Surgery on the spinal axis

Surgery for the correction of gross spinal abnormality or for the management of intradural pathology remains relatively rare and this work is performed in a few specialized centres. However, lumbar disc surgery is now extremely common and is performed in all neurosurgical units and in most hospitals with an orthopaedic department. Before 1934, occasional cases of prolapsed intervertebral disc had been described in the literature; usually they had been misdiagnosed and treated as extradural chondromas. Goldthwait [14] in 1911 proposed that disc prolapse could be a cause of compression of the cauda equina producing symptoms of sciatica and low back pain. Sporadic clinical case reports appeared thereafter and important confirmatory pathological observations were also made about this time [54]. In 1934, the neurosurgeon William J. Mixter and the orthopaedic surgeon Joseph S. Barr wrote a paper establishing the degenerative aetiology of disc herniation and its relation to sciatic pain [31]. Their work is regarded as the “classic” in this field. It was read at a meeting of the New England Surgical Society on September 30, 1933 at Boston and published in the New England Journal of Medicine.

Early accounts of lumbar intervertebral disc surgery

The first article mentioning any aspect of anaesthesia for lumbar disc surgery was by Love and Camp of the Mayo Clinic [27]. An ether anaesthetic administered by open drop method over the end of a Magill tracheal tube was used. Cervical laminectomies were performed with the patient in the upright position; other laminectomies were performed with the patient prone. In the latter, the torso was supported by two rolled pillows placed in the longitudinal axis so as not to interfere with ventilation. Surgery in the lower lumbar region was facilitated by placing a large soft pillow between the symphysis pubis and xyphoid process in order to increase the prominence of the lumbar spinous processes.

Between 1944 and 1956, several authors refer to laminectomy performed with the patient positioned on a “special operating table” [32, 41, 48]. However, it is likely that these were available only in the few neurosurgical centres where surgeons were already accustomed to open the spinal canal. Even up to 1950, this was a relatively rare event; Hunter [21], writing at that time stated that he had been unable to find a single reference in the literature to anaesthesia for spinal tumours. Haemorrhage was a constant problem, so much so that Pearce [36] stated that many workers in this field chose to operate with the patient in the lateral position so that the blood could run out of the wound rather than collect in the depths of the cavity. Bonica and Lyter [5] found that blood loss during operations on the spinal column varied from 658 to 992 ml.

Problems of positioning were compounded further by the limitations of the current general anaesthetics administered without the benefit of neuromuscular blocking drugs. The surgeon was faced, therefore, with access made difficult by

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spasm of the overlying erector spinae muscles, compounded by any anterior spinal curvature opposing the edges of the vertebral bodies through which degenerated disc material needed to be extracted. Anaesthetic and position-related venous back pressure producing excessive haemorrhage added further insult to injury. The problem of “undoing the anterior lumbar curve” alluded to previously by Love and Camp [27] must have been of considerable significance and was mentioned by two further writers: Hunter [21] stated that it was not uncommon for the surgeon to request that the patient be positioned prone over a transversely placed metal bar, and Lipton [26] stated that the surgeon would want “the table split and the abdomen packed with pillows”. Whichever method was used, the aorta and inferior vena cava must have been occluded partly or completely, with congestion and haemorrhage. Communication between the inferior vena cava and the extradural veins via the lumbar plexus was already well documented [4, 7, 35].

The first European article relating to anaesthesia for lumbar disc surgery was published in 1942 by Wiberg [52]. Dr Love, surgeon to the Mayo Clinic, had visited the Karolinska clinic in Sweden in 1939. Wiberg commented that they started by using an infiltration local anaesthetic technique advocated in the U.S., but later modified it by addition of either general anaesthesia or intrathecal local anaesthetic. This was necessitated by the excruciating pain experienced by patients when inflamed and stretched spinal roots were touched. Unfortunately, he did not mention positioning the patient for surgery. In the U.S.A., Smith, Deery and Hagman [41], describing 100 cases of surgery for herniation of the nucleus pulposus operated on between 1937 and 1943, stated that “the operation was done on a special table which places the patient in the kneeling position with the hips flexed at 90°” and he considered this positioning “an important point in the technique”. Nitikman [34] in 1946, describing a spinal (intrathecal) anaesthetic technique, also mentioned the use of a special table with a “gatch” which was raised acutely at the level of the crest of the ilium. The patient was placed over this and then two pads, 20 cm wide and 7.5 cm thick, were placed from iliac crests to the xiphoid process; these pads were tapered to half their thickness to support the chest. Similar methods using only lateral bolsters [21] or specially shaped foam pads [3] have also been described. Loss of shape and support occurs with repeated use and contamination with blood and cleaning fluids may be a risk to other patients and staff.

Falconer, McGeorge and Begg [12], reviewing 100 cases in 1948, briefly mentioned that patients were positioned with a sandbag under the groins and a pillow beneath the chest. They also pointed out that positioning the patient so that the lumbar spine was hyperextended was a useful test of the macroscopically “normal” but degenerate disc. With hyperextension, it bulges posteriorly into the vertebral canal, whereas the normal one does not.

Over-enthusiastic surgical attempts to clear the entire intervertebral disc space may result in perforation of anterior intervertebral ligaments and damage to the underlying major blood vessels. The first reports of this complication occurred as early as 1945 [25]. Fortunately, the damage on that occasion was not acute and resulted in an arteriovenous fistula between the right common iliac artery and the inferior vena cava. It was discovered some 7 months after the initial laminectomy and was repaired successfully. In 1948, Holischer [19] described a similar case, although major vessel damage was suspected at the time of discectomy. By 1954 Harbison [16], also after experience of a similar case, conducted a survey of 100 surgeons in the U.S.A. and obtained reliable information on another 25 injuries to major blood vessels occurring as a result of surgery for intervertebral lumbar disc protrusion. There was a 61% mortality from this complication in the series; six of the patients who survived developed arteriovenous fistulae and one subsequently died. Of great importance was the finding that in more than 50% of patients such injuries do not manifest themselves by external haemorrhage at the surgical site, and unless both the anaesthetist and surgeon are aware of this possibility, unexplained hypotension may be ascribed to other causes. Methods of prone positioning currently in use at that time, which forced the great vessels against the lumbar interspaces, were suggested as a contributory factor in the aetiology of this complication. In the same year, Seeley, Hughes and Jahnke [39] reported a further two cases. They examined vessels likely to be damaged at different intervertebral disc levels and urged that immediate transabdominal exploration and repair should be carried out when this complication is confirmed or seriously suspected.
Harbison's survey [16] also revealed one case of injury to the small bowel. This was recognized at the time of operation by the appearance of intestinal mucosa in the jaws of the pituitary rongeur. Immediate laparotomy was performed with closure of the torn bowel, with good results. A similar case reported by Smith and Estridge [42] was not diagnosed conclusively until laparotomy on the second day after operation. Damage to the bowel is, however, quite rare; only three of 140 reported intra-abdominal injuries were in this category.

Keeping external pressure away from the anterior abdominal wall

In an attempt to overcome the adverse effects of external pressure on the anterior wall, Ecker [10] in 1949 (fig. 1) and Lipton in 1950 [26] (fig. 2) described similar positions. The thighs were well flexed but splayed out away from the abdominal wall.
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wall. The chest was supported either by a sling (Ecker) or pillows (Lipton). However, in 1952 Gordon and Newman reported a death from acute renal failure as a result of crush injury to thigh and calf muscles [15]. A similar but non-fatal case was reported in 1969 by Keim and Weinstein [22].

By 1950 it had become apparent to Moore and Edmunds [32] that the shortcomings of specially adapted tables and the less sophisticated techniques of simple propping with sandbags and pillows required further development. They published their experience of using a "frame" over which the patient could be positioned (fig. 3). It had the twin advantages of easy storage, transport and use, together with minimal physiological disturbance for the patient. Both the Mackay [29] and the Wilson "frames" were of similar design, but with greater facility for adjustment.

Specific support for the pelvis

The next important advance was an article published in 1956 in British Journal of Anaesthesia by Taylor, Gleadhill and Bilsand [48], emphasizing the need to minimize extradural venous bleeding by avoiding abdominal and thoracic compression. This was achieved by an easily made adjustable prop which could be used on any conventional operating table. The authors acknowledged that the principle involved was copied from an operating table designed specially by Professor Norman Dott of Edinburgh. This table had a series of vertically adjustable U-shaped segments arranged across it. The patient was placed prone, and then the segment at the level of the iliac crests was raised well above the others, allowing the abdomen to sink in front of it. He postulated that, as pressure in any valveless venous system was least at its highest point, the body should be placed on the table so that the operation field is at the highest point. The thorax was supported also, but the abdomen and neck were free of external pressure. The prop (figs 4, 5) has one fixed support, and one free to be adjusted.

Fig. 4. Pelvic support made from bed blocks. The right limb is movable on the metal bar and fixed by split-pins (Taylor, Gleadhill and Bilsand, 1956 [48]).

Fig. 5. Lateral view showing the abdomen lifted clear of the table with the weight distributed between the pelvis, legs and shoulders.

Fig. 6. Measurements of the inferior vena cava pressure in the prone position by Pearce in 1957 [36].
Fig. 7. The Georgia Prone Position (Smith, Gramling and Volpitto, 1961 [45]).

Fig. 8. X-ray studies demonstrate well that femoral flexion can abolish the lumbar curve and improve posterior access to the intervertebral space.

according to the width of the patient’s pelvis. The original description shows the lateral rim of both supports higher than the medial margin, to prevent the patient slipping sideways. This is an extremely important precaution and it is a pity it was not incorporated into other copies of this prop, for example the Manchester version. Without such a precaution, any displacement of the patient always leads to compression of one femoral neurovascular bundle in the groin and operating conditions are impaired. (This is also a risk with other propping systems in which the individual props are not fixed to a firm base plate.) Scientific support for the concepts outlined above came quickly on the heels of this publication. Pearce [36], in a “Registrar’s Prize” paper to the Anaesthetic Section of the Royal Society of Medicine in 1957, provided the first recordings of inferior vena cava pressures made with a patient in the prone position (fig. 6). From a diagram of the positioning of his patients, it was clear that the “built-up” sides of the blocks prevented lateral displacement.

A modified operating table

Smith, Gramling and Volpitto [45] in 1961 described the “Georgia Prone Position” using fixed props beneath the pelvic crests. The thighs were flexed at right angles and some of the patient’s weight was supported by the knees (fig. 7). Drawings from lateral x-rays taken in this position show the effect on spinal curvature of lowering the thighs to rotate the pelvis backwards and downwards. The lumbar spine becomes flatter and this can be advantageous to the surgeon by improving posterior access to the intervertebral disc space (fig. 8). Their subjective tests of conscious volunteers placed in the prone position showed that the patient’s back and neck must be in the same plane to allow the head to be turned painlessly to each side; the arms should rest on the operating table “above” the head to prevent discomfort; the infraclavicular fossae should be free of pressure points and, in female patients, the breasts must be displaced laterally. Transverse rolls placed anywhere under the body (except under the ankles), produce pain, particularly if under the chest, iliac spine, pubis or trochanters. Later (1964) Smith [43] described a special device for use in this position, based on an adjustable automobile jack which could be placed below the
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FIG. 9. The Relton and Hall Frame designed for spinal fusion surgery using the Harrington Rod.

knees both for support, and for accurate positioning, in order to produce the desired degree of spinal curvature. By 1974, however, Smith [44] appeared to have abandoned the Georgia prone position in favour of adjustable props similar in principle to the technique of Taylor and Pearce.

Influence of reconstructive spinal surgery

The need to provide a satisfactory support system for patients undergoing orthopaedic surgery for kyphoscoliosis correction became necessary in the 1960s. Their deformity made initial positioning difficult and potentially unstable, and this was compounded when further loss of skeletal support occurred during operation. Operative blood loss was measured in a series of 44 patients by Relton and Conn [37]. Seventy-five percent of the patients lost more than 50% of their circulating blood volume. Following these studies, Relton and Hall [38] published their description of an “operation frame for spinal fusion”. This was the first, and only, frame in which four individual, adjustable supports were arranged on a rail system, allowing accurate positioning irrespective of skeletal deformity (fig. 9). Blood loss in the initial series of patients studied compared favourably with that of Relton and Conn. When the supports are positioned anterolaterally, they tend to facilitate correction of the scoliosis; any tendency towards hyperextension of the vertebral column may be counteracted partially by lowering the legs (as first demonstrated by Smith). Relton and Hall did not recommend use of the frame for laminectomy for lumbar disc protrusion because of the lordosis it induced. However, it is possible to use the lower pelvic supports mounted on a different base plate for this purpose (fig. 10) (in the same manner as Taylor’s prop) provided that some flexion of the thighs is obtained. The chest is then supported on pillows or a foam pad. The full frame has been advocated by Humphries and colleagues [20] for use in neurosurgical procedures on the upper cervical spine and posterior fossa in children. Mouradian and Simmons [33] have described a method of combining the Foster or Stryker frame with the Relton and Hall frame so that continuous skeletal traction may still be applied whilst the patient is undergoing surgery.

The acute neurological complications arising as a result of corrective surgery for scoliosis were reviewed in 1975 by MacEwan, Bunnell and Krishnaswami [28]. Seventy-four major complications involving the spinal cord occurred in 7885 operations, 50% complete paraplegia and 50% partial paraplegia. Only 36% recovered completely.

The “seated” prone position

Probably the most significant advance in prone positioning was made by Tarlov [46] in 1967 when he published a description of support via the ischial tuberosities—that is, a seated prone position with the operating table tipped steeply to approximately 45° (fig. 11). It is interesting that Ecker [10], Lipton [26] and Smith, Gramling and Volpitto [45] came close to this position without seeing that final development. Taylor, Gleadhill and Bilsand [48] did describe the use of a bicycle saddle to provide further support for their iliac crest propped position, but again failed to see the advantages of using it as a primary method. Other authors publishing later descriptions of the same idea include Hastings [17], Laurin and colleagues [23] and Dinmore [8]. The chest pad or pillows should not encroach on the neck or compress the epigastrium. There is no pressure on either the viscera or inferior vena cava, and vessels in the groin are not at risk, as they are in many other methods of support.

Even in procedures of very long duration, it is rare to see any adverse effects from pressure on the knees. Postoperative phlebothrombotic problems in the lower limbs are also rare. Tarlov [47] described two minor cases in 300 operations, and ascribed these to excessive flexion of the hips and knees. External compression apparatus can be
applied routinely below the knees. In 1969, Laurin and colleagues measured inferior vena cava pressure and found it to be as little as 2 cm H₂O [23]. Venograms of the inferior vena cava were compared with the patient on a conventional laminectomy frame and on the Tarlov seat. With the latter, back flow up into the extradural veins did not occur and more rapid emptying into the right atrium of the heart was evident.

The illustration in Tarlov’s original article and in a later one [47] shows the patient’s back to be more or less horizontal. Hastings [17] and Dinmore [8] both specify this in their text. Laurin and colleagues [23] advised that the chest should be slightly lower than the buttocks, to favour drainage of the vena cava into the left atrium. However, taking the weight off the ischial tuberosities may make the patient less stable, and it must be remembered that, in any situation where veins are opened inadvertently at a surgical procedure taking place above heart level, there is theoretically a risk of venous air embolism. Clearly this should not occur when the central venous pressure is greater than the vertical distance between the atrium and the open veins. However, with the “Tarlov” position central venous pressure is usually small—approximately 0–2 cm H₂O with the back horizontal. This was confirmed by Cook and colleagues [6] in 12 patients (table I). Distephano and colleagues [9] gave a comparison of inferior vena cava pressures measured during surgery for lumbar procedures and again confirmed that the Tarlov position is superior in this

<table>
<thead>
<tr>
<th>Patient weight (lb)</th>
<th>Operation</th>
<th>Supine under general</th>
<th>Prone on laminectomy frame</th>
<th>Sitting prone position</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>Thoracic</td>
<td>1</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>110</td>
<td>Lumbar</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>150</td>
<td>Thoracic</td>
<td>10</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>200</td>
<td>Lumbar</td>
<td>5–6</td>
<td>8–10</td>
<td>1</td>
</tr>
<tr>
<td>170</td>
<td>Thoracic</td>
<td>3–4</td>
<td>12–14</td>
<td>1–0</td>
</tr>
<tr>
<td>250</td>
<td>Lumbar</td>
<td>1</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>175</td>
<td>Lumbar</td>
<td>2</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>200</td>
<td>Lumbar</td>
<td>6</td>
<td>7.5</td>
<td>0</td>
</tr>
<tr>
<td>180</td>
<td>Lumbar</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>180</td>
<td>Lumbar</td>
<td>6–7</td>
<td>10–12</td>
<td>1–0</td>
</tr>
<tr>
<td>170</td>
<td>Lumbar</td>
<td>4</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 11. Tarlov (1967 [46]) described this as the “knee chest position”. However, the use of the term “seated prone” distinguishes it from similar less satisfactory versions (vide Lipton [26] and Ecker [10]).
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TABLE II. Central venous pressure values in a variety of positions [9]

<table>
<thead>
<tr>
<th>Arrangement</th>
<th>Average CVP (cm H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia prone</td>
<td>20.7</td>
</tr>
<tr>
<td>Prone chest rolls</td>
<td>15.9</td>
</tr>
<tr>
<td>Lateral decubitus</td>
<td>11.1</td>
</tr>
<tr>
<td>Wilson frame</td>
<td>10.1</td>
</tr>
<tr>
<td>Tuck position</td>
<td>9.4</td>
</tr>
<tr>
<td>Hastings frame</td>
<td>1.4</td>
</tr>
</tbody>
</table>

The actual risk of venous air embolism seems to be very small. There is one report of a fatality in the literature [40] but in this patient posterior fossa surgery was being performed for a large arteriovenous malformation.

The question of whether or not patients should have a central venous pressure catheter sited in the right atrium was raised by Goldberg [13] in 1977. Tarlov [47] stated that in his experience of several hundred patients, it was not necessary for lumbar surgery. He made the point that the spinal veins, unlike the large intracranial veins and dural sinuses, are not kept open by bony and fascial attachments and this may be the reason for the apparent safety of the position despite known small central venous pressures. In further correspondence on the subject Albin and colleagues [1] advocated the use of both right atrial catheters and Doppler ultrasonic transducers, even for lumbar surgery, and quoted detection of venous air embolism in neurosurgical patients in the lateral, supine and prone positions with gradients between the wound and the heart as small as 5 cm. It would appear from more recent work by Backofen and Schauble [2] that the value of a right atrial catheter lies more in its propensity as a route of aspiration than for the information it may provide. They recommend that poor risk patients who would be unlikely to tolerate a reduction in cardiac index of around 20% should have arterial and thermodilution catheters inserted.

A 15-year survey was undertaken by Wayne [50] in 1984 and he reported favourably on the use of this position. In 253 patients, there was only one case of deep vein thrombosis in the leg with uncomplicated pulmonary embolus. Together with Tarlov’s experience, this represents a fairly impressive safety record. Serious air embolism is a very rare event when the position is used for lumbar surgery.

A different approach—the evacuatable mattress

The late Dr J. V. I. Young of the London Hospital first drew attention to the use of an “evacuatable” mattress (Evac M) (fig. 12) in 1982 and published an account of its more general applications [55]. This method of support spreads the load evenly over the entire anterior body surface, thus minimizing pressure sequelae. Soft plastic granules are enclosed in a heavy duty, airtight flexible plastic container. Air may be sucked out or let in through a stoppered valve, causing a change in consistency, so that it holds its shape until opened to the atmosphere again. The anaesthetized patient is turned into the prone position whilst the mattress is still soft; the mattress is then moulded to fit the body contours, ensuring a slight gap beneath the epigastrium, and air is sucked out. The excellent heat retaining properties are a useful advantage.

Specific support for the head and neck, and protection for the face

Patients with symptoms of neck pain are often anxious before operation that their disability be

![Fig. 12. Prone position using the evacuatable mattress.](https://academic.oup.com/bja/article-abstract/67/4/452/242365/6741452242365)
noted, for fear that it will be worse afterwards. Both cervical hyperextension and rotation must be avoided. Younger patients with capacious cervical spinal canal are probably not at much risk from hyperextension, but the older patient with a canal narrowed by osteophytes may develop compromised spinal cord blood supply if the canal is narrowed further by bad positioning. Ehni [11] and Wilkes [53] reported cases of postoperative neurological deficit as a result of supine, lateral and lithotomy positioning and, although there do not appear to be any similar reports associated with the prone position, it is reasonable to assume that the cervical spinal canal may also be compromised. Great care must therefore be taken both in the actual turning process, when a short but severe episode of hyperextension can very easily take place and in the final resting position. Of the latter, Young [55] states “that it is not often appreciated how much higher the shoulders have to be than the head in the face down position to avoid extending the neck, a good guide is the absence of a transverse skin crease at the back of the neck”. Flexion of the neck and the atlanto-occipital joint should be avoided in patients with posterior fossa tumours as it may provoke brainstem ischaemia. It may be difficult to diagnose this without the use of somatosensory evoked potential monitoring [30].

Damage to the eyes in a patient in the prone position is a serious complication. The first report in the literature [49] described two cases of retinal ischaemia with unilateral blindness occurring during pulmonary resection carried out in the prone position. A rubber cushioned horse-shoe support was used. In each case undetected rotation of the head occurred and protracted direct pressure on the globe ensued. In 1954, eight similar cases were reported from the Mayo Clinic; all had rested on the horse-shoe in either the prone or sitting position [18]. Experimental work on monkeys by the same authors suggested that orbital pressure, blood loss and induced hypotension were required to reproduce the same syndrome as that observed in man. A further case of unilateral blindness occurring after the prone position was presented at a Neurosurgical Anaesthetists’ meeting in 1989 [Cooper and Ingham, personal communication]; again the horse-shoe headrest was implicated. It would appear that there is no justification nowadays to use the horse-shoe headrest when surgery is being performed in the lumbar or thoracic spinal regions. All that is necessary is a pillow or foam rubber support placed so that the weight of the head is taken directly by the forehead and there is a clear gap beneath the eyes and the top of the nose. The patient’s head should be in the neutral position, without rotation of the neck [45].

For surgery to be carried out on the neck or posterior cranial fossae, the horse-shoe remains an option for head support. However, it would be wise to ensure as far as possible that the head is strapped securely to the support and if minor adjustments are required subsequently, both the horse-shoe and the head should be moved together. The eyes should be covered to protect them from drying, abrasion or fluid contamination. Patients with intraocular lens implants are at risk of haemorrhage or secondary damage to the posterior surface of the cornea should external pressure on the eyeball cause the lens to become displaced.

A further problem with the use of the horse-shoe headrest is damage to the skin over the malar areas. Blistering and even full thickness skin loss may result from excessive pressure, abrasive forces, or both. Craniotomy involving the use of the Gigli saw is a particular risk, as the reciprocating movement inevitably rubs the malar skin against the headrest.

Alternatively, the Mayfield neurosurgical skull clamp may be used. There do not appear to be any reports of untoward effects related to the eyes, but there is always the potential for a pin to slip or become displaced.

Finally, it is worth noting that, should blindness ensue unexpectedly and for no obvious external reason, an embolic episode affecting the retinal artery should be considered. Fat, particularly, has been implicated and paradoxical air embolism is a more rare possibility.

A new hazard of prone positioning

Weinlander, Coombs and Plume [51] reported a patient who, having previously had coronary artery bypass surgery, showed ECG evidence of adverse effects on myocardial blood flow when anaesthetized and placed in the prone position. ECG abnormalities noted during surgery were confirmed in the recovery room to represent massive anterolateral ischaemia. Emergency coronary revascularization was proceeded to and at operation both saphenous vein bypass grafts were found to be patent and pulsatile. A further graft was inserted and a good recovery obtained. It would appear that the thin-walled veins used as
coronary grafts easily became compressed by pressure on the anterior chest wall. This mechanical cause of graft obstruction is reversible. Full 12-lead intraoperative ECG monitoring is now technically possible and should be considered in such patients. It would be unwise to allow surgery to begin until adverse effects of positioning can be confidently excluded.

CONCLUSIONS

The quest for the most satisfactory method of prone positioning has been influenced by the necessity of providing good operating conditions with minimal haemorrhage and by the reporting of complications and hazards encountered. Some very serious complications have been reported and they can be classified under three headings.

First, there are those arising directly as a result of the method of prone positioning. The more serious of these include crush injuries to limb muscle resulting in anuria; excessive extradural venous haemorrhage from back pressure in the femoral veins or abdomen; pressure necrosis of skin, neuropraxia and blindness.

The second group of complications arise as a consequence of the surgery being performed. Damage to underlying major vessels or even perforation of the bowel are well recorded and represent dangerous risks of intervertebral disc surgery. Extensive haemorrhage and spinal cord damage may occur with reconstructive spinal surgery. Venous air embolism is possible when the operating site is above the level of the patient’s right atrium.

Finally, there are the complications associated with anaesthesia in the prone position. The technical hazards are probably greater than the physiological ones, although in the very obese or poor risk patient the latter cannot be dismissed. The cornerstone of anaesthetic technique is the correct placement and security of a non-kinking tracheal tube. Oral secretions gravitating from the mouth may loosen the retaining strapping; inadvertent endobronchial intubation may be produced by the inevitable changes of head position associated with the turning procedure. Special attention should be taken to avoid hyperextension of the patient’s neck. Lee, Barnes and Nagel [24] were so concerned with the actual hazards of the turning procedure that they devised a method of “awake pronation” under neuroleptanalgesia.

Whichever method of prone positioning is chosen, it is wise always to check the peripheral arterial pulses in the feet before finally draping the patient, and the use of external compression apparatus to the legs may help to prevent venous stasis. The advent of modern monitoring techniques, particularly $SpO_2$, $\text{PECO}_2$, and reliable non-invasive arterial pressure devices certainly help to provide early warning of both surgical and anaesthetically related problems. If it is necessary to use one of the older or less stable methods of positioning, any adverse cardiovascular effect arising in the course of the operation should alert the anaesthetist to checking the patient’s position. Serious and otherwise unexplained hypotension should be managed by immediately abandoning the operation and returning the patient to the supine position.

The Tarlov seated position with the table tipped to 45° and the back horizontal appears to be the most satisfactory for all types of lumbar disc surgery and for some operations at higher levels. It is extremely stable, applicable to a wide range of body size and shape, and is the least likely to result in venous back pressure at the operating site. It appears to have an excellent safety record.

SUMMARY

Since the 1940s there has been an increase in the number of patients submitted for surgery of the spinal axis necessitating use of the prone position. Specifically designed operating tables were both rare and expensive, and probably only existed in a few highly specialized centres. Apparatus which could be easily made locally and used in conjunction with normal operating tables has been invented and generally used to good effect. The important historical landmarks in these developments are traced and a review of the methods and hazards is presented. Similar methods evolved almost simultaneously in differing centres. It is recommended that the Tarlov “seated prone” position should be widely used, in view of its physiological advantages and lack of adverse reports.

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