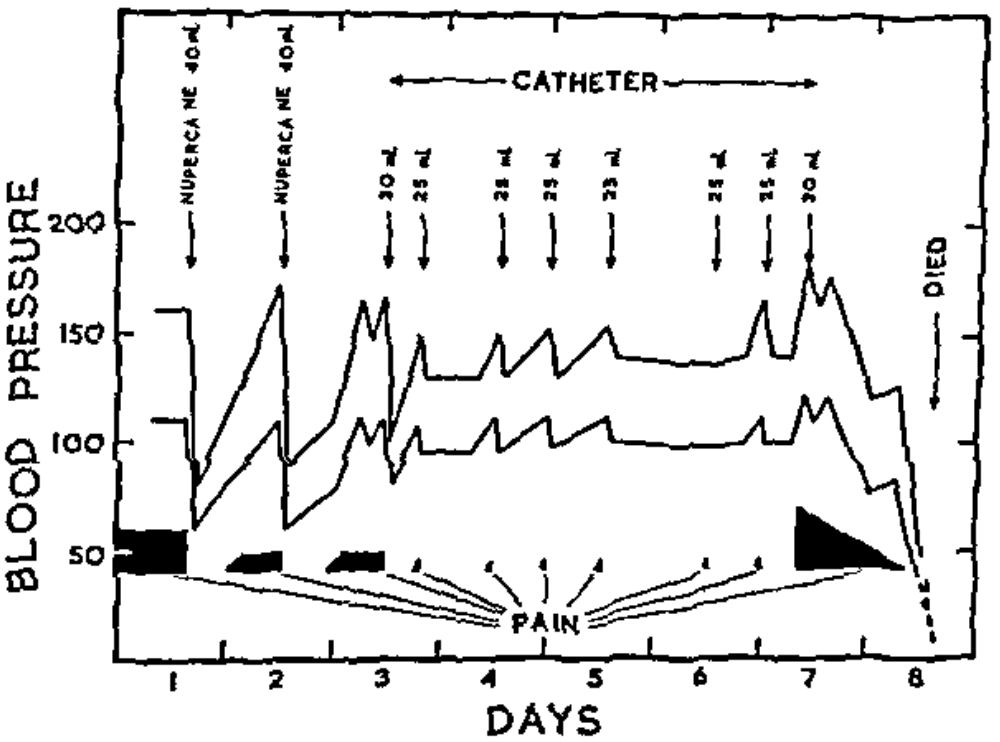

FIGURE 41

Blood pressure and pain chart of patient with dissecting aneurysm of aorta treated by intermittent injections through an indwelling epidural catheter

and third lumbar spines Thereafter the patient was kept almost *entirely pain free for three days by intermittent injections* of nupercaine whenever the pain or sharp peaks of blood pressure threatened to return (*see* Fig 41) Four days after the catheter was inserted and about four hours after the *previous injection* the blood pressure rose to 180/125 and the patient complained of terrible pain in his shoulders In his struggles the catheter which was of polyethylene became nipped between the laminae of his vertebrae and broke off making further injections useless The blood pressure gradually faded away, and the patient died the next day At post mortem a large dissecting aneurysm and massive

haemorrhage were found between the coats of the aorta Four inches of polyethylene catheter was lying loose in the epidural space

This case would have been better conducted by inserting a catheter at the outset (but none was available at the time), and fracture of the catheter would not have occurred if a vinyl plastic had been used instead of polyethylene Also, it would probably have been better to run the blood pressure at a lower level, by more frequent or larger injections

CHRONIC PAIN

Causalgia, painful phantom limbs, and post traumatic neuralgias, etc, are pains associated with disordered sympathetic action that respond to repeated blockade of the appropriate sympathetic rami[9] The continuous epidural technique is an alternative to repeated paravertebral blocks

VASCULAR INSUFFICIENCY OF LIMBS

1. Acute Ischaemia follows thrombosis or embolism of a main limb artery In order to save the limb it is necessary to establish an efficient collateral circulation as rapidly as possible This is encouraged by the removal of sympathetic vasoconstrictor tone, and is most effectively carried out by a continuous epidural block

2. Chronic Ischaemia occurs in thrombophlebitis and phlebothrombosis[10] Afferent impulses from the affected vessel travel to the cord and produce reflex vasoconstriction of collateral arteries and veins[11] The circulation to and from the limb becomes inadequate, so that tissue anoxia and capillary transudation occur distal to the thrombosed segment Pain, oedema, and swelling of the limb follow After sympathetic block, and the abolition of reflex vasoconstriction, pain, fever and swelling rapidly subside In these cases repeated blocks may be necessary to complete a cure, and again the continuous technique is indicated[12]

RENAL ISCHAEMIA

The value of sympathetic blockade to counteract the "Renal Shunt" in established anuria is debatable It is widely

held that after six to twelve hours irreversible damage has been done to the tubular epithelium and then only functional rest (achieved by a high calorie and low protein intake) and time can work a cure [13] However, the histopathology of early anuria is still *sub judice* and when the condition of the patient does not contraindicate such treatment it would seem wise to give the patient the benefit of the doubt and induce a continuous block, in order to prevent the persistence of any residual cortical ischaemia and reduce venous back pressure By so doing there is nothing to be lost, and possibly much to be gained

CONDITIONS ASSOCIATED WITH HYPERTENSION

Eclampsia.—In frank eclampsia and severe fulminating pre eclampsia, where there is no time to correct the toxaemia by other methods (such as sodium elimination by ion exchange therapy), symptomatic improvement follows a reduction of arterial and venous blood pressures The methonium drugs do this effectively, but predispose to neonatal deaths from ileus and pneumonia after delivery [14] Treatment with veratrum viride (veratrone) is also effective, but difficult to manage A continuous epidural block controls the symptoms and can be used to provide the necessary analgesia if a caesarean section is indicated

Hypertensive Cardiac Failure.—Blockade of the sympathetic outflow produces dramatic relief of this condition and subjective improvement outlasts the effects of the block [14] The "bloodless phlebotomy" that accompanies widespread vaso dilatation relieves strain on the left side of the heart, and reduces back pressure on the pulmonary vascular bed (*see* page 24 Chapter III)

Case.—It was proposed to perform thoracolumbar sympathec tomy on a man of 48 with severe hypertension and while he was awaiting admission to hospital cardiac failure occurred When seen he was cyanosed and dyspnoeic despite being propped bolt upright in bed, and was coughing up frothy sputum The blood pressure was 255/180, and physical examination and radiography showed congestion of both lungs In order to deal with the pulmonary oedema bronchoscopic aspiration and therapeutic epi dural block were carried out as emergency measures under light thiopentone anaesthesia 40 ml of 1 1000 nupercaine and 1 25

per cent procaine without adrenaline were injected between the first and second lumbar spines The blood pressure fell to 60/35 in seventeen minutes, and was then raised to 100/70 by an intravenous injection of 7 mg of methedrine The patient awoke and expressed gratitude at being able to lie flat and breathe easily for the first time in six weeks Four hours later the blood pressure had risen to 220/125 but nevertheless the patient was comfortable and able to sleep with only two pillows Complete subjective relief continued for forty eight hours and the patient was relatively improved for the following three weeks until his operation

It is in such cases that these words of Beddoes' find their true physical expression —

"Deeply have I slept
As one who hath gone down unto the springs
Of his existence and there bathed I come
Regenerate up into the world again'

* * * * *

In the foregoing the epidural space has been considered only as a site for neuronal blockade But the works of Batson, Field and Brierley, Wollam and Millen, and others referred to in Chapters II and III, suggest intriguing possibilities to the imagination As a vascular highway the space spans a venous route between cranium and pelvis, gonads and brain, the circulation of the cord passes to and fro across it, and at the dural cuffs foreign material is filtered out from the cerebrospinal fluid and passed on to the paravertebral lymph glands With future extension of anatomical and physiological knowledge, the epidural space, in one or more of its different rôles, may come to have a wider therapeutic application than at present

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APPENDIX

Since this book was completed three accidents have been encountered These are briefly described and discussed for the sake of the lessons that may be learnt from them

Massive Subarachnoid Injection

Case—A well built man aged 54 for partial gastrectomy Height, 5 ft 7 in B P 140/80 With the patient awake epidural puncture was attempted between L_1 and L_2 using the loss of-resistance technique A few drops of fluid dripped back and these were allowed to fall on the bared wrist The anaesthetist thought they were warm and feared that sub arachnoid puncture had occurred, but as the flow soon stopped and repeated aspirations with a 2 ml syringe failed to produce any more fluid he thought it justifiable to inject a test dose 9 ml of a mixture of 1/600 nupercaine and 1/200,000 adrenaline were injected After a period of 5 minutes the patient was still able to move his feet upon command, and so a further 33 ml of the analgesic solution was injected slowly At the end of injection the patient muttered, rolled his eyes upwards and became un conscious An endotracheal tube was passed under a small dose of thiopentone (200 mg) and succinylcholine (25 mg) Respira tions ceased, the blood pressure fell and the pupils became dilated A diagnosis of massive subarachnoid injection was made

Treatment—Ventilation was maintained by intermittent manual compression of the rebreathing bag, with a 50/50 mixture of nitrous-oxide and oxygen at a total flow rate of 8 litres per minute The systolic pressure was maintained above 120 mm Hg by an initial dose of 8 mg of methyl amphetamine followed by a slow saline infusion containing 2 5 µg of noradrenaline per millilitre Partial gastrectomy was performed under perfect operating conditions in 1¾ hours, but the patient remained apnoeic for a further 3½ hours 5¾ hours after the initial injection respirations were judged to be adequate in volume and the patient was allowed to wake up by discontinuing the flow of nitrous oxide The endotracheal tube was removed, and the patient said, "I must get on with my breathing exercises" And he did so There was no post-operative headache, but there was some cough and sputum for 2 days The patient was discharged home in good health on the fourteenth post-operative day

Comment

The anaesthetist should not have disregarded the warning sign of a warm reflux from the epidural needle This fluid was obviously c s f, and ideas of epidural injection should have been abandoned immediately, and the case conducted under subarachnoid analgesia or an intravenous relaxant

Toxic Reaction to Local Analgesic Drugs

Case —A nervous, obese, emphesymatous man of 66, for abdomino perineal excision of the rectum B P 160/85, Hb 82 per cent One leg amputated at mid thigh and the other ankylosed at the knee due to old battle wounds After induction of anaesthesia with 400 mg of thiopentone and nitrous oxide and oxygen, epidural puncture was carried out between L_2 and L_3 The loss of resistance sign was unmistakably positive, and repeated aspiration tests failed to reveal any blood or c s.f An analgesic solution was prepared containing 1/600 nupercaine, 1/700 amethocaine and 1/200,000 adrenaline 41 ml of this solution was injected at the rate of 0 5 ml per second, with a pause of more than 1 minute after the first 21 ml About 15 or 30 seconds after completing the injection convulsive movements started in the face and neck and spread to involve the whole body 150 mg of thiopentone were injected into a jugular vein and the convulsions stopped and the patient became apnoeic The pupils were not dilated

Treatment —An endotracheal tube was passed and artificial respiration carried out with 100 per cent. oxygen The operating table was tilted head-down, and an intravenous injection of methyl amphetamine attempted in order to combat the anticipated vascular collapse However, the patient had very poor superficial veins and the only one that could be found was now obscured by haematoma, and so 30 mg of methedrine were injected intramuscularly The blood pressure fell rapidly As the abdomen was prepared and the surgeon standing ready it was decided that the surest way to restore the failing circulation would be to administer a noradrenaline infusion into one of the major intra abdominal vessels The abdomen was rapidly opened and a saline infusion containing 4 µg of noradrenaline to the millilitre injected into one of the iliac arteries In the meantime the peripheral pulse had become unrecordable and the pupils had suddenly dilated (indicating cerebral anoxia) and the surgeon reported that aortic pulsation had ceased Cardiac massage was

carried out and about 5 minutes later cardiac action recommenced at the rate of 30 beats per minute Despite a rapid flow of noradrenaline together with a pint of blood given intra arterially the peripheral blood pressure remained unrecordable although carotid pulsations could be clearly felt Five hours later cardiac action finally ceased

Comment

This was clearly a case of toxic absorption of analgesic drugs Careful and repeated aspiration through the epidural needle had not shown any evidence of venous puncture and the epidural solution was injected over such a long period (2¾ minutes) that if the needle point had been in a vein convulsions would almost certainly have occurred sooner Therefore it must be concluded that the convulsions were due to very rapid absorption from the epidural space The administration of two toxic drugs (nupercaine and amethocaine) at the same time is undesirable and must have contributed to the severity of the reaction The case need not have ended fatally if the impending vascular collapse could have been prevented in time this is borne out by the relatively late onset of pupillary dilatation and by the response to noradrenaline once the heart had been restarted

Case —A thin woman of 74 for gastrectomy Height 5 ft 5 in B P 160/90 Epidural puncture was carried out between L_2 and L_3 under light endotracheal anaesthesia Aspiration tests for blood or c.s f were negative 36 ml of 1 2 per cent xylocaine and 1/150 000 adrenaline were injected at the rate of 0 5 ml per second with a pause of 1 minute after the first 20 ml 30 seconds after completing the injection generalised convulsions occurred The face became suffused and the skin of the upper chest a mottled purple colour The pupils remained moderately small

Treatment —150 mg of thiopentone and 30 mg of methedrine were given intravenously Spontaneous respirations ceased and ventilation was maintained by artificial respiration with a 50/50 mixture of nitrous-oxide and oxygen Owing to the prompt administration of methyl amphetamine the blood pressure did not fall and the systolic pressure was maintained above 120 mm Hg by a noradrenaline drip containing 3 µg of noradrenaline per millilitre The operation was completed after 30 minutes (the patient had an inoperable tumour) and 10 minutes later

adequate spontaneous respirations returned The endotracheal tube was removed and the noradrenaline drip stopped The patient regained consciousness promptly and was able to move her legs Analgesia was present up to the fifth thoracic segment

Comment

Blood pressure and respiration were under control from the outset, and despite a severe toxic reaction the patient came to no harm The area of analgesia was surprisingly limited considering the relatively large dose of epidural solution injected, for the calculated level of analgesia (on the basis of the formula on p 81) should have been up to T_2 Both the onset of toxic convulsions and the deficit in the area of anal gesia could be explained on the assumption that a few milli litres of solution were injected into an epidural vein instead of into the epidural space But if this had occurred, convulsions would probably have started earlier than they did

Three lessons may be learned from these cases —

1 The two accidents most to be feared in epidural analgesia are massive subarachnoid injection and toxic reactions to the injected drugs In both these conditions the end results are the same, namely apnoea and profound hypotension, but the behaviour of the pupils is different In massive subarachnoid injection the pupils become large owing to paralysis of the oculomotor nerves, but in toxic reactions they do not dilate unless cerebral anoxia occurs from untreated vascular hypo-tension The treatment of the two conditions is the same Adequate oxygenation must be maintained by artificial respira tion, and vascular collapse must be prevented by the prompt intravenous administration of vasopressor drugs

2 The " Test Dose " can be quite useless if a period of only five minutes is allowed before injecting the main dose

3 Toxic reactions will be less likely to occur if epidural injections are made very slowly and with frequent pauses If convulsions do occur, it is essential to obtain prompt control of respiration and the vascular system Therefore facilities for such control should always be ready to hand when attempt ing epidural analgesia

AUTHOR INDEX

Where the name of an author appears in the text the page number is indicated by numerals in ordinary type. The page numbers of bibliographical references are indicated by italics. Where an author's work is directly concerned with epidural analgesia the name is printed in heavy type.

SUBJECT INDEX