Positioning - Miller

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INTRODUCTION: GOALS OF POSITIONING FOR THE SURGICAL PATIENT

In general, the goal of surgical positioning is to facilitate the surgeon's technical approach while balancing risk factors. Surgical techniques have been expanded by the flexibility provided by anesthesia methodology, so that new areas of the body have become accessible and new positions have been developed. All surgical positions carry some degree of position-related risk; these risks are increased in the anesthetized patient, who cannot make the clinician aware of compromised positions. The goal of providing the best surgical exposure is always balanced by the need to minimize the risk to the patient.

PHYSIOLOGIC EFFECTS OF CHANGE IN POSITION FROM VERTICAL TO HORIZONTAL IN HUMANS

Body responses to alterations in position are in response to gravity. Most of the changes are related to gravitational effects on blood and its distribution within the venous, pulmonary, and arterial systems. There are also important effects on pulmonary mechanics and perfusion, again related to gravity.

Cardiovascular System

There is evidence that changes in blood volume occur as we change from erect to supine. Some of these are demonstrable within minutes, 1 whereas others are associated with long-term bed rest. For most purposes, the redistribution of blood volume within the vascular system that is caused by position changes is more important. In the erect position, there is opportunity for considerable increase in transmural vascular pressure in the lower extremities because of the hydrostatic effects of the columns of blood. This increase is limited by increased pressure in the tissue surrounding the vessels, which is due to muscle tone and contraction required to maintain the erect position, and by venous valves. Even with this compensation, clinically there is considerable blood volume or capacity within the lower-extremity vascular bed. 2

A complex system of reflexes in both the venous and the arterial systems maintains blood pressure during changes in position. Although these reflexes work in concert, anesthesia can blunt the response of selected limbs of the system, thereby altering the final response in either direction. The venous atrial reflexes are responses both to stretching of the atrial wall and to autonomic nervous influences. Arterial pressor reflexes are more directly related to autonomic response to baroreceptors in the aortic arch and the carotid sinus. Changes in position alone do not alter the responsiveness of these reflexes, but other factors, including drugs and age, are important in this alteration of response.

Cardiac output tends to increase immediately on assumption of the supine position. Venous blood from the lower body flows back to the heart, stretching the atrial wall, and stroke volume increases. If contractility and arterial tone remained constant, arterial pressure would rise. Baroreceptor impulses travel afferently from the aorta via the vagus nerve and from the carotid sinus via the glossopharyngeal nerve to the medulla. Increased efferent parasympathetic and decreased efferent sympathetic activity change the parasympathetic/sympathetic balance, which causes decreased heart rate, stroke volume, and contractility and thereby results in little change in blood pressure. 3

Pulmonary System

During spontaneous ventilation in the erect position, the primary force of inspiration is the downward movement of the diaphragm. In the supine position, the diaphragm shifts upward and outward and contributes only about two-thirds of the ventilatory force. In the erect position, the abdominal contents and the diaphragm shift downward, allowing functional residual capacity and total lung capacity to increase. When supine, the abdominal contents move cephalad, stretching the posterior portion of the diaphragm more cephalad. The resulting diaphragmatic contraction provides greater movement of the posterior portion of the diaphragm, with increased ventilation of the dependent portions of the lung. This aids in matching ventilation to perfusion because the dependent portions of the lung are also preferentially perfused. However, total lung capacity and functional residual capacity decrease in the supine position. In the anesthetized, mechanically ventilated, supine patient, the position of the diaphragm and its subsequent function change slightly. The diaphragm shifts still more cephalad, reducing functional residual capacity even more from the awake value. Intermittent positive-pressure ventilation (IPPV) does not restore the diaphragm to the awake position. Differential ventilation occurs within the lung during IPPV, and those areas that are gravitationally lower receive proportionately more ventilation. In the supine position, ventilation is more nearly uniform throughout, with a smaller gradient anterior to posterior. 4, 5

HORIZONTAL POSITIONS

The transition from supine to lateral to prone is a continuum, with various procedures placing the torso at all points of the circle. The usual and common supine position is generally considered to be safer than modifications. The most common serious positional injuries are peripheral nerve injuries.
Select an item below

* Supine
* Lateral
* Lateral Oblique
* Trendelenburg

Supine

The lithotomy position is most used in gynecologic and urologic surgery. The simultaneous elevation of the legs while the person is in the supine position provides the advantages of reducing torsion on the pelvis and lower back and promotes translocation of vascular volume centrally (Fig. 26–1). However, the areas that support the weight of the legs provide points of potential nerve and muscle injury. The goal is to suspend or support the legs so that they are flexed at the hips perpendicular to the torso and spread far enough apart to allow appropriate access to the abdomen (Fig. 26–2). Sometimes, less or more flexion is required (Figs. 26–3, 26–4). There are several devices to support the legs, the vertical bars being common to all of these. The support from the bar may be by built-in concave metal supports (seeFigs. 26–2, 26–3) or by straps (see Fig. 26–4 ; Fig. 26–5) Both of these positions usually require additional padding.

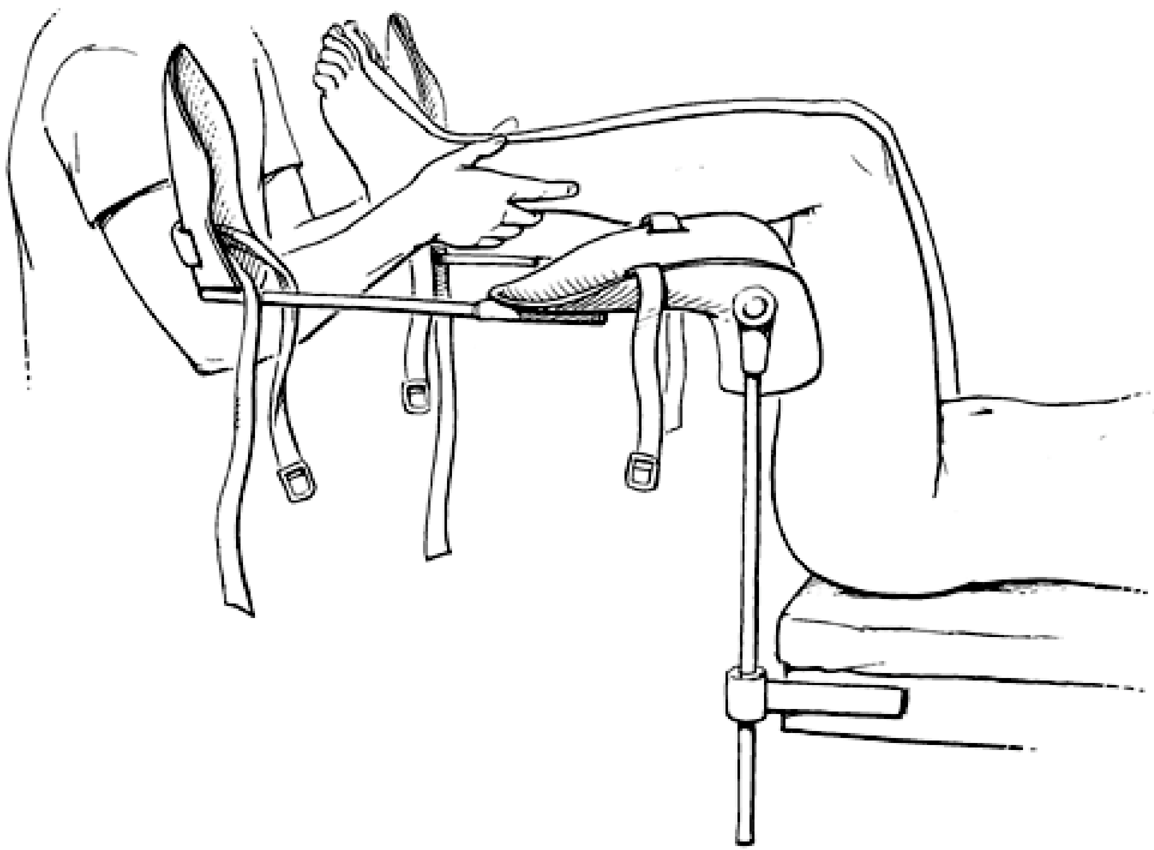

FIGURE 26–1 (A) Flexing, then raising of the legs for the lithotomy position. (B) Holding the legs and stirrups for final positioning. (Adapted from Goldstein55)

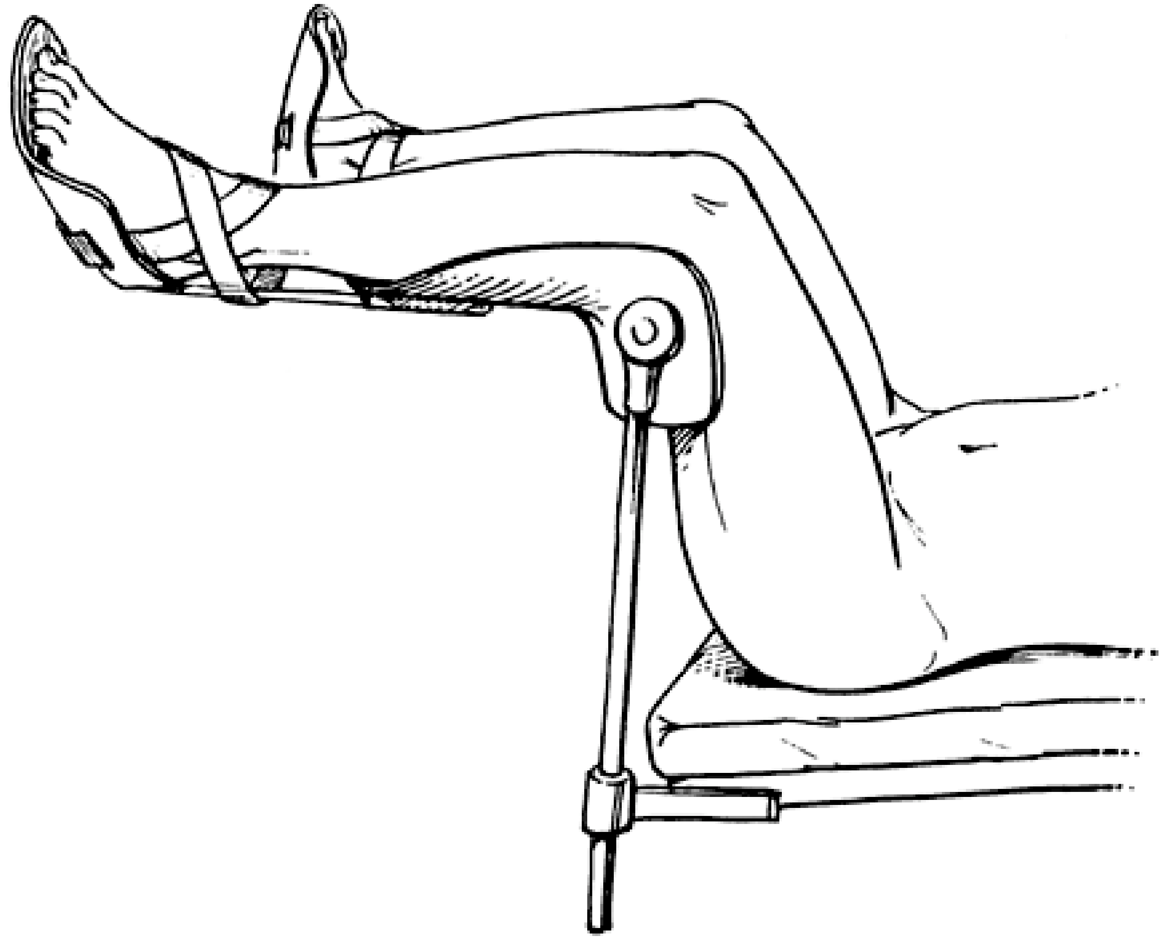

FIGURE 26–2 Final lithotomy position showing leg placement. See text for potential risks. (Adapted from Goldstein55)

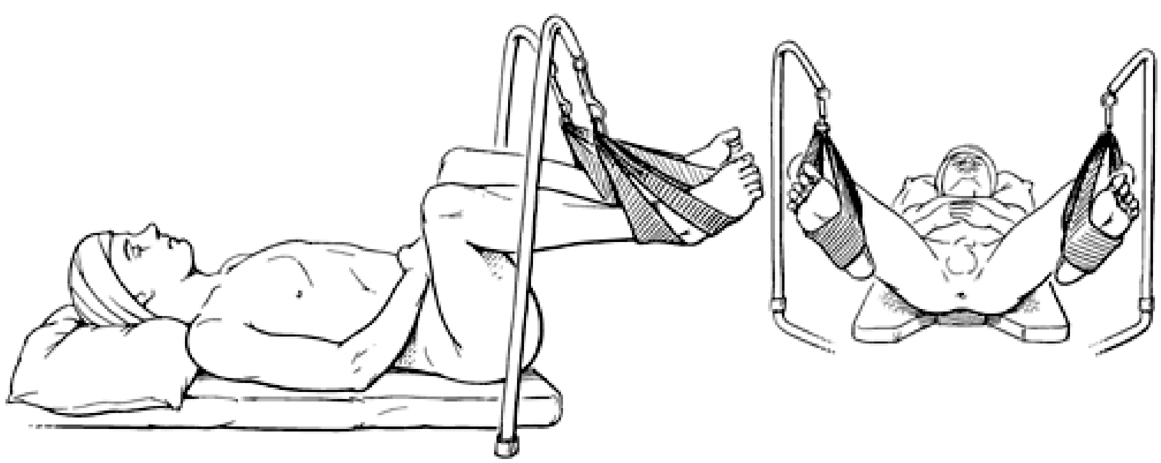

FIGURE 26–4 Lithotomy with hip flexion slightly greater than 90 degrees. Legs do not touch support poles (inset). (Adapted from Kropp56)

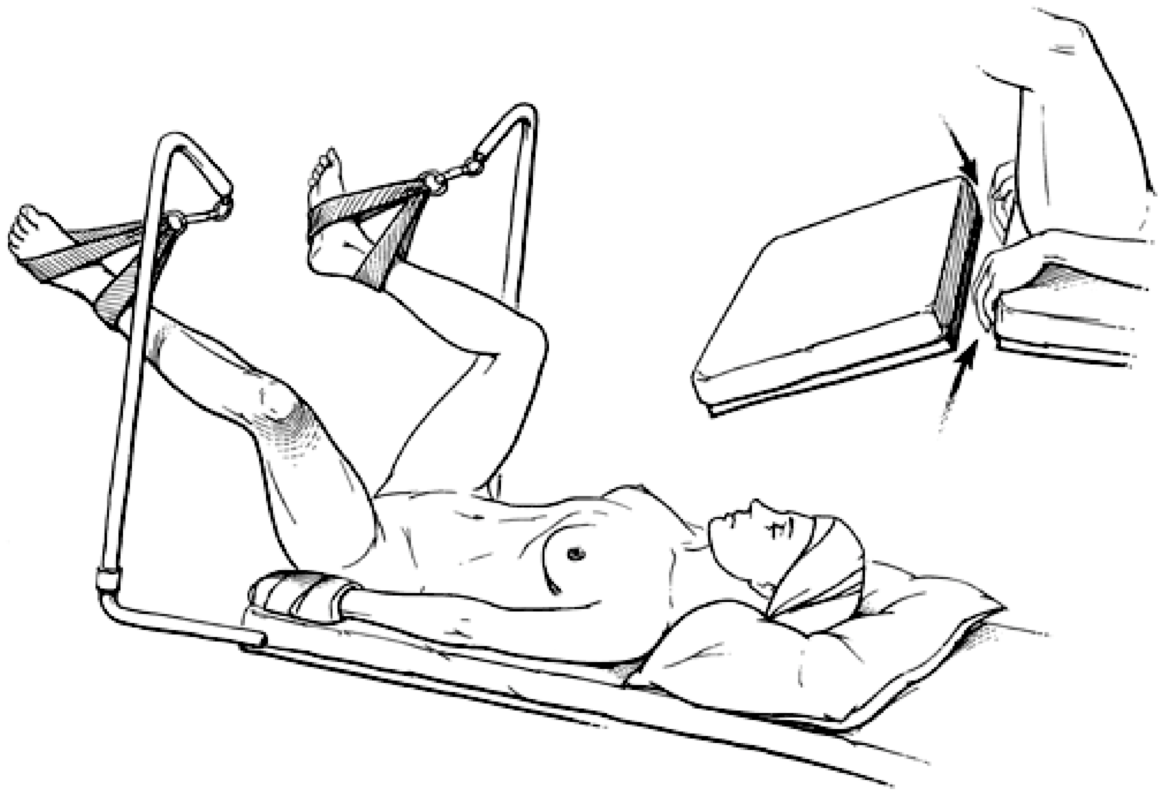

FIGURE 26–5 Lithotomy position with straps instead of stirrups for leg support. Inset shows the risk to fingers when the lower portion of the operating table is lowered. (Adapted from Welborn57)

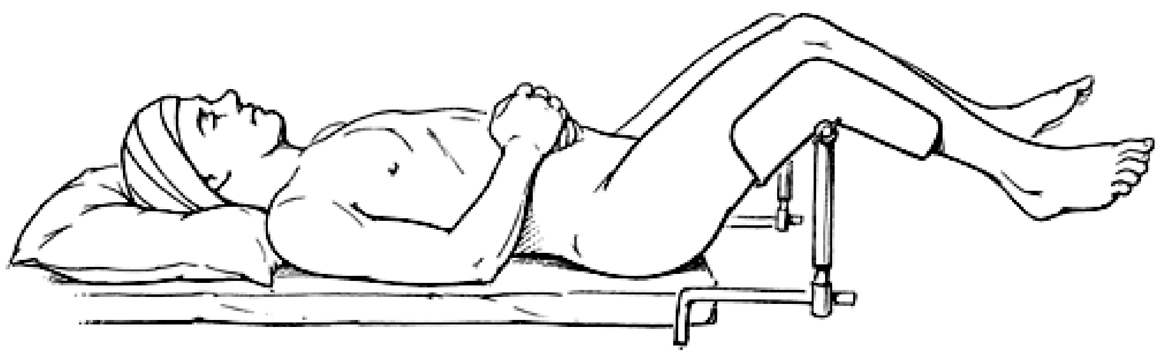

FIGURE 26–3 Lithotomy position with less hip flexion for endoscopic procedures such as transurethral resection of the prostate. (Adapted from Kropp56)

There is risk of injury to the peroneal nerve if it is compressed between the head of the fibula and the bar or the support structures. Pressure over the medial tibial condyle may result in saphenous nerve injury. There is no obvious sign that such compression is occurring, and it can apparently be prevented by proper padding of the leg. Femoral nerve injury is probably due to angulation of the thigh such that the inguinal ligament is stretched tightly and compresses the femoral nerve. Obturator nerve injury is also related to greater degrees of thigh flexion, perhaps by stretching the nerve as it exits the obturator foramen. Bilateral lower compartment syndrome can occur in the lithotomy position and is perhaps related to the duration of the case, the tightening of the leg straps, the dorsiflexion of the ankle, or the surgeon leaning on the suspended leg for long periods of time. 6, 7 The pathogenesis of the compartment syndrome probably involves direct local muscle pressure as the initiating event. 8, 9

A devastating injury in this position, which is fortunately uncommon, is hand and finger injury. As the foot of the bed is being rolled to a vertical position, care must be taken that the fingers are not caught in the gap and crushed (see Fig. 26–5). Compartment syndrome of the hand can occur if it is compressed between the buttocks and the operating table. 10 Extension of the arms perpendicular to the body prevents such an occurrence but introduces the possibility that the arms will be pushed too far cephalad. This stretches the brachial plexus and can result in nerve injury. The general practical rule is that the arms should be at an angle no greater than 90 degrees when extended on fixed arm boards. In the lithotomy position, pooling of the preparation solution at the buttocks and lower back can result in a chemical burn; it is wise to remove all drapes in this area after preparation so that puddles of residual solution can be removed.

Lateral

As the torso is tilted slightly laterally, usually a pad is placed under the shoulder so that the head and neck can be turned without tension. Such turning of the shoulder area alone may place torque on the lower back. It may be useful to place a pad under the hip so that it can follow the tilt of the shoulder and prevent the torque on the spine. Extreme lateral neck flexion has been reported to cause transient Horner syndrome. 11

Thoracotomy patients are usually placed in the full lateral position. The arm is placed perpendicular to the torso, either on a pillow or on an overarm rest to support its weight (Fig. 26–6) ; the arm is usually taped in this position. Care must be taken that the tape does not impinge on the ulnar nerve at the elbow or on the radial nerve as it wraps around the radial groove in the upper third of the humerus. For some thoracotomy procedures, a higher chest exposure is needed, and the arm is placed above the shoulder plane. Special care must be taken to avoid plexus injury in these situations (Fig. 26–7). Tension on the brachial plexus can be reduced by bringing the arm into a more anterior plane with the body. The lower chest is generally supported with an axillary roll. This places the weight of the chest on the rib cage and prevents the shoulder and axilla from being compressed; such compression of the axilla can lead to brachial plexus injury in the down arm. Palpation of the arterial pulse in the down arm is sometimes used as a measure of the adequacy of decompression. However, because the axillary brachial plexus can be substantially compressed well before pulses are lost, this method is probably insufficient evidence of safety. If the peripheral arm pulse is absent, substantial compression must have already occurred, and the patient and roll should be repositioned.

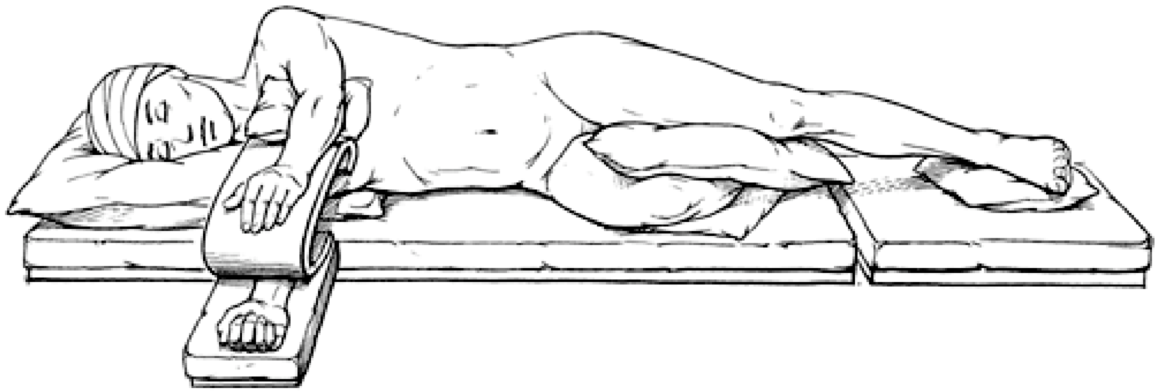

FIGURE 26–6 The lateral position showing upper arm rest in position; axillary roll, which supports the chest to free the axilla; and one type of leg positioning. (Adapted from Day58)

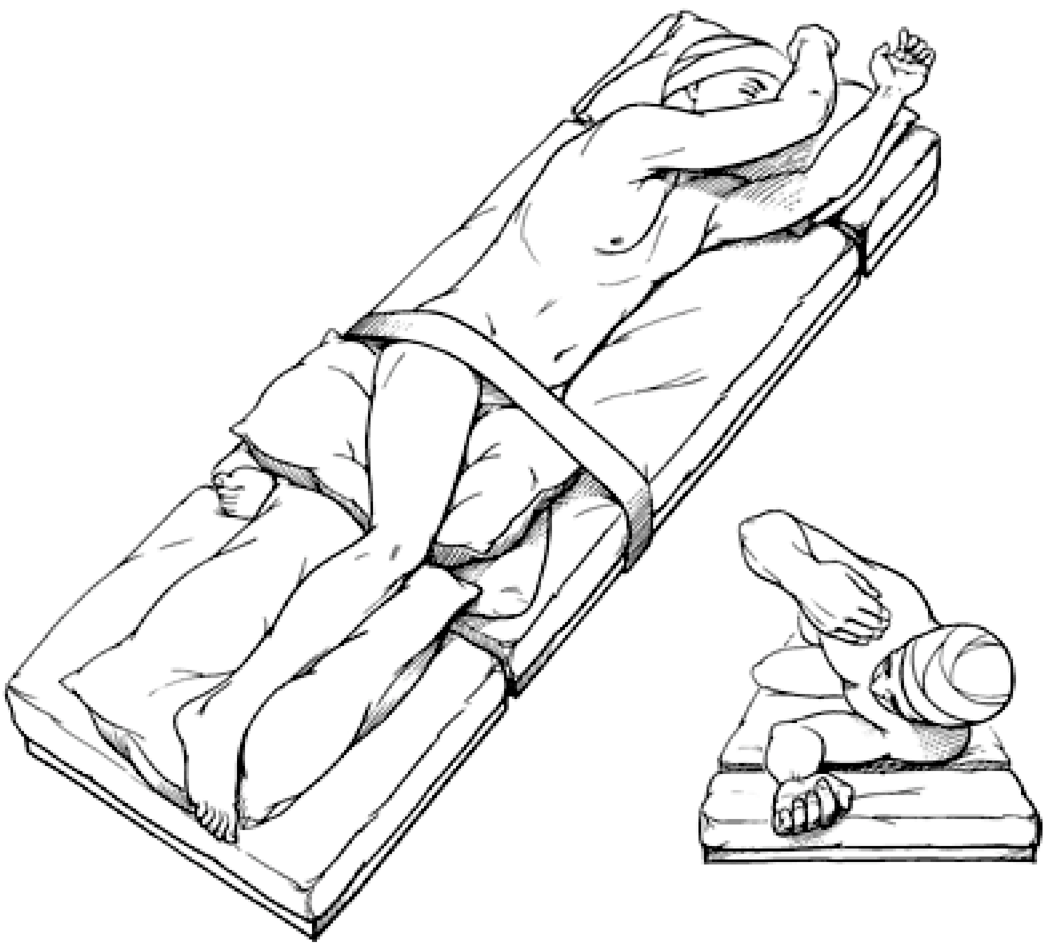

FIGURE 26–7 The lateral decubitus position for thoracotomy, showing a more headward position of the arms to facilitate surgical exposure. (Adapted from Lawson59)

Lateral Oblique

The lateral oblique (sometimes called the three-quarters prone) position is used primarily for exposure of the posterior fossa in neurosurgery but may be used for other procedures on the back and upper neck. In this position, the torso is rotated from supine to lateral (Fig. 26–8). 12 The upper leg is brought forward and flexed slightly, and the lower leg is left straight. The head-holder pins may be placed before or after the patient is turned. An axillary roll is placed under the chest to support the weight of the body and thus prevent the down axilla from being compressed. This is done at an angle, slightly higher posteriorly and slightly more caudad anteriorly. It should be possible to get part of a hand in the space between the chest wall and the axilla. The lower shoulder is brought to the forward edge of the bed or just slightly over it (Fig. 26–9). The patient is then rotated to three-quarters prone so that the lateral occipital skull is accessible to the surgeon or so that the patient is looking directly at the floor. The upper arm is placed downward near the side wherever it falls comfortably. The upper shoulder must not be so high that it interferes with surgical access.

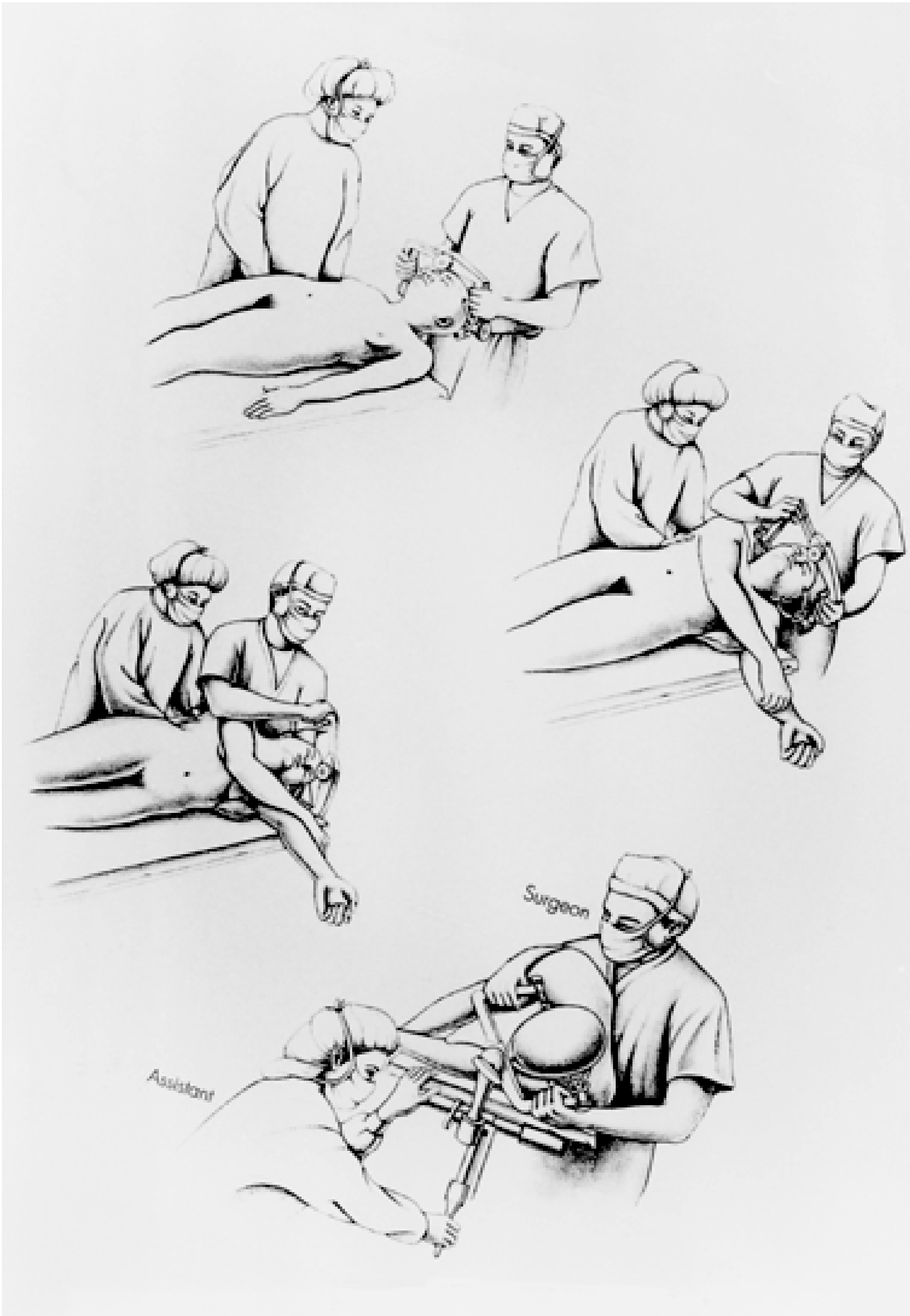

FIGURE 26–8 Movement of the patient from the supine to the lateral oblique position. (From Tew and Scodary12)

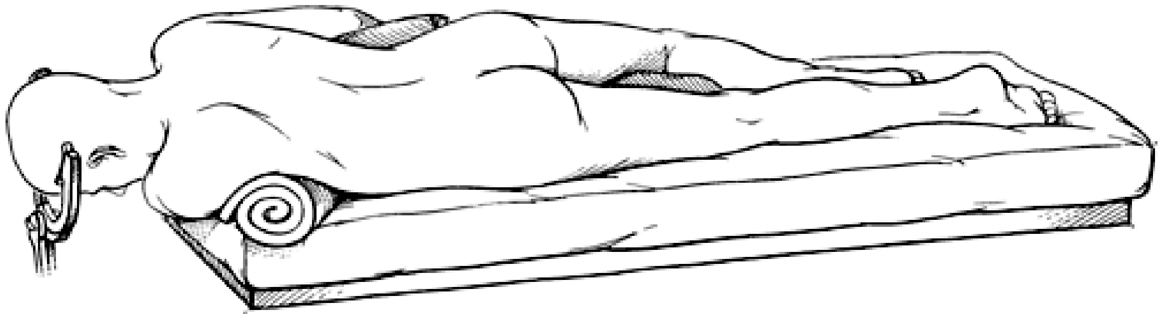

FIGURE 26–9 The lateral oblique (three-quarters prone) position. The axillary roll is placed under the chest, and the lower shoulder is brought forward to the edge of the bed or just slightly over the edge.

In obese patients, especially women, it may not be possible to fit the lower arm below the torso; it may have to be placed posteriorly and parallel to the torso. This position places considerable weight on the head of the humerus and acromion, and these areas should be padded carefully without excessive bulk. Attention must be paid to the lower breast to prevent pressure on the nipple and areola. Extreme flexion of the head might compromise cervical spinal cord perfusion; quadriplegia can occur in the prone position despite this precaution. 13

Monitoring such a patient requires special attention. The electrocardiograph (ECG) electrodes must not be placed in the dependent areas, where pressure necrosis can develop under the metal connections or wires. An arterial catheter is helpful in obtaining an accurate assessment of pressure. The incidence of Doppler-detected venous air embolism (VAE) during craniectomy in this position is about 10 percent. Consideration should be given to the use of the precordial Doppler and a central access line. However, positioning the precordial Doppler in this position is difficult and may not be effective for monitoring for VAE. Opinions vary regarding the value of an atrial catheter for air retrieval in this situation.

There are several difficulties in placing a patient in this position. Pressure on the dependent axilla and its contents and breast tissue are appropriate concerns, but there are no real guidelines for how much pressure is acceptable. The ability to place one‘s own hand into the axilla and feel for compression there is a good starting point, as is observation to be sure that the areola is free. Clinical experience must ultimately be the guide.

Trendelenburg

The Trendelenburg modification of the supine position places the head down, often with the knees flexed, so that the patient does not slide headward on the table. Shoulder braces may be used to restrict patient movement, but the weight of the torso can put considerable tension and stretch on the brachial plexus, with resultant injury.

The position moves the viscera cephalad and is used to improve exposure during lower abdominal surgery, to increase venous return after spinal anesthesia, or to increase central blood volume to facilitate jugular or subclavian cannulation, as well as to minimize aspiration during regurgitation by facilitating removal of material from the pharynx.

This position causes an increase in central venous pressure, intracranial and intraocular pressure, myocardial work, and pulmonary venous pressure and a decrease in pulmonary compliance and functional residual capacity. 14, 15 If longer operations are planned, we believe that endotracheal intubation is clearly indicated. There are no data demonstrating a higher incidence of unexpected neurologic events in patients placed in the steep Trendelenburg position for long operations, but there is one case report of a patient who had a cerebral hemorrhage during such a procedure and emerged with a significant neurologic deficit. 16 Clinical swelling of the face, eyelids and conjunctiva, and tongue has been observed, along with a plethoric color of venous stasis in the head and neck. Lingual and buccal nerve neuropathy can occur. 17 In patients with substantial swelling, it may be prudent to delay removal of the endotracheal tube until that situation has improved.

UNUSUAL POSITIONS

Positions for Orthopedic Surgery

Total hip arthroplasty, femoral neck fractures, and midfemur fractures for open reduction and internal fixation require different positions because of the need for surgical access and roentgenographic and fluoroscopic guidance(Figs. 26–10, 26–11) (Ch. 60) The lateral decubitus position is usually used for total hip arthroplasty. Patients having total hip arthroplasty often have concomitant degenerative cervical spine disease or at best some limitation of motion of the neck, which causes pain if exceeded. Careful alignment of the neck and head with the thoracic spine is usually not difficult. The down hip and leg are at risk during total hip arthroplasty in the lateral decubitus position. Rhabdomyolysis, much like that in a crush injury (five of the six patients reported were obese), 18 arterial insufficiency resulting in below-the-knee amputation, massive swelling of the thigh, and renal failure associated with myoglobinuria have been reported. Use of the pulse oximeter to detect excessive pressure on the femoral triangle has been suggested. 19

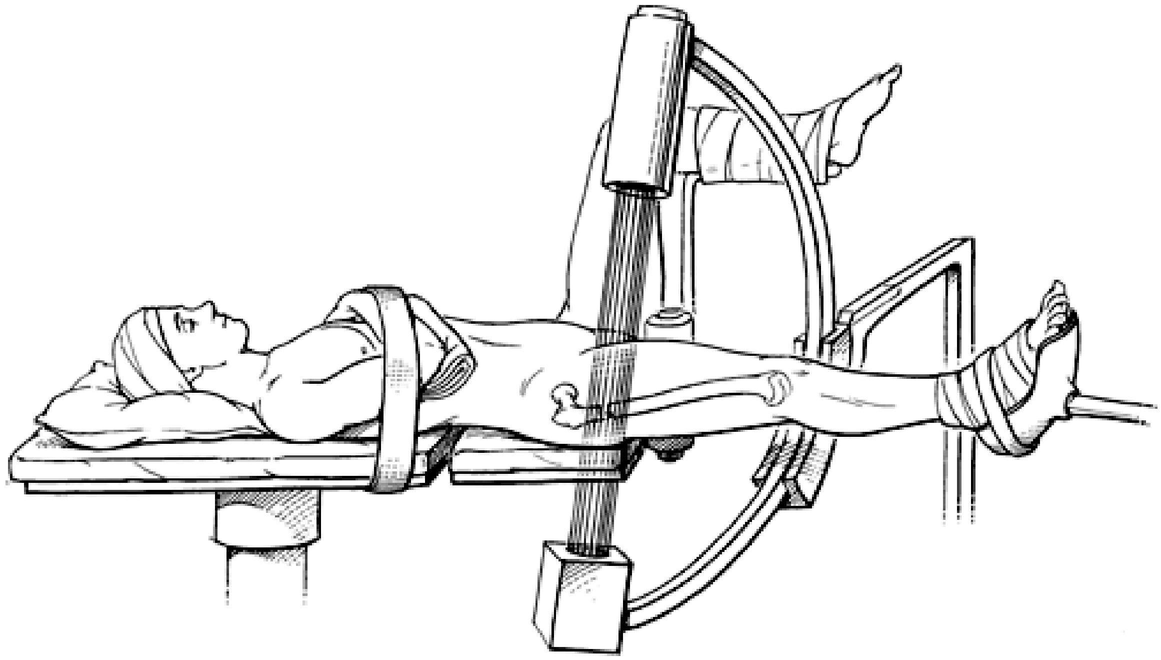

FIGURE 26–10 Femoral neck fractures can be managed in the supine position on the fracture table. (Adapted from Day58)

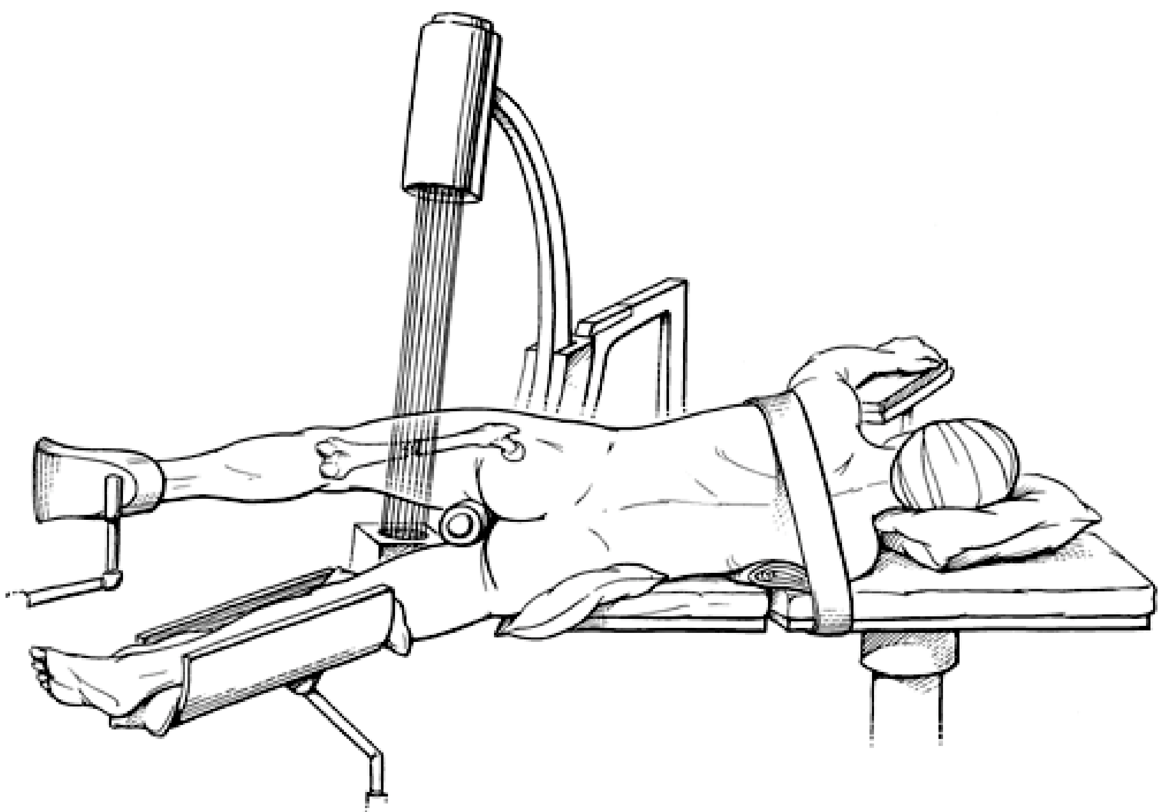

FIGURE 26–11 For midfemoral fractures, the patient is placed on the fracture table in the lateral position, with the legs spaced and positioned to allow roentgenography at an angle in several planes. (Adapted from Day58)

The orthopedic fracture table consists of a body section to support the head and thorax, a sacral plate for the pelvis with a perineal post, and adjustable foot plates. The most important features of the table are the ability to maintain traction on the extremity and to obtain surgical and fluoroscopic access. Because the patients requiring this table are often in pain, anesthesia is usually induced before the patient is moved to the table. If regional anesthesia is used, the fracture side should be placed up. Once the patient has been transferred, the arm on the fracture side should be placed so that it does not interfere with surgical access to the fracture; placing it across the chest directly or on an overarm board is effective.

Complications from this position include brachial plexus injury, lower-extremity compartment syndrome, and pudendal nerve injury related to the post. 20, 21

Position for Shoulder Surgery

The use of the “beach chair,” “barber‘s chair,” or semirecumbent position is increasing in popularity in parallel with surgical procedures on the shoulder. The key element of the position is that it provides both anterior and posterior access to the shoulder, with the upper extremity freely mobile. Extreme rotation of the head away from the operative side can result in stretching of the brachial plexus during surgical manipulation. Figure 26–12 shows one method of securing the endotracheal tube and head to prevent movement and accidental extubation. 22 Although the head is not elevated as much as is required for neurosurgical procedures, the surgical field is clearly higher than the heart. An impressive complication of shoulder arthroscopy is rapid, progressive, and complete airway obstruction, caused by extravasation of the fluid used during visualization out of the capsule and into the tissues of the neck. 23

FIGURE 26–12 Lateral view of upright shoulder position. The endotracheal tube and head are secured to prevent movement and accidental extubation.

SITTING POSITION

The sitting position is said to offer some surgical advantages (Table 26–1). Surgeons might weigh these advantages differently, but most would agree that ease of surgical exposure, amount of blood pooling in the operative field, and operative position of the surgeon are different among the sitting, lateral, supine, and prone positions. Some anesthesiologists believe that access to the endotracheal tube, reduction of facial swelling, and ability to observe facial nerve function are notable advantages of the sitting position in anesthetic management. One workable arrangement of equipment and operating table for procedures using the sitting position (and performed by a right-handed surgeon) is shown in Figure 26–13 . The two most common procedures performed in the sitting position are cervical laminectomy and posterior fossa exploration. Hazards to the patient undergoing posterior fossa craniectomy in the sitting position include VAE, hypotension, vital sign changes resulting from brain-stem manipulation, specific cranial nerve stimulation, airway obstruction, and position-related brain-stem ischemia. These are not unique to the sitting position and may occur in other positions as well.

Management should be directed at the prevention, early detection, and treatment of these problems.

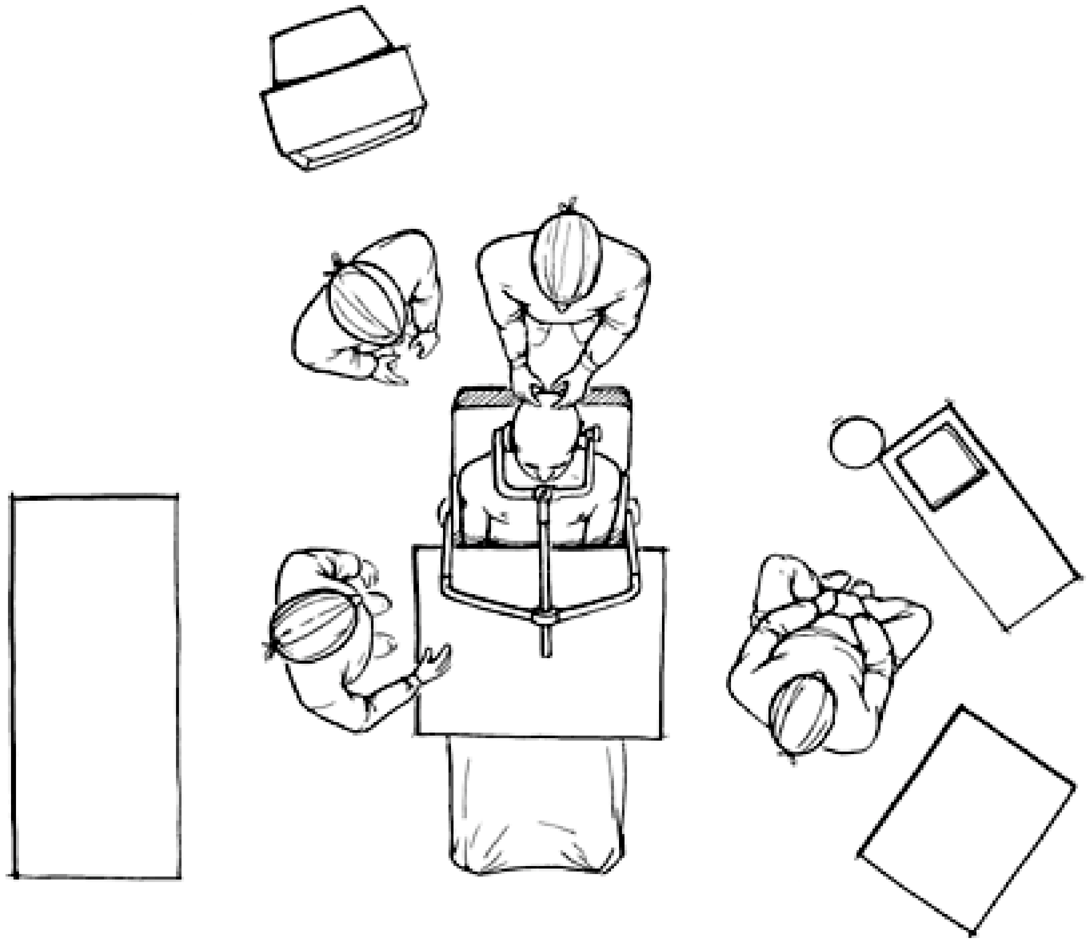

FIGURE 26–13 Arrangement for surgery in the sitting position. The scrub nurse is to the right of the surgeon to place instruments into the surgeon‘s right hand. The entire left side of the patient is available for the anesthesiologist‘s care.

There is much concern about the use of the sitting position, and some even suggest that it constitutes malpractice for today‘s surgery. These intimidating statements may have some basis in fact but in general do not consider the large body of information about the safety of the sitting position.

Safety

Several large published series show a remarkably similar and favorable safety record for operations using the sitting position. 24, 25, 26, 27 The sitting position is being used less, and more posterior fossa procedures are being performed in horizontal positions. The sitting position is becoming a conscious selection rather than an automatic response for any posterior fossa lesion. There are risks and benefits for each position, and these must be weighed in the overall care of the patient.

A study by Black et al 24 put the problem into perspective, and its results are consistent with those of other studies. These authors retrospectively reviewed 579 posterior fossa craniectomies (333 sitting and 246 horizontal) performed concurrently from 1981 through 1984. It is the only study in the literature comparing the sitting and horizontal positions; no prospective randomized comparative study has been performed to date. Intraoperatively, the incidence of hypotension did not differ between the two groups either from induction of anesthesia to incision or from incision to closure. About 20 percent of the patients in each group became hypotensive during each of these periods; all responded to vasopressors and/or fluids. The incidence of VAE in patients monitored by Doppler ultrasound was significantly greater in the sitting position (45%) than in the horizontal position (12%).

Another important difference between the two groups was the need for blood transfusion, confirming the traditional surgical impression that upright patients bleed less. More than 2 units of blood were required in 13 percent of the patients in the horizontal position and in only 3 percent of those in the sitting position. Average blood volume transfused was also lower for the patients in the sitting position.

After surgery, no differences were found in cardiac or respiratory complications. The perioperative myocardial infarction rate was less than 1 percent overall and was not different in the two groups. Respiratory complications were found in 2.5 percent of patients and did not differ between groups or in comparison with other studies. 26 Thus, the data do not support the general selection of either the sitting or the horizontal position based on outcome. There are certain risks and advantages to each, and selection of position should be made with these in mind as they relate to the specific patient.

There are some conditions that seem prudent to consider as relative contraindications to the sitting position (Table 26–2). However, there are few objective data to support our approach. If a shunt tube is in place from the cerebral ventricular system to the right atrium, air may enter the end of the shunt as cerebrospinal fluid drains out and may be pulled into the heart. The noncollapsible tubing acts as a noncollapsible vein and allows air to pass unimpeded into the heart. This is not a potential problem with a ventriculoperitoneal shunt, because the air would have no venous access. We recommend that a patient with a ventriculoatrial shunt in place have the shunt tied off before the patient undergoes an intracranial procedure in the sitting position. Some patients experience cerebral ischemia whenever they assume the upright position. Their cardiovascular and cerebrovascular systems may both be implicated in this situation. These patients may present for an extracranial-intracranial bypass for the posterior cerebral circulation; some surgeons believe that the sitting position gives the best exposure for this procedure. We cannot be sure that cerebral circulation will be maintained in the sitting position, because we must not only place the patient upright but must also provide an anesthetic. It seems a reasonable balance of risks and benefits to place such a patient in the horizontal position.

TABLE 26–2. Relative Contraindications to Operative Sitting Position

There has been a suggestion that if the left atrial pressure, as measured by pulmonary artery occlusion pressure, is less than the right atrial pressure in the sitting position, the patient should be placed horizontally because of an increased risk of paradoxical embolism. 28 This is based on two important assumptions: first, the left atrial pressure will be greater than the right atrial pressure in the horizontal position; second, the atrial pressure gradient and its direction constitute a prognostic indicator of whether VAE will become paradoxical air embolism (PAE). Some work suggests that these assumptions may not be applicable. In a pig model with an iatrogenic atrial septal defect, the atrial pressure gradient before air embolism was unrelated to the occurrence of PAE. 29 Thus, we believe that decisions regarding the use of the sitting position based on estimates of preoperative atrial pressure gradients are not well founded. Some patients demonstrate a potential right-to-left shunt before surgery. Platypnea-orthodeoxia is an unusual cardiovascular illness in which the atrial gradients apparently reverse when the upright position is assumed 30 ; patients with this condition are well oxygenated in the supine position but become desaturated in the upright position because of unsaturated blood passing from right to left at the atrial level. Other patients demonstrate a patent foramen ovale before surgery during a cardiac work-up, and still others may have a known right-to-left shunt. These patients might be at greater risk for PAE should VAE occur, and therefore it seems prudent to give these findings appropriate consideration before using the sitting position for such patients.

Some suggest that the sitting position should be avoided in patients with cardiac instability or at extremes of age because of a possible need to resuscitate intraoperatively. We believe that it is no easier to provide chest compression in the prone or lateral position than in the sitting position; all are equally undesirable. The rare need to resuscitate probably does not justify giving up whatever surgical advantage is thought to be gained by the use of the sitting position. Thus, in our opinion, these last considerations are not relative contraindications.

There are several details that should be considered when a patient is placed into a sitting or semirecumbent position (Fig. 26–14). Attention to detail in these matters probably only rarely prevents complications, but some of the complications can be major and are long remembered. Strict attention should be paid to the flexion of the head on the neck. We usually position the awake patient for up to 1 minute to see how much flexion can be tolerated, and that degree of flexion is not exceeded after the patient has been anesthetized. In general, we try to place two fingers between the chin and the sternum when positioning is complete as a possible way to prevent spinal cord ischemia with postoperative quadriparesis or quadriplegia. We have accepted one fingerbreadth, but only in selected circumstances. Although there is no study to show that this approach is effective, we have had no cases of quadriplegia attributable to cervical flexion in our practice.

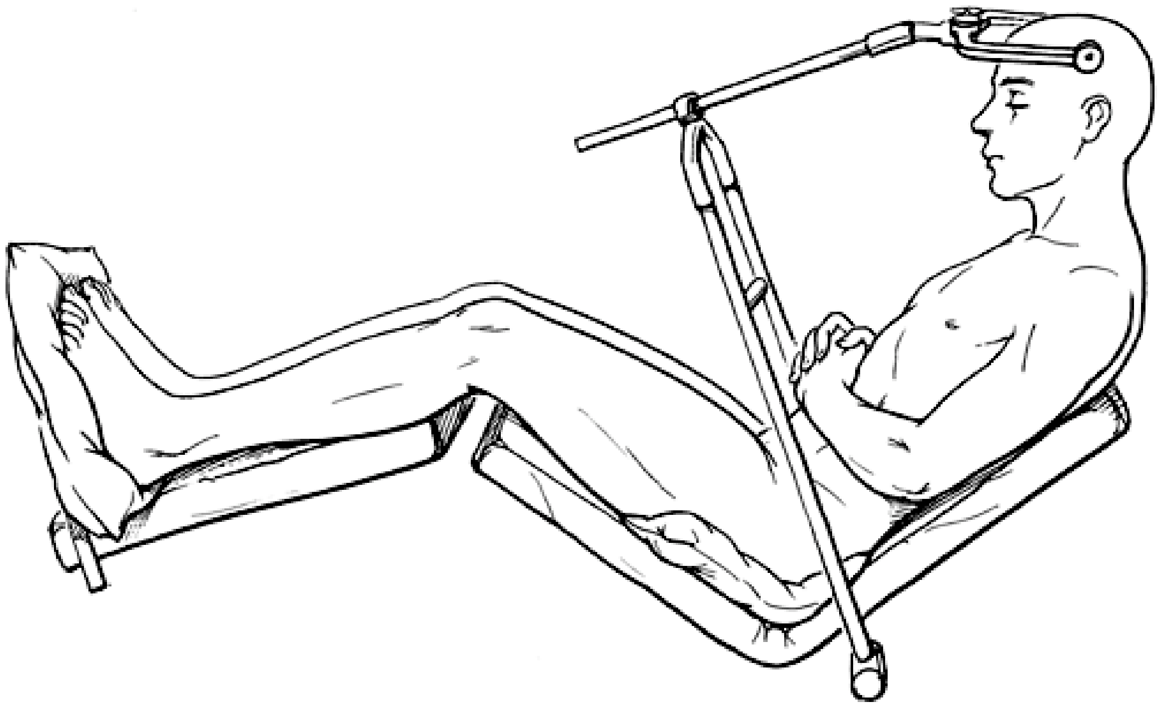

FIGURE 26–14 The patient is in a semisitting position with the knees flexed slightly. The headrest support is fastened to the upper part of the table so that the head can be lowered without changing the relationship of the pinion head holder to the torso. The arms must be supported (not shown) so that the weight of the arm does not stretch the brachial plexus. The buttock area is padded. (Adapted from Martin60)

In the sitting position, the arms tend to hang by the side. When muscle relaxants are used, the downward force caused by the weight of the arms is sufficient to stretch the brachial plexus and cause unilateral arm paralysis or weakness. This is not a theoretical consideration in our practice. This situation can be prevented by the placement of blankets under the elbow and forearm to support the weight of the arm so that there is no downward stretch on the arm, and the arm is actually pushed up slightly, giving the appearance of a slight shoulder shrug.

The hips are often flexed for two reasons: (1) this position tends to place the buttocks at an angle to support the weight of the body, and (2) it is thought to aid venous return. The legs must not be outstretched, however, because this places considerable tension on the sciatic nerve and can result in postoperative weakness. Bending the legs at the knees removes this tension, and placing an artificial fat pad under the buttocks to include the sciatic notch of the pelvis may reduce the chances of pressure ischemia of the nerve. Venous return may be aided and thromboembolism may be prevented by the use of elastic leg wrapping or alternating inflatable leg wraps (e.g., sequential TEDS).

Monitoring

The data from many studies indicate that the sitting position seems relatively safe, provided that adequate monitoring is used (Chs. 28 29 30 31 32 33 34 35 36 37to 38).

Central Nervous System

Central nervous system monitoring techniques for patients in the sitting position are directed not only at minimizing the hazards of the position but also at providing positive information to the surgeon, particularly during posterior fossa exploration. The same central nervous system monitoring is required for any infratentorial procedure, regardless of surgical position. The response of the vital signs to brain-stem manipulation and the response of the cranial nerves to stimulation can provide pathophysiologic data that the surgeon can use in real time during dissection (Table 26–3).

TABLE 26–3. Cranial Nerve Stimulation During Posterior Fossa Surgery

The ECG is an effective monitor of brain-stem compression. Spontaneous respiration has been advocated as a means of detecting transgression of the respiratory centers during posterior fossa exploration. However, a large series has indicated that monitoring the ECG provides adequate warning of brain-stem compromise during light anesthesia while mechanical ventilation is used to maintain reduced arterial carbon dioxide tension levels. 31 Brain-stem auditory evoked responses and somatosensory evoked potentials can provide an electrophysiologic monitor for early detection of brain-stem compromise. Stimulation of the seventh cranial nerve results in a facial twitch that is visible in the seated patient. Electromyography over the distribution of this nerve can aid in the detection of stimulation of the facial nerve if the face is not accessible to palpation or visual assessment. This is especially true in the prone patient because it is not appropriate to have the anesthesiologist under drapes with a flashlight looking for facial twitch. The observation period can be protracted and can result in failure to properly monitor other parameters of anesthesia response because of unavoidable diversion of field of view and attention.

Cerebral Perfusion Pressure

Blood pressure and pulse rate are measured to monitor several interrelated systems and factors. Some operations performed in the sitting position might result in sudden and extreme changes in pulse rate and blood pressure either because of the surgery or because of VAE. Intra-arterial blood pressure measurements yield instantaneous information, particularly with regard to cerebral perfusion pressure. They can be easily obtained when the strain gauge is zeroed to the base of the skull, which can be accomplished by use of the routine zero at the heart level with the patient supine and by placement of the strain gauge at the level of the external auditory meatus once the patient is placed in the sitting position.

Venous Air Embolism

Let us examine the most troublesome complications of the sitting position as well as those that are common but not very troublesome. The most feared complication of surgery in the sitting position is VAE with subsequent PAE to the brain. This complication not only places the patient at risk from the air itself but also can cause a surgeon who lacks confidence in the ability of the anesthesia team to take care of the problem to become distracted and concerned; this takes the focus away from the job at hand, namely performing the surgery. Thus, we believe that open communication between the anesthesiologist and the surgeon about air before and during the surgery improves the level of awareness and the confidence that the situation can be managed appropriately. That is not to say that disasters cannot happen even with the best of management; however, early detection of such problems usually prevents their progression to disastrous consequences. We also believe that it is an oversimplification to place all patients in the horizontal position because of the risk of air without regard for the increased surgical risk of compromised exposure in certain patients.

Monitoring for VAE can be approached from several aspects. Monitors include a precordial Doppler device, a right-sided heart catheter, a capnograph or mass spectrometer, an esophageal stethoscope, a transcutaneous oxygen monitor, and a transesophageal echocardiogram. The most sensitive of these methods are transesophageal echocardiography and Doppler ultrasound, followed by expired nitrogen fraction, end-tidal carbon dioxide, transcutaneous oxygen, right-sided heart catheterization, and, least sensitive, esophageal stethoscope measurements. None of these monitoring methods is totally reliable; we believe that it is generally necessary to use at least three of them to ensure that VAE can be detected (Fig. 26–15).

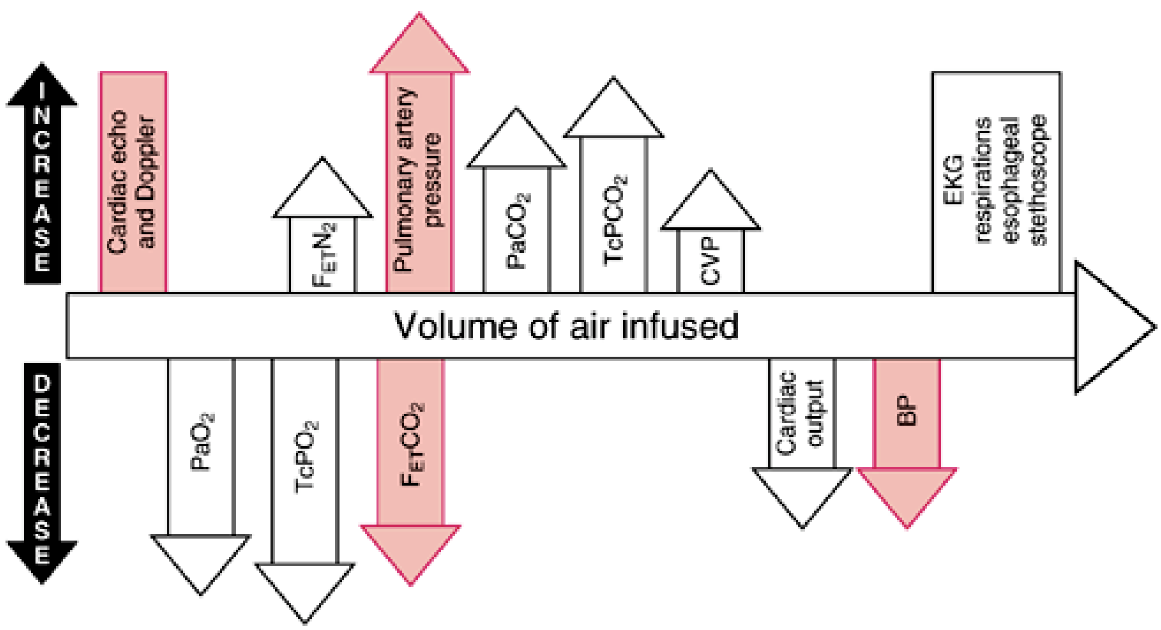

FIGURE 26–15 Changes in detection parameters for venous air embolism with increasing air volume. Data are aggregated from human and animal studies under a wide variety of circumstances. (Modified from Cucchiara et al61)

The risk of VAE is not eliminated by placing the patient horizontal, but it is reduced. A 12 percent incidence of Doppler-detected air occurs in supine infratentorial craniectomy cases. 24 Once VAE has occurred, about 20 percent of patients will have hypotension, regardless of their position. Except in the unusual situation of massive VAE, these episodes can be expected to respond promptly to vasopressor therapy.

The precordial Doppler device is advocated as the basic monitor for reducing complications caused by VAE. It is reasonably priced, relatively easy to use, noninvasive, and sensitive; its position over the right side of the heart can be verified by rapid injection of agitated saline into the central venous circulation, and its sounds can be heard by both surgeon and anesthesiologist. Its sensitivity has led some to criticize its use because it may indicate “insignificant air” before hemodynamic consequences ensue. Protagonists argue that such sensitivity is precisely the early warning needed to identify the occurrence of VAE and to stop its entry surgically to prevent further secondary complications.

The use of the right-sided heart catheter has evolved and has been improved to an extent such that air can frequently be aspirated when it is detected by Doppler monitoring. But what are the real functions of the right-sided heart catheter? 32 Rapid injection of agitated saline through the catheter can help to confirm that the Doppler probe is properly placed over the right side of the heart. The aspiration of air confirms or establishes the diagnosis of VAE. The role of the catheter in the treatment of VAE is more anecdotal and less solidly founded. The aspiration of air from the right atrium during VAE is occasionally life saving; this is limited to the rare situation of massive VAE. Whether routine aspiration of smaller or medium quantities of air from the heart can prevent PAE or cardiopulmonary complications is not known. Right atrial multiorifice catheters allow a larger amount of air to be aspirated than single-orifice catheters. Proper placement of the right atrial catheter high in the right atrium can increase its effectiveness because this is where the air tends to localize (Fig. 26–16). 33

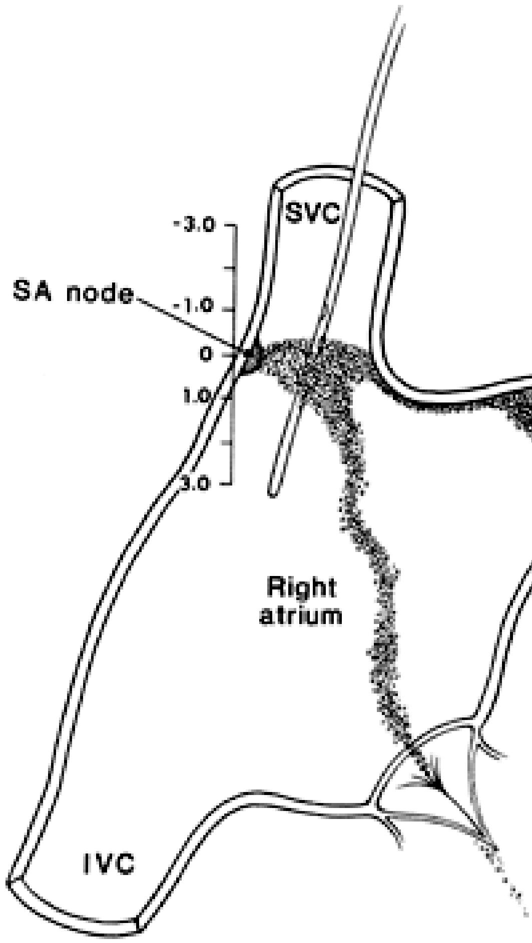

FIGURE 26–16 The air tends to localize at the atrial superior vena caval (SVC) junction, moving through the tricuspid valve or into upright portions of the atrium. The multiorifice catheter placement most likely to aspirate air is shown. The ECG tracing from the catheter in this position is described inFig. 30–17 . The conceptualization of localization of air embolism in the upright heart is based on a human cardiac model and human echocardiographic findings. (From Cucchiara et al61)

The right-sided heart catheter may be positioned by ECG control, roentgenography, or pressure recordings. It is likely that the ECG trace from a multiorifice catheter comes from the proximal hole, usually 2 cm from the tip. 34, 35 Thus, the tracing sought is slightly different with these catheters. The standard concept of a progressively more negative P wave as the catheter is advanced still applies, but the proximal orifice should be placed in the superior vena cava, allowing the portion of the catheter that has the holes to float at the superior vena cava/high right atrial level. The P wave should be large and negative, with no positive component (Fig. 26–17). This indicates that the proximal orifice is not in the atrium. In practice, one can usually obtain an increasingly negative P wave that finally develops a small positive deflection and then withdraw slightly to an all-negative P wave. Care must be taken when the arm is returned to the side because the catheter will likely migrate a little more centrally and may need to be withdrawn slightly. 36 Placement of the right atrial catheter through an arm vein by ECG control can be performed in 5 minutes or less in 53 percent of patients and in 15 minutes or less in 92 percent of patients. The overall success rate in several studies was greater than 90 percent. 37

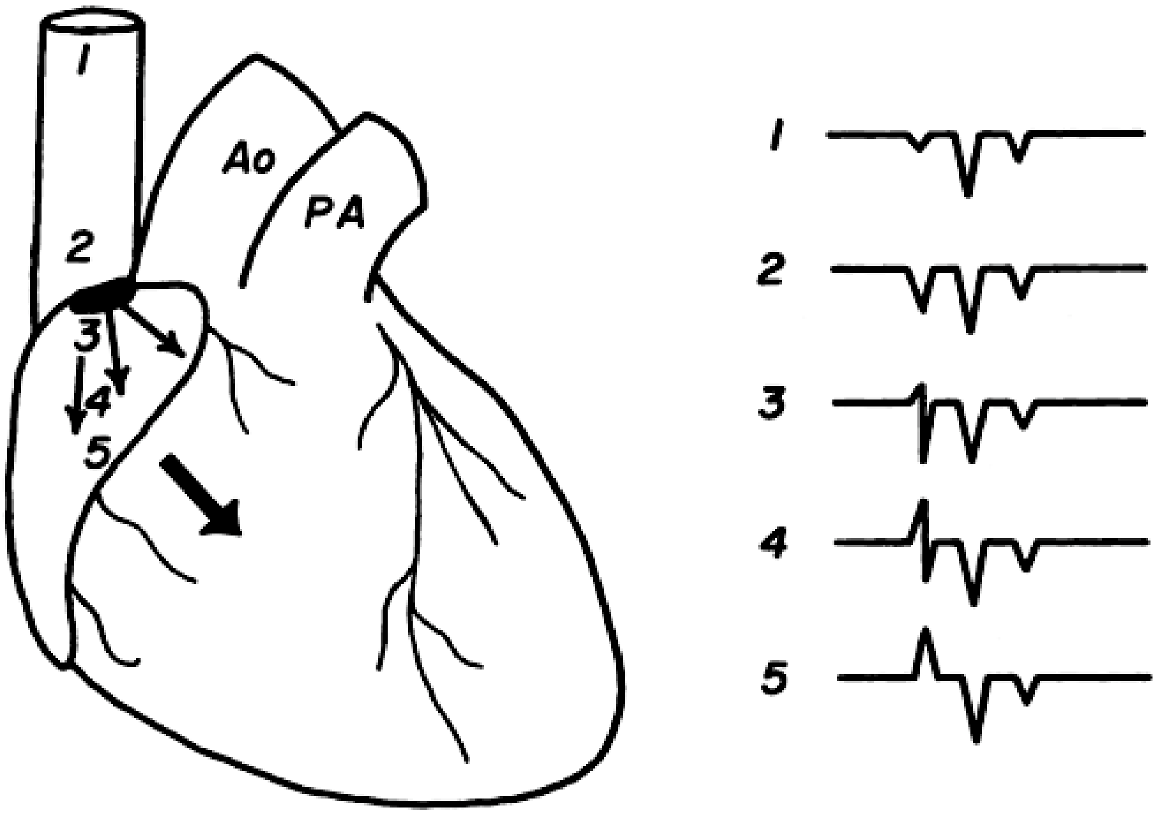

FIGURE 26–17 The intracardiac ECG for each position is shown. With a single-orifice catheter, tracing 4 indicates mid–right atrial position. Since the ECG trace originates from the proximal orifice of a multiorifice catheter and since placement as shown inFig. 30–15 is desirable, tracing 2 should be sought. (From Cucchiara et al 37)

The use of a pulmonary artery catheter for the aspiration of a VAE has generally been unsatisfactory because of the small lumen size and slow speed of blood return. However, other information can be obtained from the pulmonary artery catheter. The entry of air into the pulmonary circulation causes pulmonary artery pressures to rise. One can use this information to evaluate when the VAE has cleared the pulmonary circulation. If pulmonary artery pressure rises during the VAE and the Doppler recording clears, a return of pulmonary artery pressure to previous levels suggests that the air obstructing the pulmonary circulation has been moved more distally and has probably been excreted through the lungs. 38

Capnography and mass spectrometry demonstrate a decrease in end-tidal carbon dioxide during VAE with intermediate sensitivity. One can expect to see changes in end-tidal carbon dioxide after Doppler changes occur but before hemodynamic changes occur.

When enough air has been entrained to cause hemodynamic changes, the end-tidal carbon dioxide usually decreases within a few breaths after the Doppler change. Sensitive mass spectrometry can show increases in expired nitrogen fraction as the VAE is excreted through the lung. Transcutaneous oxygen tension monitoring is also intermediate in sensitivity but has more practical and technical problems, making its use in the operating room somewhat less popular. 39

Transesophageal echocardiography is still a research tool but holds considerable promise in the diagnosis of VAE. It is very sensitive and allows visualization of air in the cardiac chambers themselves, thus providing the unique opportunity to identify the occurrence of air in the left side of the heart 40 (Fig. 26–18). Transcranial Doppler monitoring may identify air in the arteries of the brain. The only other clinical way to identify PAE during surgery in the sitting position is for the surgeon to visualize air in the small arteries of the brain or spinal cord. This implies that it is already late because the air is already in the vessels to the brain in amounts large enough to be readily seen and is likely to cause focal cerebral ischemia.

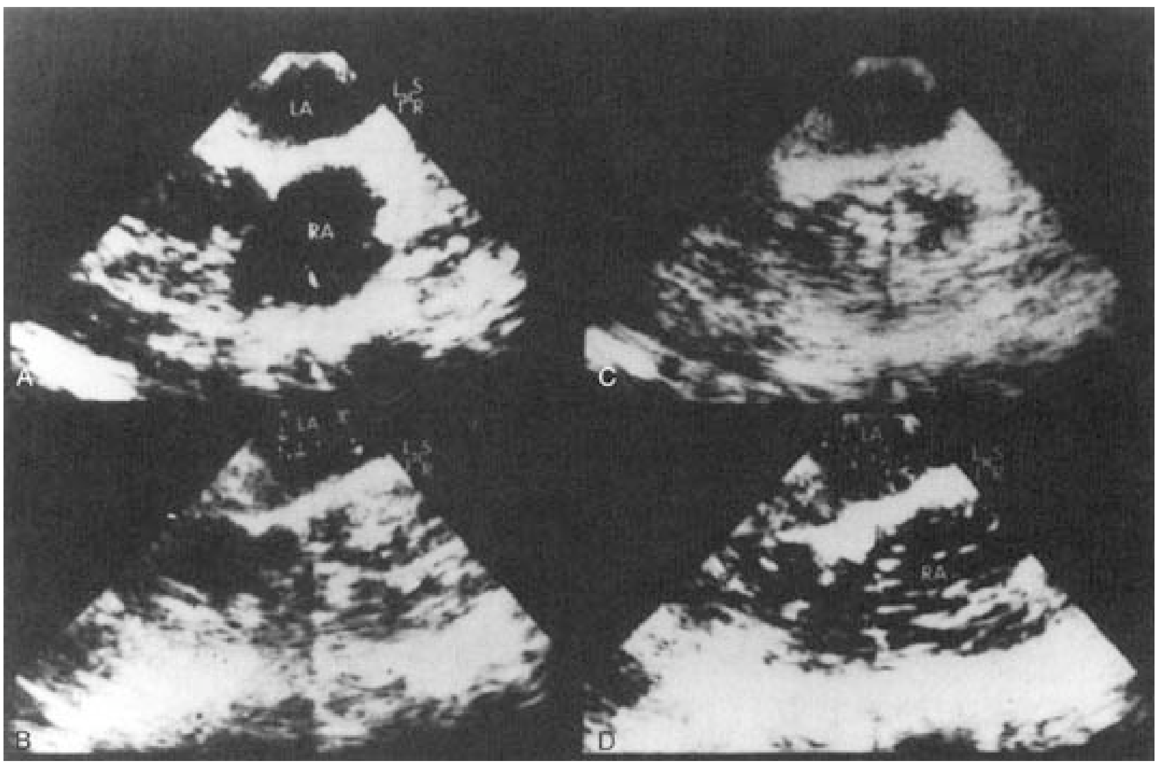

FIGURE 26–18 Paradoxical air as noted by transesophageal echocardiography. (A) Normal; (B) air in right atrium; (C) air in left atrium, right atrium nearly opacified; (D) more air in left and right atrium. (From Cucchiara et al40)

PERIPHERAL NERVE INJURY

Mechanism of Peripheral Nerve Injuries

In position-related nerve injuries, there are two basic forces that impair nerve function and, if severe or prolonged, impair axonal structure. Nerves that course superficially for long distances between two points of fixation are particularly vulnerable to stretch injury. Neural structures that are adjacent to or pass over bony surfaces in a small area are subject to compression between internal and ex-ternal structures, with resultant injury. The final result is likely the same—nerve ischemia resulting from reduction of blood flow through the intraneural vasa nervorum. The combination of stretch and ischemia makes the nerve more vulnerable to injury. 41 Compression injury usually occurs at a point along the nerve course; the smaller the contact point, the greater the focus of the force in compressing the nerve. Awake patients usually move when pain and paresthesia associated with nerve ischemia occur. Ischemia that persists for over 30 minutes can result in nerve palsy. 41

Intraoperative diagnosis of nerve impairment during general anesthesia is usually clinical. The distal pulse should be checked where nerves and blood vessels pass together. Pulse oximetry and capillary refill are measures of impaired blood flow. If there is sufficient external pressure on the axilla, for example, to decrease these parameters from prepositioning values, there is certainly enough pressure to reduce blood flow to the nerve through the small vessels supplying the adjacent nerves. Conversely, intact perfusion by these clinical measures does not guarantee normal nerve perfusion and function. Somatosensory evoked potentials from medial nerve stimulation can be lost despite preservation of peripheral pulse, capillary refill, and pulse oximetry saturation and plethysmography. 42

There are three types of nerve injury based on structure and function. Neurapraxic injury occurs with a loss of function (or occurrence of dysfunction) in the nerve without demonstrable anatomic injury. This is the type of injury related to positioning that is most likely to occur during anesthesia. Recovery is complete within 6 weeks, and no long-term treatment is indicated or needed. Axonotmesis occurs with anatomic disruption of the axon but preservation of the nerve sheath and connective tissue. The axon degenerates distal to the lesion and regenerates at a rate of about 1 mm/day. Function gradually returns, but in longer nerves, such as those of the upper extremity, this may take a year. Surgery is not usually indicated, but physical therapy is helpful to prevent degeneration of the joints and muscles and to reintroduce those structures to load bearing when they are reinnervated. Neurotmesis results in axon, sheath, and connective tissue disruption. This leads to degeneration of the axon distal to the injury, but regeneration usually does not occur. Neurosurgical, rehabilitation, and pain services intervention may be helpful in these types of injuries. 43

Ulnar Nerve Injury During Anesthesia

Although the true frequency of nerve injuries during anesthesia and surgery is not known, some pieces of information help to place the problem in perspective. A 1990 analysis of the American Society of Anesthesiologists Closed Claims Project database showed that 15 percent of the claims were for nerve injuries. Three distributions accounted for 73 percent of those cases: ulnar (34%), brachial plexus (23%), and lumbosacral nerve root

(16%). The mechanism of ulnar nerve injury during anesthesia is unclear. In most cases, the injury seems to have occurred despite all the precautions of padding and careful placement of the elbow to protect the nerve. Some have questioned whether the injury is even preventable. [44]

The so-called cubital tunnel external compression syndrome has been advanced as a possible mechanism for postoperative ulnar nerve injury. [44] The ulnar nerve passes through the cubital tunnel of the elbow as it courses to the forearm. The anatomic boundaries of the cubital tunnel are the floor (the medial ligament of the elbow) and the roof (the arcuate ligament, which extends from the medial epicondyle of the humerus to the medial aspect of the olecranon process of the ulna). The nerve lies superficially in the tunnel and thus is vulnerable to injury. Perhaps when the arm is fixed at the patient‘s side or to an abducted arm board with the forearm pronated, the cubital tunnel is placed in contact with the surface of the cushion, and the nerve is externally compressed within the tunnel. Supination of the forearm places the olecranon process of the ulna in contact with the flat surface and might reduce its vulnerability. Importantly, flexion of the elbow to more than 90 degrees tenses the arcuate ligament and reduces the volume of the tunnel containing the ulnar nerve, possibly compressing it. Although this is a theoretical consideration, there is no evidence that altering the position of the arms in the supine patient during anesthesia and surgery decreases the likelihood of ulnar nerve injury. Ulnar nerve injury is more common in men (5:1, male/female ratio), which suggests some anatomic predisposition of the tunnel [45] or hypermobility of the nerve. [46] Preexisting medical diseases, such as diabetes and vitamin deficiency, and chronic subclinical compression of the ulnar nerve at this level have also been implicated as possible causes of this postoperative complication. Warner et al [47] retrospectively reviewed the records of 1,129,692 consecutive procedures on patients undergoing diagnostic or noncardiac surgical procedures at the Mayo Clinic over a 35-year period. Persistent (>3 months) ulnar neuropathies occurred at a rate of 1:2,729 patients. Nine percent were bilateral, and most were not noted until at least 24 hours after the procedure.

A particularly high incidence of postoperative ulnar nerve palsy has been noted in patients having cardiac surgical sternal retraction (60%). [48, 49, 50] Intraoperative somatosensory evoked potentials have been shown to identify those patients in whom persistent peripheral nerve deficits have occurred. [51] The mechanism is again unclear, but wide retraction of the sternum and first rib fractures may play a role. Placement of the arms at the side or abducted 90 degrees on padded arm boards did not eliminate the problem of ulnar nerve injury. There is a separate clinical entity of chronic compression of the ulnar nerve by focal constriction under the aponeurosis connecting the heads of the flexor carpi ulnaris muscle (Fig. 26–19). [52, 53] Perhaps the effects of the blood pressure cuff, decreased neural vascular flow during cardiac bypass, and external pressure of positioning and/or central line placement produce additive effects on a more vulnerable nerve. [44] Evidence supports the conclusion that ulnar nerve palsy is not always a preventable complication despite the best efforts at careful positioning and padding.

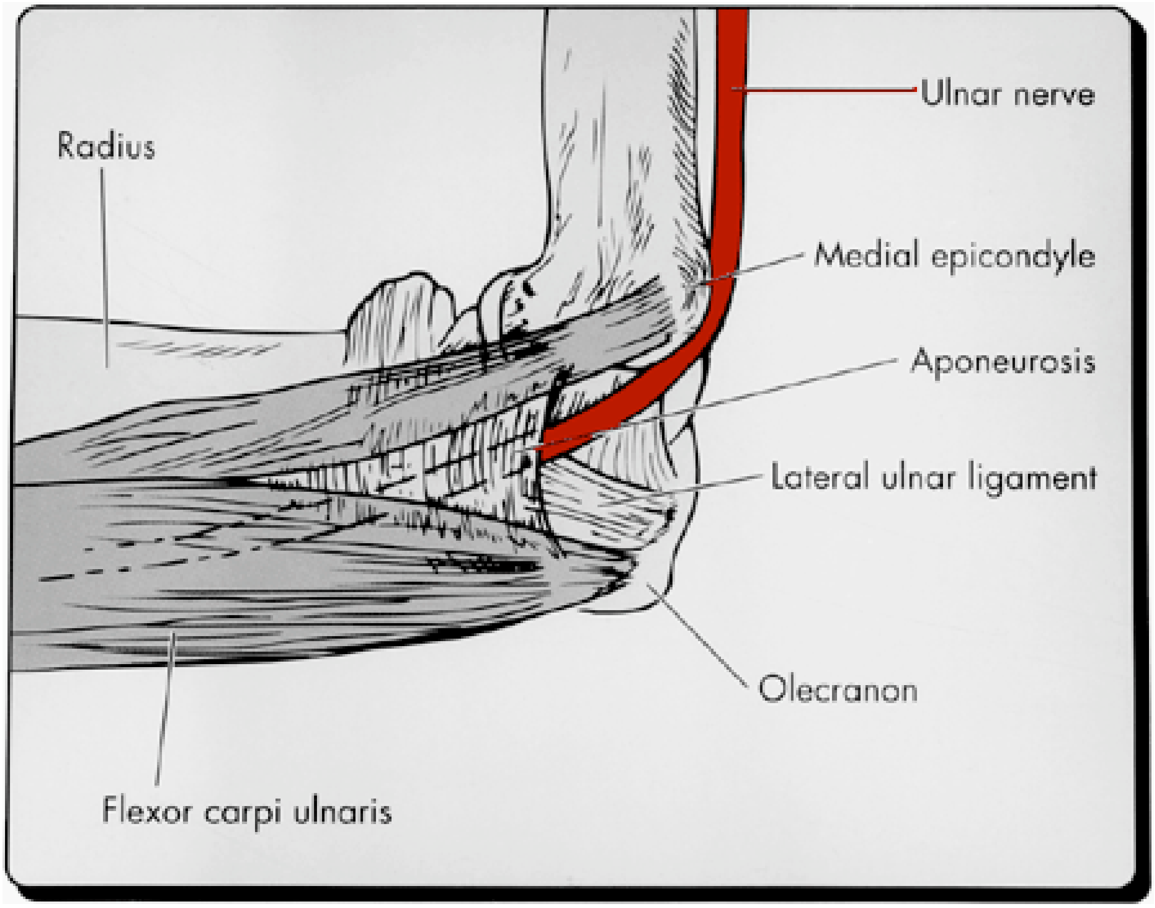

FIGURE 26–19 Anatomic compression of the ulnar nerve.

EYE INJURY

The frequency of eye injury during anesthesia and surgery is low. If the pressure on the eye exceeds venous pressure, the veins may collapse, arterial inflow may continue, and arterial hemorrhage may occur. If pressure on the eye exceeds arterial pressure, arterial inflow may be dramatically reduced, resulting in ischemia of the retina. The use of the horseshoe headrest (Fig. 26–20) carries the risk of such pressure injury to the eye because the head may shift during the procedure, even if the head is properly positioned at the beginning of the case. Corneal abrasion during neurosurgical procedures has been shown to be largely preventable by the application of eye tape but has not been shown to be influenced by the use of eye ointment. In patients undergoing lumbar laminectomy, the abrasions usually occur in the down eye. 54

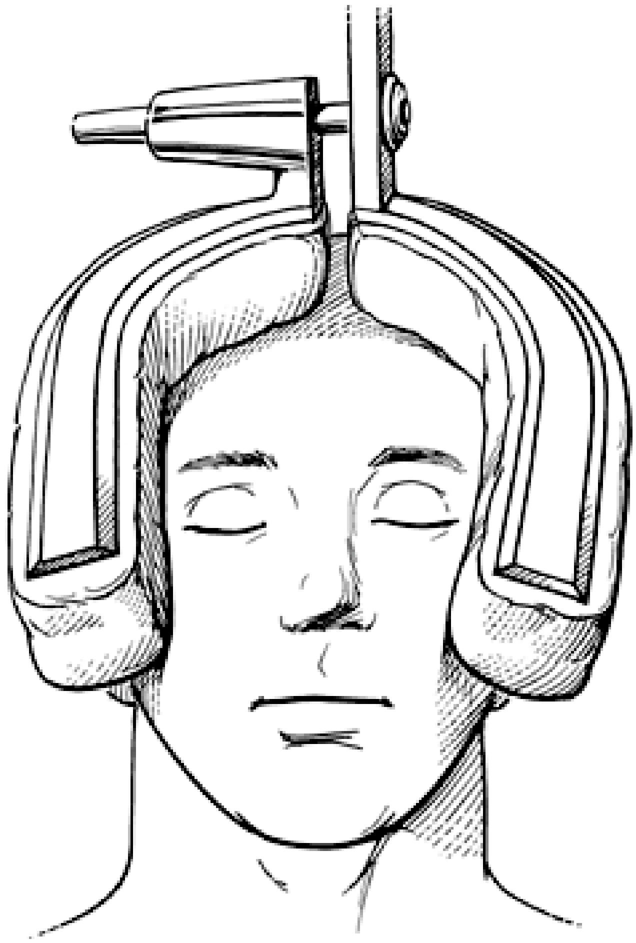

FIGURE 26–20 The head can slip while in the horseshoe headrest, and pressure may develop in the eye owing to the weight of the head. (Adapted from Reid and Grundy62)

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