produces the same effect on the encephalogram, but in this case the changes are irreversible if present for more than a brief period. In the case reported the longest period of complete inactivity in the electroencephalogram was 1 minute 45 seconds.

The electroencephalographic changes in circulatory arrest are sufficiently rapid to allow the surgeon immediately to assess the efficiency of cardiac massage.

The sensitivity of the electroencephalogram during the cessation of the circulation has been demonstrated during the course of mitral valvotomy. During the brief period of occlusion of the orifice of the mitral valve the record becomes momentarily abnormal, but returns to the normal picture immediately the circulation is restored (Fig. 5). The reason for the alteration in EEG recording being even more rapid than in cases of cardiac arrest is not known.

We have also made use of the electroencephalogram to determine the adequacy of the circulation during operation on a carotid body tumour. Here we used a twin-channel machine, using fronto-occipital leads on each side. During the initial part of the operation the records were similar, as would be expected (Fig. 6A). A fall of blood pressure from 110–55 mm. Hg systolic, produced by Arfonad and posturing, in twelve minutes did not alter the pattern. During dissection of the tumour, with partial occlusion of the common carotid artery, the corresponding record became dominated by slow waves up to an amplitude of 50 microvolts (Fig. 6B). These resulted from anoxæmia. No additional anæsthetic drug had been administered nor was there any alteration in blood pressure, the record on the normal side remaining the same as at 6A. Application of the clamp to the common carotid for one minute produced increased cortical suppression in the affected hemisphere (Fig. 6C). Recovery did not occur during one minute following its removal. During the ten-minute period following ligation of the vessel an increase in cortical activity on the affected side occurred with loss of the periods of suppression, decrease of the high voltage low frequency waves and reappearance of fast activity.

Following operation this patient remained drowsy for a period much greater than would be expected from the total dosage of depressant drugs. The following day he complained of severe headache, confined to the affected side. Both these effects were probably the clinical manifestation of the period of cerebral anoxia. No permanent brain damage ensued, nor had this been expected from the brief duration electroencephalographic findings.

SUMMARY.—(1) The physiological basis for the electroencephalogram is described. (2) The value of encephalography in anæsthesia is described in relation to the usua anæsthetic agents. (3) The effects produced by anoxia, carbon dioxide, hypotension and hypothermia are discussed. (4) Cases are reported of the use of the electroencephalogram in various forms of circulatory disturbance.

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The Role of Posture in Laminectomy [*Abridged*]

REGISTRARS' PRIZE ESSAY

By D. J. PEARCE, M.B., F.F.A. R.C.S., D.A.

TROUBLESOME hæmorrhage has always been a consistent feature during laminectomy, often making adequate exploration of the vertebral canal and nerve roots impossible. Hæmorrhage can occur at all stages of the operation: initially, from the superficial tissues and muscles and, later, from the cut spinous processes and laminæ and the epidural veins. The blood loss during operations on the spinal column and cord varies from 658 ml. to 992 ml. (Bonica and Lyter, 1951).

In the efforts to combat this problem many techniques have been used; originally local infiltration (Freiberg and Perlman, 1943) was carried out, but more often to obviate the deleterious effects of ether anæsthesia rather than to reduce blood loss. Other workers used spinal anæsthesia (Nitikman, 1945; Hunter, 1950), pointing out that the blood-pressure fall and degree of muscle relaxation provided ideal conditions. Similar arguments have been advanced in favour of epidural anæsthesia (Bromage, 1952). Further progress was made with the introduction of the hypotensive agents of the methonium series (Davison, 1950;

Enderby, 1950; Organe, 1950; Scurr, 1951) and Arfonad (Magill, Scurr, and Wyman, 1953), although Wyman has pointed out the inconsistency of results with these methods. Other workers have shown that, despite the attenuation of bleeding from the superficial tissues with the use of these drugs, considerable hæmorrhage could still occur from the deeper structures (Rollason, 1953).

Closely associated with this is the problem of posture; for bilateral explorations of the vertebral canal the prone position has been advocated (Pennybacker, 1950), providing that an efficient suction apparatus is available to keep the operative field clear of blood. This disadvantage has caused many workers to adopt the lateral posture, so that blood tends to run out of the wound rather than collect in the depths of a cavity.

From our study of 80 cases of lumbar laminectomy it was evident that the operative conditions were extremely variable. The anæsthetic methods included spinal, epidural—with and without the addition of adrenaline hydrochloride solution—and general anæsthesia, the latter with and without the use of hypotensive drugs. Both prone and lateral positions were employed. Even with the use of pentamethonium iodide or Arfonad, which in most cases considerably reduced bleeding from the superficial tissues, it was apparent that difficulty had often been experienced in identifying the disc lesion owing to troublesome hæmorrhage from the deeper structures. Comments such as, "Persistent ooze from the raw, bony surfaces", or, "Troublesome bleeding from epidural veins", were only too common in the anæsthetic notes. It was also noted that post-operative oozing from the wounds and hæmatoma formation occurred frequently. That the latter is a well-recognized complication is a fact also borne out by other workers (O'Connell, 1951). In view of the disappointing discrepancy in these results it was felt that a further study should be carried out.

METHODS OF STUDY

Since it was realized that the chief difficulty was venous oozing, the studies were directed towards the elimination of inferior vena caval compression, the cause of the congestion.

(1) *Anatomy of the venous drainage of the lumbar vertebræ and vertebral canal.*—The vertebral bodies contain and are surrounded by an extensive network of veins, forming a vast potential venous reservoir. All of these vessels, together with venous channels from the vertebræ themselves, drain into segmental intervertebral veins which accompany the spinal nerves through each foramen and thence to the lumbar veins. The drainage of the lumbar veins, of which there are five pairs, is variable. The third and fourth pairs end in the inferior vena cava, while the first and second pairs either drain into the inferior vena cava or the ascending lumbar vein. The latter is a vessel which passes upwards on the roots of the transverse processes, anastomosing with the ilio-lumbar vein below and connecting together the other lumbar veins; it also receives tributaries from the anterior external vertebral plexus. The fifth pair of lumbar veins drain into the ilio-lumbar veins.

(2) *Venous pressure measurements.*—Venous pressure measurements were taken from the lower end of the inferior vena cava by means of a cardiac catheter connected to a simple water manometer. Six series of results were obtained (Table I). In each case it was clearly

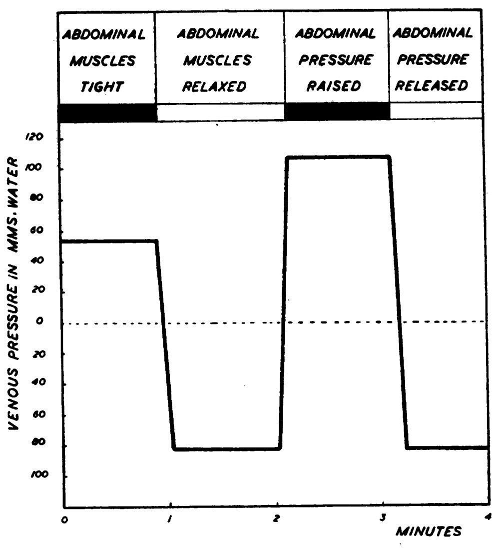

FIG. 1.—Venous pressure changes in the prone supported posture.

TABLE I.—VENOUS PRESSURE CHANGES IN THE PRONE SUPPORTED POSTURE (Maximum Readings in mm. H_2O)

Case No.	With abdomen hanging free	With abdomen compressed
1	10–25	170–200
2	45	180
3	0–15 0–10	300+
4	0–25	150
5	40	115
6	-80	110

demonstrated that pressure on the abdomen, sufficient to cause obstruction of the inferior vena cava, produced a remarkable rise of venous pressure, in some cases to more than 300 mm. H_2O. Even the slightest compression caused a rapid increase of 30–40 mm. H_2O, a rise of pressure probably large enough to distend the thin-walled epidural veins.

In comparing the different postures it was found that the lowest corrected venous pressure (-80 to $+45$ mm. H_2O) occurred in the prone position with a large block under the chest and several small sandbags under each anterior superior iliac spine; by using muscle relaxants the abdominal wall was allowed to hang quite freely and clear of the table surface (Fig. 1). Using controlled respiration, however, it was essential that no build-up of carbon dioxide occurred nor increase of pressure during the expiratory phase, as this caused a rapid rise of venous pressure. With the return of spontaneous respiration and contraction of the abdominal muscles an average increase of pressure of approximately 100 mm. H_2O occurred and this rose even higher if the patient was allowed to strain.

(3) *Histology of the epidural veins.*—These veins are thin-walled (Franklin, 1937), contain little or no muscle tissue, and valves are present in only a few of the smaller channels, so that the slightest rise in venous pressure will cause distension.

(4) *Dye injection studies in the cadaver.*—Harris (1941) has drawn attention to the original papers describing the anatomy of the spinal and vertebral veins. The classical paper by Batson (1940) on the metastatic spread of prostatic carcinoma re-emphasized the rich anastomoses of the vertebral plexuses with the inferior vena cava. Furthermore, from his experiments on cadavers and live monkeys he was able to show that a rise of intra-abdominal pressure, sufficient to produce compression of the inferior vena cava, caused radio-opaque dyestuffs to pass into the vertebral system of veins.

This experiment was carried out in the human cadaver, colloidal barium sulphate solution being injected through a cannula in the deep dorsal vein of the penis and serial X-ray films taken. Without obstruction the dye flowed easily along the inferior vena cava (Fig. 2), but when this was ligated the barium was seen to pass into the anastomotic channels (Fig. 3).

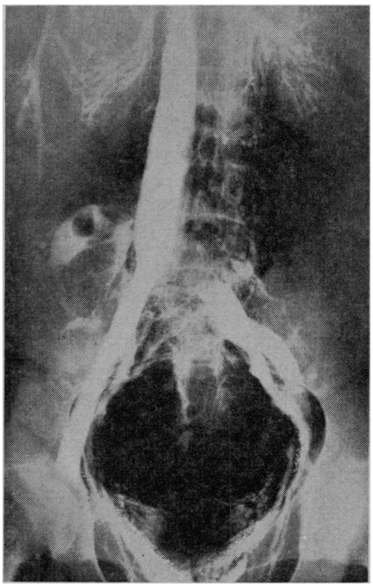

FIG. 2.—Normal flow of radio-opaque dye along the i.v.c. Antero-posterior view.

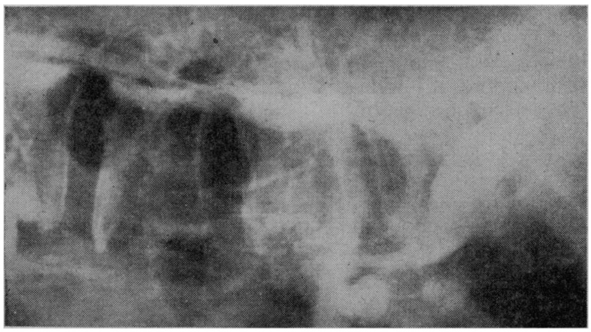

FIG. 3.—Flow of dye into the anastomotic channels with the i.v.c. ligated. Lateral view.

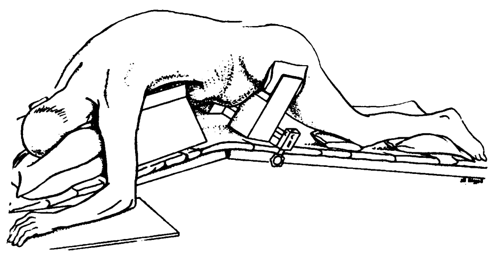

FIG. 4.—Position of patient for laminectomy.

From these results it became obvious that compression of the abdomen and inferior vena cava during laminectomy should be avoided at all costs, in order to eliminate completely the possibility of hæmorrhage from engorged epidural veins. It was also felt that reduction of hæmorrhage from the superficial tissues could best be achieved by infiltration with 1/250,000 adrenaline hydrochloride solution.

TECHNIQUE EMPLOYED

The standard principles of general anæsthesia are observed, using sodium thiopentone, nitrous oxide and oxygen, supplemented by pethidine and muscle relaxants as the anæsthetic agents. In these cases suxamethonium chloride, in drip form, has been used to provide muscle relaxation. Endotracheal intubation with a cuffed oral Magill tube is used in all cases to ensure complete control of the airway and to prevent aspiration of any regurgitated gastric fluids during positioning on the table.

The patient is placed in the prone posture with a large supporting block under the upper part of the chest and adjustable, well-padded supports under the anterior superior iliac spines (Fig. 4). In this way the abdomen is allowed to hang freely. The legs are lowered slightly and the knees and ankles supported by soft pads. The hands are allowed to rest on stools, placed on each side of the operating table. A head-down posture is never allowed in patients who have recently had a myelogram.

To reduce bleeding from the superficial tissues a solution of 0·25% lignocaine hydrochloride with 1/250,000 adrenaline is used, according to the method described by the late Dr. Rait-Smith (1949) for chordotomy. Using a strictly aseptic technique, approximately 10 ml. of solution are injected down to the root of each lumbar transverse process in a fan-wise direction two fingerbreadths from the mid-line. In this way a barrier of solution is deposited in the muscles and in the angle formed between the transverse process and the lamina of the vertebra. Three spaces above and three spaces below the suspected site of the disc lesion are infiltrated on each side. Finally, a superficial mid-line skin wheal is raised at the site of the surgical incision. The total volume of solution used is 120–150 ml. The infiltration can be carried out either by the anæsthetist or the surgeon, as conditions permit. In case of superficial œdema caused by the infiltration, a scratch mark should be left at a predetermined site as a landmark for the benefit of the surgeon.

In some of the cases chlorpromazine hydrochloride was used in order to obtain the reversal of the adrenaline pressor reflex, but no real difference was noted in the results and it is not considered an essential part of the technique.

RESULTS

A further 25 cases of laminectomy have been carried out using this technique. In all of them the operating conditions have been so outstanding that the use of Spencer-Wells forceps and diathermy has been entirely unnecessary and the suction apparatus rarely required. An extremely thorough exploration of the vertebral canal and nerve roots has been possible and yet, in many instances, the actual operating time has been reduced to thirty minutes. It was thought at first that the lack of flexion of the lumbar vertebræ would be a disadvantage, but in practice this is not so.

Also, the increase in the time allowed for the induction of anæsthesia, positioning and local infiltration has been more than offset by the reduction in the actual operating time.

Apart from one post-operative chest infection no complications have occurred. In each case the wound has healed by first intention and no hæmatomata or sero-sanguineous exudates have been encountered. The addition of 0·25% lignocaine hydrochloride to the solution used for infiltration appears to provide more immediate post-operative relief.

Although this series has been based on cases of prolapsed intervertebral disc, it follows, nevertheless, that this method can be employed in laminectomy for all other causes, except those in which sepsis is thought to be present.

SUMMARY.—(1) The anæsthetic techniques employed in laminectomy in an attempt to provide a bloodless field for the surgeon are reviewed briefly and the discrepancy in operating conditions noted in a series of eighty cases. (2) The role of posture is studied by means of venous pressure measurements from the inferior vena cava, the histology of the epidural veins and dye-injection studies in the cadaver. (3) The method of anæsthesia used successfully in a further series of 25 cases of laminectomy is described.

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