breakdown, and if we wait for complete ciliary palsy it is a difficult business getting the cilia to function again.

We have in the history of appendicectomy what may prove to be in some measure a parallel to the treatment of antral infections. One of the chief indications for appendicectomy used to be a bulging of the abdominal wall by the abscess; and those who first advocated removing the appendix early enough to prevent such a state of affairs were regarded as enterprising, to use the least radical term. But the profession now prides itself upon early diagnosis, and upon removal of the appendix before it has made the patient really ill! Similarly we now do tracheotomy in time to prevent the very things which used to be given as the indications for tracheotomy. Surely the time has come to adopt a similar attitude with regard to antral infections, and to operate in time to prevent the occurrence of empyema.

LATENT SINUSITIS

There are some antral infections which begin suddenly, with obvious suppuration—inflammations which may yield permanently to one or two lavages. But the commonest antral infection is an insidious affair, the origin of which seems very often to be traceable to one of the big influenza epidemics, as mentioned earlier. It may occur in noses apparently quite normal in structure, but it is usually found in cases where the nose offers some pronounced mechanical predisposition. (In this connexion, perhaps someone at this meeting will be able to give us some fresh ideas as to why, in a nose with marked disparity between the two sides, the antrum on the roomier side is so often the one to show signs of infection first.) But even in the absence of mechanical troubles there are definite signs. The first thing to notice is the general appearance of the nasal mucosa. Is it moist, and pink as a kitten's tongue? No. On one or both sides the mucosa has the appearance of raw steak that has been allowed to dry, and in place of the colourless mucin which should moisten its surface there is a dryish, scanty film of muco-pus which over the middle turbinate is usually aggregated into small flakes. This appearance of the middle turbinate as a sign of recondite sinusitis is of the greatest value; but it is difficult to be sure of any diagnostic difference between its appearance in frontal, ethmoidal or antral infection. On palpation it is found that the mucosa over the middle concha, which should fit the bone like a glove, may be several millimetres thick, and may in ethmoiditis be actually oedematous.

Now for transillumination. There are laryngologists who soar above the evidence obtainable by this test. The meaning of a relative opacity may not be obvious, but it is not to be regarded as a criterion of normality. Transillumination cannot be dismissed with a wave of the hand; and it is surely our function to supply guidance as to the possible significance thereof. It is of particular importance in cases in which a previous transillumination has shown a symmetrical translucency. During the early stages of a nasal infection one usually finds that in place of a pair of clearly defined infra-orbital crescents, there are two equally vague and undefined sub-luminous areas—not black, but lacking their former clear-cut translucency. After a week or so, one infra-orbital crescent may clear up, while the other remains vague. Now what is the significance of this diminution of the normal light? Antral lavage at this stage may produce nothing, or at most a small "blob" of muco-pus—much too small to prevent the transmission of light. The dimness is due to hyperaemia or to oedema of the lining, and its existence is duly noted, chiefly for future reference, for hyperaemia on one occasion is no indication for operation. The im-

portance of the discovery is that it is a contraindication to light-hearted tonsillectomy later on.

Let us suppose that we have a sore throat which presents all the stigmata of a nasal origin, and suppose the symptoms duly subside. We are in a stronger position when it recurs (for recur it will, if the antral lining is deeply infected) because we can note the reconstitution of our chain of circumstantial evidence as the separate items arise again. The first thing complained of is probably the sore throat; but I would here remark that there are probably always premonitory signs before the sore throat if one is lucky enough to see the patient at the right time. How often is a house-surgeon frightened by a rise of temperature after some clean operation, only to find 48 hours later that the patient complains of a sore throat. The temperature is not the only sign that precedes the sore throat. If in a suspected case you make a practice of transilluminating the antra, you will suddenly one day find a dimness where there was usually translucency; whereupon you can safely tell the patient he will have a sore throat or a cold in a day or so. Sooner or later there will be a glazed look upon the middle turbinate, and a pharyngeal film, with tenderness of the glands. The presence or absence of the tonsils naturally leads to some alteration of the picture, but the knowledge gleaned during the previous attack will permit one to see the tonsillar involvement in its right perspective—namely, as a result rather than a cause.

CONCLUSIONS

It will be seen that this paper, ostensibly upon throats, is really a covert attack upon the antrum. I freely admit this, except that I would include hidden ethmoidal infection as being at least as frequent.

I urge no operation upon the ethmoids in this connexion, but I submit that there is a case for an early and not extensive operation upon the antrum; and believing as I do that it is doubtful whether the mucosa can ever return really to normal when once it has got to the stage of chronic empyema, I ask for the pontifical blessing of the Section upon indications for drainage based on the repetition of a convincing chain of circumstantial evidence rather than a belated positive result to a proof-puncture.

SUB-ARACHNOID BLOCK GENERAL ANALGESIA; "SPINAL" ANAESTHESIA; RESPIRATORY PARALYSIS; FALLACIES AND METHODS *

BY

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The title of this paper comprehends all the results obtainable on the nervous system by the injection of analgesic substances within the sub-arachnoid space. It includes nothing which was not observed as a result of the earliest employment of cocaine, but the interpretation of the results over the intervening period has been clouded with error, copied from one textbook or paper into another, and persisting in some of the latest publications. The basis of understanding is anatomical and physical.

ANATOMY AND PHYSICS

"The arachnoid membrane is a gauzy reticulum of almost web-like delicacy which in reality pervades the space it occupies. Its outer surface, or that closely related

* Read in opening a discussion in the Section of Anaesthetics at the Annual Meeting of the British Medical Association, Eastbourne, 1931.

to the dura mater and bounding the sub-dural cavity, alone shows a sufficiently organized structure to merit the name of a membrane. This quickly grades into a loose, spongy reticulum which pervades the thick sub-arachnoid cavity throughout, and the strands of which are directly continuous into the more compact tissue of the pia mater. This sponge-like arachnoid tissue holds the cerebro-spinal fluid of the sub-arachnoid cavity, the meshes of the sponge constituting a reticular web of intercommunicating spaces. The cranial sub-arachnoid cavity is larger and the strands of the web are relatively more abundant than in the spinal canal." (Morris.)

The spinal sub-arachnoid cavity passes up through the foramen magnum and enlarges into the cisterna magna, which is posterior, and in the dorsal decubitus dependent, and into the cisterna pontis and the cisterna basalis, which are anterior, more elevated, and contain the cranial nerve roots. The sub-arachnoid space surrounds the entire brain stem, and the roots of all the nerves in the body pass through it. In this situation they are bare of fibrous sheath and therefore easily affected by analgesic solutions. The sensory root of the fifth cranial is the largest and most compact in the body, but the spinal roots have their constituent fibres spread out into a fan-like arrangement of entry and exit from the cord. Those of the cervical and lumbar enlargements supplying the limbs are more bulky than those of the intervening thoracic nerves. The lowest roots of the conus medullaris are centrally placed in the cauda equina and are overlaid by the higher trunks of the leash. As these higher lumbar nerves escape through their foramina, the lower become more isolated and exposed. The pia mater spinalis consists of two layers, the outer fibrous, and between them ramifies a rich plexus of blood vessels. The dentate ligaments support the cord in its central position, but do not effectively divide the space into an anterior and posterior compartment. The reticulate formation of the arachnoid, the structure of the pia mater and the vascularity of the intra-dural contents, the superficial area of which is relatively very great, are factors of prime importance which determine the distribution of soluble injected substances.

The cerebro-spinal¹ fluid is secreted by the chorioid plexuses and passes through the medial and lateral foramina of the fourth ventricle into the cisterna magna, whence it is distributed over the brain and cord. The secretion of fluid can be very rapid, and it is probable that when a large quantity is withdrawn it is rapidly replaced. The absorption of additional fluid injected is also very rapid, and because of the great vascularity of the lining membranes and the large surface area, the absorption of foreign chemical substances into the blood is only second in effectiveness and rapidly to direct intravenous injection, the rate of absorption being proportional to the concentration, and decreasing progressively as this becomes lowered. Though it is impossible to imagine complete stasis in any living body fluid, there is not in the spinal canal any movement which can be called a circulation which would effect the immediate distribution of drugs injected. Waves of condensation and rarefaction are communicated to the fluid by the respiratory and cardiac impulses which may have some effect over a more prolonged period. The specific gravity of the fluid is not constant, but varies between 1.004 and 1.010. The movement of injected solutions is determined by their relative weight. The sinking of a hyperbaric fluid in one which is relatively hypobaric is determined by a difference so delicate that an estimation of the difference would be impossible by any coarse method. If the surface layer of water is cooled it sinks to the bottom of the container, or if the bottom layer is warmed it rises to the top. Thus a hypobaric injection

moves only when the heavier cerebro-spinal fluid can descend from above and displace it upward. The rate of movement will depend on the degree of difference between the specific gravities of the two fluids and the angle which the spine makes with the horizontal. The behaviour of solutions injected into the sub-arachnoid space is modified by the anatomical contents, and the absorptive surface to which they are exposed.

FALLACIES

The experimental work of Corning and its clinical application by Bier and other subsequent workers is described in most textbooks on the subject, but it is noteworthy that operations on the head and neck were performed under this method early in its history, long before Barker experimented in this country. This is not surprising, since the moderate Trendelenburg position has always been thought necessary to ensure a good blood supply to the medullary centres, and some of the solutions then used were among the heaviest ever employed, while cocaine was used in dosage not thought permissible to-day. It was this extension of the analgesia to the head, and a high mortality rate, which proved so alarming to the early workers, who had an abiding fear of the direct action of the drug on the medullary centres, and stimulated Barker² to try to devise a method whereby the effect could be controlled to the lower regions of the body. Barker demonstrated that the drug could not spread upward by a process of simple diffusion, a *fact which is indisputable*, and by injecting relatively heavy solutions into glass tubes shaped to the curve of the spine and containing saline solution, he showed that unless the inclination was too great the solution descended to the lowest part of the dorsal curve and "here it would remain more or less undiluted in contact with the structures around."

These glass tube experiments have been the origin of much misconception because there is no clear run down for the solution in the body, nor do they represent the rapid absorption by the tissues and into the blood which is such an important feature *in vivo*. They also gave the impression that the dose descended in concentrated form to a certain level of the cord, where if held long enough it became "fixed" by the nerve tissue. Barker refers to the action of the drug on the roots, but writes more frequently of the cord, suggesting that he was not clear on this point. The term "fixed" is very inapt, because a very large portion of whatever drug is injected is rushing round the body in the circulation until it is either excreted or destroyed. Remembering that before Barker's time the saline and other solutions were said to "diffuse" into the neck, and that analgesia of the whole body was obtained, it is not surprising to find that his heavy stovain glucose solution, S.G. 1.030, controlled by dosage and posture to the dorsal region, came to be known as "indiffusible" and the saline solutions as "diffusible."

This in spite of the fact that the "diffusible" Chaput solution, S.G. 1.080, was heavier than anything Barker subsequently employed. Arising from this muddle is the fallacy prevalent in our textbooks to-day that mixtures containing glucose are heavy solutions, and saline solutions "light" solutions. Gwathmey³ states that "solutions of lighter specific gravity than the cerebro-spinal fluid are generally called diffusible, whereas those of heavier specific gravity are called non-diffusible." Actually 10 per cent. novocain in distilled water, S.G. 1.017, is a heavy solution. Another error prevalent in America and sponsored by Labat⁴ is that when cerebro-spinal fluid is the solvent of novocain crystals, no spread by gravity will take place in the Trendelenburg position. It is impossible to add anything soluble to the cerebro-spinal fluid without increasing the specific gravity of that portion of it which happens for the time being to be solvent. Assuming a fluid of S.G.

1.006, then a 10 per cent. addition of novocain crystals will raise the S.G. to 1.023. Addition of 250 mg. to 10 c.cm. of fluid will raise the S.G. to 1.010, and will operate in precisely the same manner as that amount of 2½ per cent. novocain in normal saline and will be subject to gravitational diffusion. The large volume of the low concentration will move just as effectively, though at first more slowly, as the small volume of the high concentration.

SPINOCAINE AND DUROCAINE

The addition of alcohol to a solution to make it lighter, attempted by Babcock in 1909 and patented by Dr. Pitkin nearly twenty years later, serves only to effect a temporary reduction of specific gravity after injection. The two mixtures spinocain, S.G. 1.005, and durocaine, S.G. 1.002, appear to respond to a variety of different treatments. An expansion of the solution over the thoracic nerve roots is said to be effected by an addition of cerebro-spinal fluid of anything between 1 and 10 c.cm. in volume without regard to the length of the spine. After injection, some tilt the table into the head-up position and others into the Trendelenburg. For the past two and a half years incomparable analgesias have been claimed in the dorsal decubitus, but recently both administrator and patient have made a *volle face* and the ventral position is adopted. A viscous substance called gliadine, 0.00325 gram per c.cm., is said to delay absorption and to prolong analgesia, but the dosage has coincidentally increased beyond anything previously heard of. One claims constant complete abdominal analgesia in the up-tilt lateral position in 1 minute 25 seconds, another that it may be delayed as long as 47 minutes. These fall into a separate system known as "controllable spinal analgesia." One observer has asked, "After all, does controllability matter?"

The explanation of the fallacies underlying the administration of these solutions is a very simple one. The ingredients fall into two distinct classes, volatile and non-volatile. The low specific gravity is due entirely to the volatile member. The rate of absorption into the blood of a volatile substance is out of all proportion more rapid than that of a non-volatile substance. If spinocain were floated on to the surface of a warm saline, the alcohol would evaporate into the air, and the novocain would be dissolved in the saline. When injected into the sub-arachnoid space and mixed with cerebro-spinal fluid, the specific gravities of the two fluids become averaged, and the mixture only slightly hypobaric. The rate of upward-displacement would therefore be slow and progressively retarded by further mixture with heavier fluid. The "air bubble in a spirit level" arrangement is possible only between two media which are not miscible. The rate of absorption of the volatile alcohol will be far more rapid than the non-volatile novocain, and the solution quickly passes through an isobaric stage and becomes hyperbaric. The end-result is always novocain dissolved in cerebro-spinal fluid. The one constant feature in the ritual of these administrations is the Trendelenburg position.

The dosage of novocain is so high that the amount absorbed into the blood causes a general analgesic state, and the itching, drowsiness, and stupidity of the patient which has been described by various observers⁵ is evidence of the action of the circulating drug on the sensory nerve endings in the skin and on the cortical cells of the cerebrum. When the Trendelenburg position is adopted immediately after injection the solution hangs until the alcohol has been absorbed, when gravitational diffusion commences. All the novocain absorbed into the blood before this begins serves only to poison the patient and effects no useful purpose. In consequence, the dosage sometimes used is more than double that necessary for the production of analgesia by a more rational method.

GRAVITATIONAL DIFFUSION

The process of diffusion by gravity in the body differs from the descent of a heavy fluid *in vitro*, because of the meshwork of baffles which the solution encounters, resulting is more and more mixture with the lighter fluid, and the fact that the drug is all the while being rapidly extracted into the blood and by the nerves. Thus absorption and dilution result in progressive diminution of specific gravity and a progressive slowing of the movement, which is also limited in the horizontal position by the curve of the spine. In the Trendelenburg position the effect of gravity is not to move the dose in high concentration to the most dependent part, but to spread it out in ever-decreasing concentration over a distance which will be proportional to the amount of drug injected, and as more butter is required to spread a large piece of bread than a small one, so more drug is required to spread a long spine than a short one, a factor which has never been considered. The body weight is important in relation to blood dosage, a fact which is apparent when considering the high relative dosage and frequent development of sleep in children, reported from the earliest period to the present day.

The dentate ligaments no doubt have at first some directing action in supporting and spreading the solution over the anterior roots, but it always tends to sag and give the greater concentration to the posterior roots, especially in the higher regions. When the high tide of effective concentration reaches well above the centre, then both anterior and posterior roots receive the drug; when it sinks below the centre, then only posterior roots are affected. This result, together with the fact that with moderate dosage only a low concentration reaches the neck, explains how the motor roots of the phrenics and upper intercostals can carry on when the head is analgesic. Analgesia always extends higher than paralysis, and the upper segments of the abdominal muscles may be imperfectly relaxed with absence of pain sense at the same and at higher levels. The arms are not paralysed even in the highest analgesias by this method. The graded effect of all analgesics on mixed nerves has long been known both experimentally and clinically. Pain sense is the first to go, then follow touch, muscle sense, and finally motor power. Return is in the reverse order, and a leg may be operated on long after movement has returned. If the injection is dilute, short analgesia is developed without loss of power. The size of a nerve root or trunk also determines the effect of a particular concentration of drug. Gravitational diffusion is an inaccurate method, wasteful of power, and uneven in distribution, for if the drug wanders beyond its intended area, loss of concentration results where it is most needed. But although moderate doses of novocain spread by gravity into the neck may not paralyse respiration, they undoubtedly impair the activity of the centre and the conductivity of the motor roots of the phrenics and intercostals in proportion to the concentration which each receives, the one through the blood and the others directly, for the respiration under high blocks is often reduced to a minimum.

KOSTER'S THEORY AND EXPERIMENTS

There has lately been some attempt to reintroduce this method for operations on the head and neck, and the name of Koster of America has been prominent in this connexion. Koster⁶ exposed the medulla and upper cervical cord in frogs and guinea-pigs and applied novocain solution direct to this region. He records that the animals became analgesic all over and that they also became somnolent. He also applied solution to mixed nerve trunks in order to demonstrate that sensory fibres are more easily affected than motor, a fact which was already known. He deduced from these experiments that the strength of novocain which was

effective in interrupting the sensory conduction paths in this region did not affect the respiratory centre because this is a motor mechanism and therefore not so easily affected. He also states that the somnolence was due to diffusion of novocain to the cortex. Applying these results to human beings he propounds the theory that all past fears of paralysing respiration have been groundless, and all that is necessary is to keep the patient's head low in order to ensure a good blood supply to the medullary centres. All administration in the human being has until recently been by means of hyperbaric solutions. The anterior root block seen under hypobaric solutions of percaïne revealed definite proof that the action of the analgesic is not direct into the cord but only on the roots, for it became evident that the motor side could be paralysed when the sensory fibres were left free. This disposes of the theory that muscular relaxation is due only to lack of stimulus, and suggests that the pia mater is impervious to analgesics; it should also be remembered that the spinal pia has a fibrous layer. Koster's experiments depend on the direct action of the drug through the pia mater into the conduction tracts. Before applying novocain he determined that the lumbar reflex arc was intact by stimulating the skin of the leg. After a presumed transverse section of the sensory conduction paths by novocain, he states that the animals became analgesic all over and that stimulation of the legs produced no response. Now 1 per cent. novocain injected up the spine of human beings will paralyse motor fibres of the anterior roots, but Koster states that a 2½ per cent. solution applied to the medulla of these animals did not. Is it not obvious that this strength never reached the motor mechanism in this region? Did it reach the sensory tracts? Assuming that it did, what abolished the reflex arc in the lumbar region, for no novocain was applied here, and it could not have run down to the lumbar roots because the animals were in the Trendelenburg position? Was this due to central motor inhibition? Is it not possible that the animals were analgesic and somnolent from blood absorption? Whatever the explanation may be the experiments were based on a fallacy, and provide no material evidence whatever for a generalization applicable in our operating theatres. One case of respiratory embarrassment on the operating table is worth a thousand such experiments.

RESPIRATORY EMBARRASSMENT AND COLLAPSE

The danger in intra-thecal administration is not a vaso-motor effect from a regional block of the thoracic and lumbar roots, which proves to be of much less significance than was formerly thought, but from blood absorption and paralysis of the vaso-motor centre, leading in some cases with excessive dosage to severe collapse to a pulseless state. The nausea and vomiting which sometimes occur after injection, apart from surgical manipulation, is similarly due to stimulation of the vomiting centre by the poison, as well as low blood pressure. This may be realized by injecting the full contents of a spinal ampoule into a muscle. It is not to be expected, therefore, that the respiratory centre will escape entirely, and the degree to which it may be affected will depend on the amount of the dose in relation to the body weight of the patient. The effect on the cortex shown by the drowsiness and tendency of the patient to sleep also depends on the amount of the drug circulating in the blood. The zenith of blood content is probably reached about 15 to 20 minutes after injection by the gravitational method, and a little earlier by the direct method, because of the larger absorptive surface to which the drug is immediately exposed.

Cushny⁷ states that the relative non-toxicity of novocain is due to the fact that novocain is destroyed by the liver

and cocaine is not. The slow absorption from infiltrations, especially with adrenaline, gives the liver time to deal with the poison, but when novocain is injected intravenously the toxicity more nearly approaches that of cocaine. On account of the rapid absorption of spinal injections their toxicity must be reckoned as only less high than those administered intravenously. If the dosage is high and the body sloped, a variable concentration will reach the anterior roots of the phrenics and intercostals and reduce their conductivity in proportion to the concentration, and the respiration becomes shallow and slow. Anoxaemia will further reduce the centre and increase a tendency to sleep, for it is a powerful, and our last, anaesthetic.

The respiratory centre may therefore be paralysed by an overdose of the drug in the blood, or by a combination of reinforcing agents of which the analgesic and a preliminary narcotic may be the cause. If the centre is badly fatigued and poisoned by drugs it may be difficult to keep it active, whatever means may be adopted. An overdose of percaïne whether by infiltration or by intra-thecal injection will paralyse the centre, and a competent hypobaric solution injected into the neck will paralyse the phrenics and intercostals. Koster states in relation to the human subjects, "In many patients, particularly in children, when head anaesthesia is induced by encouraging diffusion of the drug upward to the medulla, it is found that sleep results." This appears to have been the experience through the history of the method from the earliest cocaine days, and is but due to the fact that the dosage has been relatively high in children compared with body weight. This sleep has also been ascribed to the complete isolation of the consciousness from all body stimuli: a mind deprived of body sensation, yet capable of that most potent of all experiences, fear, and falling asleep on the operating table out of sheer boredom from want of stimuli. To produce general analgesia, all that is necessary is to inject a sufficient dose of novocain in the lumbar region, thereafter inclining the body in the Trendelenburg position. This spreads the drug over the nerve roots, at the same time exposing it to an enormous absorptive surface. The general effect on the patient may be profound. Koster admits that in some cases a peripheral pulse is not to be expected, but implies that this is no disadvantage, since the surgeon can always refer to the aorta, a consolation not available to the specialist in anaesthesia. This condition almost resembles a state of suspended animation, and I have remarked that the patient is "hibernating." And so it seems. Every function of the body is depressed to its lowest level: no pulse can be felt or, when palpable, may be reduced in rate as low as 30 to 40 per minute. The conductivity of the phrenics is reduced and respiration is just sufficient for life. A short period of sleep may be observed and the lips and cheeks may puff out as they do under chloroform.

There are two components at work, a regional nerve root block and a blood dose of novocain. To what extent the cranial nerve roots are directly involved is an interesting question. In the dorsal decubitus the novocain will first be directed towards the cisterna magna, and from here it may spread over the base of the brain, but the arachnoid reticulum is here at its densest and the amount of fluid far greater than it has already encountered in the spine. In such high dilution the novocain has to attack the largest and most compact sensory root in the body.

Is it not probable that an amount of novocain injected in the lumbar region, capable of spreading the sub-arachnoid space as far as the fifth cranial roots, may also be capable of producing general analgesia apart from nerve block, if not actually general anaesthesia?

Dickson Wright⁸ is an enthusiastic advocate of spinal injections for operations on the head and thorax, but says

that "shallow and slow respirations may be worrying." He records a respiratory rate of six per minute, and says, "The patient was asleep and I did not care to wake her to tell her to breathe faster." When admonition is inapplicable, carbon dioxide and oxygen are indicated. The outstanding clinical features of such cases are a reduced frequency and amplitude of respiration, and very low blood pressure, sometimes reaching a pulseless state. The one means imperfect lung ventilation, and the other a reduced rate of blood flow through the lung capillaries. Both tend to anoxaemia and a vicious circle which may end in an arrest of respiration, and it is no recommendation to claim that the majority survive.

JONNESCO'S PRACTICE

Jonnesco's practice was based on the fallacy of direct medullary action, and on the principle that strychnine injected with the drug stimulated the centre and kept it active. Strychnine has no action on nerve fibres, and to reach the cells of brain or cord must first be absorbed into the circulation. But cells paralysed by an analgesic would not respond to stimulants, nor would the latter avail to stimulate cells whose conducting fibres were blocked. Nothing but the possibility of damaging the cord prevents Jonnesco's puncture between D1 and D2 from being a practical method. Short analgesias in the area of the cervical nerves could be obtained by injecting small volumes of dilute solutions, and the motor roots of the phrenics and some of the extraordinary muscles of respiration would have their conductivity reduced but not abolished. To gain longer analgesias stronger solutions would be required which might paralyse the phrenics and some extraordinary muscles, leaving the intercostals to carry on respiration. But the rigid chests of old people would be a bar to such a procedure. It follows therefore that only short analgesias would be advisable by this method. Dilute solutions can be injected up from the lumbar region, but the large volume required means more drug for blood absorption. There must be a very dilute solution of percaine which could be operated in this manner, but what the strength is I cannot say at the moment. The 1-1,500 strength would paralyse the phrenics, and must not be injected into the neck.

Clearly separated from the foregoing is that kind of administration which is intended for abdominal and lower operations, the acknowledged territory of what is generally known as spinal analgesia. Such administrations have in the past frequently passed intended limits, and merged into general anaesthesia, from want of interpretation of the factors involved. This division comprises two subdivisions which require different treatment, limited thoracic nerve root block, and intra-dural caudal block.

LIMITED THORACIC NERVE ROOT BLOCK

Splanchnic block for abdominal surgery requires that the drug shall pass the roots of the 4th or 5th thoracic nerves. Between these and the 4th cervical roots is a sufficient interval to give a wide margin of safety. There are only two possible ways of spreading an analgesic over the roots from the lumbar region:—

- (1) Gravitational diffusion, which can be limited only by dosage and a moderate angle of the table, and gives an uneven distribution.
- (2) By manipulating a syringe:
  - (a) Using cerebro-spinal fluid; simple addition of drug is followed by gravitational diffusion.
  - (b) direct injection of foreign fluid charged with the drug; if this is hyperbaric gravitational diffusion follows; if it is isobaric or hypobaric no spread follows in the Trendelenburg position.

The adult spine is most variable in length. Measurements in my series of cases from the inter-iliac line to

the 7th cervical spine with the body in full flexion have varied between 16 and 22 inches, and both shorter and longer probably exist. In addition, the cubic capacity of the dura in women must be reckoned as rather less than that in men.

The Method of Barbotage or Replacement

This is the method of withdrawing the cerebro-spinal fluid and adding the drug to it before reinjecting. This is impracticable with novocain, because a hyperbaric solution is always produced. Percaine may be used up to 3 c.cm. of 1 in 200 dissolved in acidulated distilled water. This will produce an approximately isobaric solution, and will apply equal concentration to both anterior and posterior roots. Analgesia will therefore outlast abdominal muscular paralysis, but relaxation will be good. The amount of fluid withdrawn must be proportioned to the length of the spine, otherwise no constant nerve root level can be expected. The disadvantages of this method are that the withdrawal of a large quantity of fluid is tiresome and not always successful with a fine needle, and the addition of so small a quantity of acid fluid to a large quantity of alkaline fluid may result in the precipitation of the percaine. Quarella,⁹ who favours this method, regards scopolamine and morphine as an essential part of the technique, and it may be that this is because the level of root block is not always what has been aimed at, for how can it be constant if the spine has not been measured?

The Method of Direct Injection

This means the injecting of a dilute hypobaric of the drug without withdrawing cerebro-spinal fluid. This is the simplest method, a full account of which has been given elsewhere.¹⁰ To calculate the volume of fluid required to pass the 5th thoracic roots, take a measurement from the inter-iliac line to the 7th cervical spine with the body in full flexion; from the number of inches recorded deduct 4 for men, and 6 for women; this result indicates the number of cubic centimetres of solution to inject between L1 and L2, or L2 and L3. This formula is put forward as a basis for a moderate increase with experience, and as a reminder that women require rather less than men. If the operation is pelvic the injection should be made between L4 and L5 in order to hit the lowest nerves in their most exposed situation. For gynaecological operations 10 to 12 c.cm. should be ample.

In the dorsal decubitus a hypobaric solution tends to apply itself in greater concentration to the anterior roots, and in some cases may give abdominal muscular paralysis and no analgesia. In the lateral position, a unilateral effect is produced, a result of importance, because the upper affected side is at the disposal of the surgeon. The degree of this separation depends on the amount of the difference between the specific gravities of the two fluids, and the rate of injection. To produce this effect in the lateral position, make a slow injection, for the more rapid the injection the better the mixture of the two fluids. To ensure analgesia, the patient must be put in the ventral decubitus after injection for from 5 to 10 minutes; the duration of the analgesia will depend on the time spent in this position. If in any case this position seems inadvisable, the two lateral may be used consecutively. It will be found that, as a result of the continued action of the drug on the anterior roots when the patient is put on the back, the paralysis of the abdominal muscles will probably outlast the analgesia. The nearest approach to an ideal drug for this method yet produced is percaine, because it is capable of producing a prolonged effect on nerve fibres in such high dilution that the rate of absorption into the blood is very slow. A rapid general toxic effect is thus avoided. It may be used in strengths of

1-1,000, 1-1,500, and 1-2,000, dissolved in acidulated 0.5 per cent. saline (S.G. 1.0034). The normal saline solutions, S.G. 1.006, are midway between possible variations in the specific gravity of the cerebro-spinal fluid. By this method sufficient acid fluid is injected with the percaïne to keep it in solution.

The latest fallacy to arise is that "percaïne gives such marvellous relaxation." The perfect and lasting relaxation is due to the method of administration whereby the powerful drug is efficiently applied to the anterior roots. It is correct to say that isobaric and more especially hypobaric solutions give good relaxation, and that hyperbaric solutions spread by gravity tend to give poor relaxation in the upper segments of the abdominal wall. Thus a percaïne-glucose solution would have this defect. In spite of this profound regional root block the fall of blood pressure after percaïne injections, though occasionally smart, is never so severe as after massive doses of novocain, nor is toxic vomiting and pallor so much in evidence. Novocain may be used in this way: 1 per cent. dissolved in 0.25 per cent. saline, S.G. 1.003, or in 0.5 per cent. saline, S.G. 1.005. If 1 per cent. in normal saline is used, S.G. 1.0077, the patient may be kept horizontal in the dorsal decubitus until absorption has reduced the specific gravity, and both roots should be fairly evenly affected. The strength of these solutions may be increased in proportion to the faith of the user in the non-toxicity of this drug. When higher percentage is used sodium chloride must be left out proportionately to preserve the required specific gravity of the solution. The strength limit in which novocain can be used as a certain hypobaric solution is 2 per cent. in distilled water. When dosage becomes high, blood-absorption will dominate the picture.

LIMITED INTRA-DURAL CAUDAL BLOCK

Intra-dural caudal block requires different treatment from that of thoracic root block because the nerve trunks are more resistant than the roots. The 1 in 1,500 percaïne solution when completely effective in the abdominal area sometimes leaves some power of movement in the legs, and deep sensation, showing that the lumbar nerves are more difficult to affect both in their roots and trunks than the thoracic. For limited caudal block, stronger solutions are therefore required. The novocain and stovaine solutions in common use always hit the cauda equina in their strongest concentration, and the most profound effect is in the legs and perineum, but the only way they can be limited is by sitting the patient up after injection. Limited block in the horizontal position requires an isobaric or a hypobaric solution. Percaïne dissolved in acidulated distilled water or 0.5 per cent. saline may be used in strengths from 1 in 100 down, and the amount of drug need never exceed from 5 to 10 milligrams. Thus $\frac{1}{2}$ to 1 c.cm. of 1-100; 1 to 2 c.cm. of 1-200; and so on. Six to eight hours' duration of analgesia is possible with this drug, but such prolonged effects are doubtful practice. A great variety of strengths may be used, the object being to effect a good local mixture with cerebro-spinal fluid at the site of puncture. When the operation is on the leg, the barbotage must be sufficient to spread the drug on to the first lumbar nerve, or higher according to the site of the operation. The duration of analgesia will depend on the amount of barbotage used and the dilution attained in the cerebro-spinal fluid. Novocain up to 4 per cent. in distilled water may similarly be used.

GENERAL CONSIDERATIONS

One of the most prevalent fallacies used to be that spinal analgesia is a method to be used when the patient is in too low a condition to take a general anaesthetic, and a common utterance was: "He is too bad for a general,

better give him a spinal," and this in relation to serious cardiac disease. It hardly seems necessary to condemn the administration of massive doses of novocain, with the possible severe fall in blood pressure, when the mechanical efficiency of the heart and the state of the myocardium is defective. A profound fall in blood pressure means a reduced coronary circulation, and only a sound heart can be submitted to such an ordeal. It is certain that ephedrine cannot be relied upon to prevent fall of pressure, though it may alleviate it. It should be injected into a muscle or into a vein and not into the fibrous tissue of the intervertebral ligaments, where absorption must be slow. A limited caudal block or a block of a few thoracic roots may be undertaken when a more extensive effect would be inadvisable, and it is necessary to distinguish clearly between the risks involved in low and high operations, since the necessities of dosage and the vaso-motor effects are greater in the latter. The advent of percaïne undoubtedly extends the use of this method in poor risks, and the 1 in 2,000 solution will accomplish much in short abdominal interventions, with very low general toxicity. But this drug will not confer immortality on anyone. High thoracic root block finds its best application in the muscular man about to undergo a gastric operation, who would otherwise require a harsh general anaesthesia to bring him into a good state of relaxation.

My own outlook is "This man is too strong for a general, better give him a spinal." For normal people spinal analgesia may be offered as an alternative to anyone who wishes to avoid general anaesthesia, and its advantages in lung disease, especially tuberculosis and other pathological conditions, are well recognized. But because in bad risks spinal analgesia has disadvantages of its own, it does not always follow that its use is excluded in such cases, for the post-operative risk of general anaesthesia may be even worse. The temporary stimulation of ether may be the most certain way of getting a patient off the table alive, but the subsequent depression may yet be disastrous, and it cannot be expected that an anaesthetist shall devote the whole of his experience to avoiding the coroner's court, and qualifying his patient for a death certificate.

For such judgement as may be required in these cases no rule can be made. For operations on the head and neck this method cannot compare in regard to safety with a well-planned sophisticated gas anaesthesia by intubation methods, or a two-way insufflation of ether. In operations on the thorax when a mechanical difficulty in respiration already exists I believe no valid argument can be found in its favour, though a unilateral effect with 1 in 2,000 percaïne may be of service for an operation on the lower chest wall. In relation to its employment for such operations as dissection of tonsils after injection of massive doses of novocain in the lumbar region, I am reminded of the criticism attributed to Dr. Johnson, when shown a little dog walking on its hind legs: "Sir, to be sure it is done, but it is not well done; the marvel is that it can be done at all."

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