Chapter 26
Positioning of Neurosurgical Patients

Hiroyuki Jimbo and Yukio Ikeda

Abstract In order to reach the lesions through the minimal invasive corridor, patients are sometimes immobilized in specific postures that seem nonphysiological during neurosurgical procedures. There is concern that these positions may result in peripheral neuropathy and formation of pressure ulcers. The limitations of movements in the diaphragm and rib cage may affect respiratory functions. It is not uncommon that the skull is placed in anteflexion or greatly rotated, thus causing inhibition of venous return and increased intracranial pressure. If the head position is elevated extremely high and the pressure in the venous sinus becomes negative, there is a risk of the development of an air embolism.

To avoid these problems, the checkup points and physiological effects in the basic positioning of neurosurgical procedures are mentioned in this chapter.

Keywords Positioning • Venous return • Intracranial pressure • Air embolism

26.1 Introduction

During neurosurgical procedures, the method of approach is selected so that it is minimally invasive to healthy brain tissue and by considering how to reach the intracranial lesions. As a result, patients are sometimes immobilized in specific postures that seem nonphysiological [1, 2]. Patients are often forced to maintain that posture for many hours. Even when there is excessive load or compression to a localized region, hyperextension of joints, or impairment of blood flow, patients under general anesthesia are unable to complain or change these positions, and therefore, there is concern that these positions may result in peripheral neuropathy or the formation of pressure ulcers. Some types of body postures may put limitations on movements of the diaphragm and the rib cage and may affect respiratory functions. It is not uncommon that the skull is placed in anteflexion or greatly rotated, thus causing inhibition of venous return and increased intracranial pressure.

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Various attentions are necessary to avoid these problems that are characteristic in neurosurgical procedures.

26.2 General Characteristics of Body Positioning During Neurosurgery

26.2.1 The Necessity of Stable Fixation of the Skull

During neurosurgical procedures, the skull needs to be fixed in a stable manner. The Sugita frame (Mizuho Ikakogyo Co., Ltd., Tokyo, Japan), which is a rotating device that provides fixation of the skull with four pins, the three-point Mayfield skull fixation device (Integra LifeSciences Corporation, Plainsboro, NJ, USA), and supporting devices provide stable fixation of the skull, and the surgical procedure can be performed safely and easily. Stable fixation of the skull is essential in stereotactic brain surgery. Loosening of the support device during surgery is extremely dangerous, and thus, there is a need for full verification. When there is no strict need for fixation of the skull, a doughnut-shaped round mat or a horseshoe-shaped head support is used. Tracheal tubes that are safe to manage intraoperatively are used, and their depth is reconfirmed and fixed after the body's posture has been fixed.

26.2.2 Measures Against Peripheral Neuropathies, Pressure Ulcers, and Deep Vein Thrombosis

Areas that are loaded with weight or compressed need to be checked. It is therefore important that weight load and pressure are distributed and reduced by applying buffering objects, such as pads or pillows, in order to avoid compressing areas that peripheral nerves pass through and to prevent hyperextension of nerves traveling through joints and blood flow deficits in the extremities. Once peripheral neuropathy occurs, it takes a few months to achieve recovery; in some cases, irreversible handicaps may persist thereafter. Particularly, when patient conditions are associated with systemic diseases, such as diabetes, renal disease, or diseases of the spinal column, such as spinal canal stenosis or thoracic outlet syndrome, there is a high probability of the development of neuropathies. For these reasons, preoperative checkups are required.

As a preventive measure against deep vein thrombosis, the patient wears elastic stockings and uses an intermittent pneumatic compression device.

26.2.3 Considerations for Venous Return

Under general anesthesia, sympathetic-mediated vasomotor activities are inhibited. If a muscle relaxant is used, the muscle pump cannot be expected to be active, and thus, venous return to the heart is impaired. Particularly in neurosurgical and brain surgical procedures, it is not uncommon that the skull is placed in anteflexion or greatly rotated, thus causing further inhibition of venous return and increased intracranial pressure. A slight elevation of the skull at angles of 15–20° promotes venous return and reduces bleeding of venous origin in the operative field. However, caution is needed. If the head is elevated too high, the venous pressure becomes negative, and, as a result, air is likely to flow into the sinuses and veins and cause air embolisms.

26.3 Basic Positioning During Neurosurgical Procedures

26.3.1 Supine Position

26.3.1.1 Indications

The use of the supine position makes it possible to handle intracranial lesions, such as those in the frontal region, temporal region, anterior half of the parietal region, lateral ventricle, third ventricle, anterior part of the base of the skull, interior part of the base of the skull, and upper part of the posterior fossa, as well as pituitary lesions, lesions in the cervical spine, and carotid artery lesions.

26.3.1.2 Setting of the Body Posture

In the supine position, complications are less frequent than those found in other positions; however, caution is needed to avoid compression of the eyeballs or the supraorbital nerve by anesthesia masks or endotracheal tubes. In the supine position, the sites that are likely to be compressed and to develop pressure ulcers include the occipital region, sacral region, and heels. In addition, the use of a horseshoe or a round mat for long hours is likely to cause hair loss [3]; thus, fixation with pins is preferable in case the surgery lasts long hours. The upper extremities are placed in supination to prevent ulnar nerve paralysis, which is caused by compression of the elbow by the operating table. In addition, there is a need to consider the possibility of radial nerve palsy due to compression on the external side of the upper arm or brachial plexus palsy due to rotation of the head or hyperextension of the neck. When the head is rotated, excessive force should not be applied to the endotracheal tube. Particularly in obese patients, impairments in venous return due to torsion of the neck should be prevented with a suitable shoulder pillow. In the anteflexion

posture, caution should be used because of the possibility of one-lung ventilation due to bending or pushing of the endotracheal tube, and, inversely, in the retroflexion posture, one should be careful that the tube does not fall out.

26.3.1.3 Physiological Effects

The ventilatory volume is thought to decrease by about 10 % in the supine position. However, under general anesthesia, this has virtually no clinical impact. A slight elevation of the head promotes venous return and may potentially reduce venous hemorrhages. This also reduces the load on the back. Conversely, placing the head in a low position may lead to the congestion of veins in the brain and an increase in intracranial pressure. During a parietal craniotomy with head rotation to the left or right, an excessive lordotic position may cause venostasis. Due to muscle tension, pain, and reflexes that are associated with specific receptors, a subject who is awake is protected from compression and hyperextension. However, their effects disappear when a muscle relaxant is administered after the induction of anesthesia. Therefore, caution is needed.

26.3.2 Prone Position

26.3.2.1 Indications

The prone position is used in surgeries involving the posterior half of the skull, as well as in spinal and vertebral surgeries requiring a posterior approach.

This is applicable to intracranial diseases that affect the parietal lobe, occipital lobe, posterior half of the corpus callosum, pineal region, cerebellum, cerebellopontine angle, fourth ventricle, brainstem, and craniocervical junction.

26.3.2.2 Setting of the Body Posture

Before surgery, patients need to be asked to adopt the body posture and head position that are expected to be used during surgery to check whether there are symptoms of compression of the brain stem or cervical spinal cord, such as numbness of the extremities or respiratory depression. This is particularly important in surgeries involving the craniocervical junction. In addition, a confirmation of the safe range of motion for the neck needs to be performed, and, if necessary, the subjects should be instructed to wear a cervical orthosis.

Anesthesia is induced on a transportation stretcher, an airway is secured, an indwelling balloon catheter is put in place, and the arterial pressure is visually monitored, after which the body's posture is changed. At the time when the body's posture is changed, the anesthesiologist should perform the removal and installment

of the monitor in the right order and should consider minimizing the time interval during which the patient is without monitoring. Careful caution must always be exercised in regard to the complications of the prone position, namely, ischemia of the retina and blindness that is associated with an increase in intraocular pressure. The optic papilla is anatomically poor in terms of autoregulation and development of collateral circulation [4]. Hypotension, anemia, and venostasis that occur during surgery facilitate the development of ocular compression-induced disorders [5]. Thus, during surgery, it should be confirmed that the eyeballs are not subjected to increased pressure after movements of the neck and head. Considerable caution is also needed with regard to other pressure points, namely, the chest, axillary regions, iliac crests, femurs, genitals, and knees. A pad or a thick pillow is deployed on the chest and pelvis, and mobility is given to the abdominal wall to facilitate respiratory movements. The neck is placed in anteflexion, a pad is deployed underneath, the patient is placed in a reverse Trendelenburg position, the knees are bent, a pillow is placed at the ankle joint, and the lower thigh is lifted up (Fig. 26.1a, b).

In surgical procedures that involve the posterior part of the skull, the head must be placed at a higher elevation than the heart to maintain low intracranial venous pressure [6]. The backplate of the bed is tilted to ensure that the upper body is elevated by 10–30°. If the neck is fixed in further anteflexion to improve the visibility of the surgical field, the head will be in a lower position, and the upper body will need to be lifted up even further (Fig. 26.1c). However, if the angle

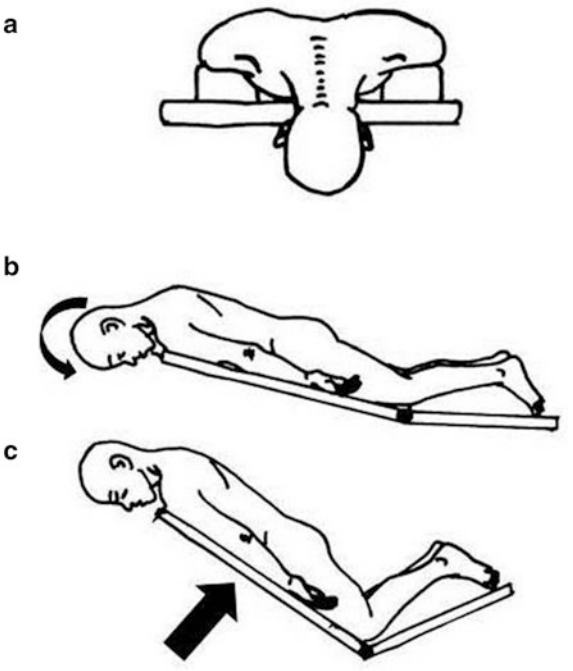

Fig. 26.1 (**a**) The schema showing a basic prone position in which the neck is placed in anteflexion. (**b**) The schema showing a basic prone position in which a pad is deployed underneath, the patient is placed in a reverse Trendelenburg position, the knees are bent, a pillow is placed at the ankle joint, and the lower thigh is lifted up. (**c**) If the neck is fixed in further anteflexion, the upper body needs to be lifted up

reaches 45° or more, there is a risk of the development of an air embolism. In addition, stronger anteflexion may cause a narrowing of the anteroposterior diameter of the hypopharynx, and, in surgical procedures that last long hours, caution is needed because ischemia may occur in association with compression of the tongue base by foreign objects, such as the endotracheal tube. Macroglossia due to reperfusion edema may occur after extubation, and it may rapidly cause airway obstruction [7].

In surgical procedures that involve the chest or lumbar spine, compression of the inferior vena cava needs to be reduced. Pressure in the epidural venous plexus may increase because of impairments of the venous backflow in the inferior vena cava. This may increase the amount of bleeding from a laminectomy. Therefore, during spinal surgery, spinal surgery frames such as the Relton-Hall type, Wilson type, and Andrews' improved type are effective in preventing compression of the inferior vena cava by managing abdominal pressure.

26.3.2.3 Physiological Effects

The decrease in ventilation volume is about 10 %. Unless suitable assistive devices are used, severe restrictive ventilator impairments may occur. In other words, there is restriction of the movements of the diaphragm due to the compression of internal abdominal organs, as well as a limitation of breathing movements due to anterior compression of the chest and abdomen. This results in the development of hypoventilation and hypoxemia due to a decrease in lung-thorax compliance. The decrease in ventilator volume can be maintained at about 10 % by reducing compression of the chest and abdomen through the use of rolls, spinal surgery frames, and direction indicators. In the circulatory system, a decrease in blood pressure and a decrease in venous pressure may develop as a result of a decrease in venous return due to compression of the femoral vein and abdominal vena cava.

26.3.3 Lateral Position

26.3.3.1 Indications

Compared with the prone and supine positions, the lateral position is more complex, includes many variations, and is often associated with positioning-related complications. The lateral position is used in surgical procedures, such as various approaches that use a temporal craniotomy (skull base surgery, including the infratemporal fossa approach, anterior transpetrosal approach, presigmoid transpetrosal approach, translabyrinthine approach, and transjugular approach) and in lateral approaches to the cervical spine, posterior cranial fossa, and cerebellopontine angle lesions that use the lateral suboccipital approach, as well as the transthoracic/retroperitoneal approach to the thoracic and lumbar spine.

Variants of the lateral position include the park-bench position [8], lateral oblique position [9], three-quarter prone position [10], and Janetta position (semilateral position) which is used in the treatment of trigeminal neuralgia and hemifacial spasm.

26.3.3.2 Setting of the Body Posture

A pillow is placed under the axillary cavity to reduce the load of the body weight on the shoulder on the lower side of the body and to prevent impairments of blood circulation in the lower extremities. The lower limb on the lower side of the body is placed in flexion, the other lower limb on the upper side of the body is placed in extension, and a pad is placed between the two lower limbs. A chest-and-waist support is used for the immobilization of the patient's body. On the ventral side, support is applied to the pubic bone and sternum. On the dorsal side, support is applied to the thoracic spine, pelvis, and buttocks. In the park-bench position, the lower limb on the lower side of the body is fixed with an arm rest that is placed between the operating table and the craniostat (Fig. 26.2). Measures are taken to prevent the shoulder joint on the lower side of the body from going into abduction, and the elbow is placed in a slight flexion. In addition, venous return from the lower extremities, as well as intracranial venous return, can be maintained by raising the patient's upper body and by putting it in a jack-knife position, which means it is bent at the waist. If the upper body is elevated higher than 30° in the lateral position, the pressure in the venous sinus will become negative, and an air embolism may occur as a result [11].

When performing an approach to the cerebellopontine angle, the shoulder on the upper side of the body may interfere with the visibility of the tentorial notch, and therefore, it is pulled to the caudal side. Under such circumstances, caution is needed because the use of excessive force to pull on the shoulder joint may cause brachial plexus paralysis. In the same way as in the prone position, the face of a patient in the lateral position is often turned toward the floor, and the endotracheal tube may easily come out as a result of the gravity of the tube itself and saliva. Thus, fixation needs to be ensured. Head fixation with rotation and flexion of the neck is likely to be accompanied by an increase in the cuff pressure of the endotracheal tube, and the persistence of excessive cuff pressure may result in recurrent nerve paralysis due to the endotracheal tube.

26.3.3.3 Physiological Effects

In the lateral position, the decrease in ventilator volume is about 10 %. In the lung on the upper side of the body, the ventilation volume increases due to an increase in compliance, whereas in the lung on the lower side of the body it decreases as a result of a decrease in compliance. Meanwhile, due to the influence of gravity, pulmonary blood flow increases in the lung on the lower side of the body and

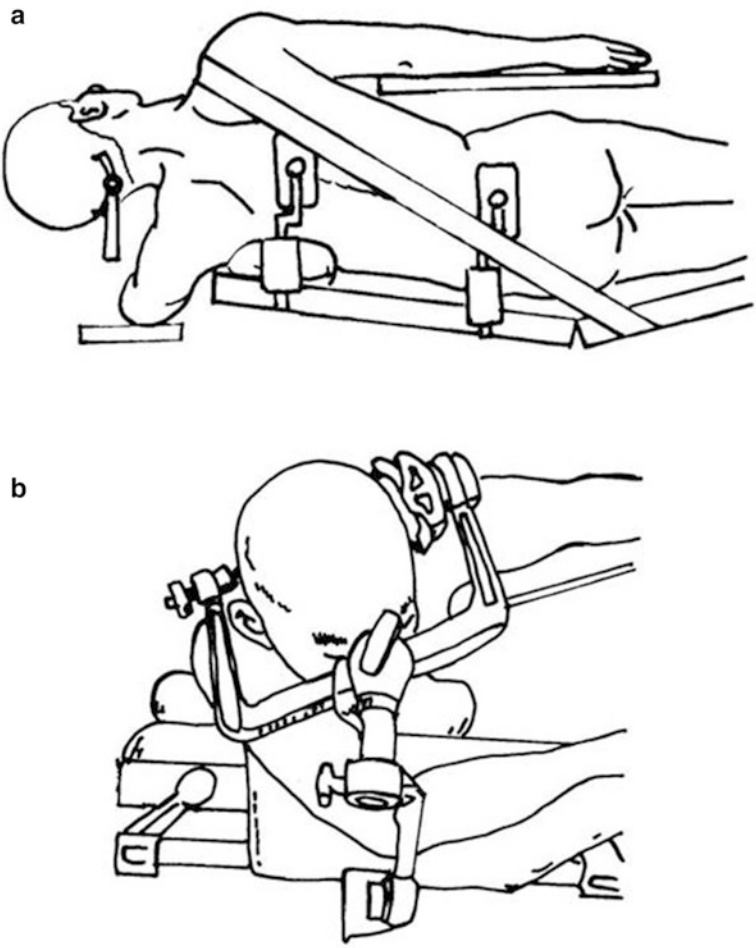

Fig. 26.2 (**a**) The schema showing a basic park-bench position in which the shoulder on the upper side of the body is pulled to the caudal side. (**b**) The schema showing a park-bench position in which the face of a patient is rotated to the floor, and the lower limb on the lower side of the body is fixed with an armrest that is placed between the operating table and the craniostat

decreases in the lung on the upper side. As a result, the dead-space effect increases in the lung on the upper side of the body, and a shunt-like effect increases in the lung on the lower side of the body. This is likely to cause an imbalance in the ventilation-perfusion ratio. A disorder that occurs in the lung on the lower side of the body facilitates the development of hypoxemia and hypercapnia. Setting the position of the body while monitoring percutaneous oxygen saturation (SpO_2) and end-tidal CO_2 ($ETCO_2$) has also been recommended [12]; however, partial pressure of carbon dioxide in arterial blood ($PaCO_2$) and $ETCO_2$ shows marked disparities in the lateral position.

26.3.4 Sitting Position

26.3.4.1 Indications

The sitting position is used in pineal tumor surgery, upper cervical spine surgery, and surgical procedures that involve the posterior cranial fossa (the floor of the fourth ventricle, the pontomedullary junction, and the cerebellar vermis). This position makes it easy to reach the midline region. However, it should be avoided in patients with low cardiac functional reserve, in postoperative patients who underwent ventriculoatrial shunt surgery, in patients with a defect in the atrioventricular septum, and in those who are likely to develop an air embolism. In addition, based on extensive experience in surgeries that have been conducted in the sitting position, the morbidity and mortality that are associated with the sitting position are said to be within an acceptable range [13–18]. However, the risks are considered to be higher if the procedures are performed by teams who have little opportunity to conduct surgeries under such conditions.

26.3.4.2 Setting of the Body Posture

In general, the half-seated position, which is closer to the resting posture, is used more often than the sitting position (Fig. 26.3). This is because this position allows for the fixation of the head at a lower position and for a reduction in the difference in the height between the surgical field and the heart. A three-point fixation of the head is performed in the supine position. The backplate is folded in such a way that the buttocks are placed low and the upper part of the body is raised up. The hands are placed on the abdomen and are fixed gently. A pillow is deployed under the knee, and the lower extremities are placed as high as possible in a horizontal position. To ensure that the procedure can be performed even when there is an urgent need for

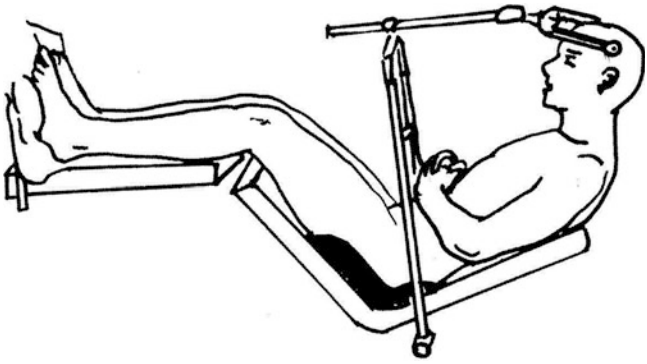

Fig. 26.3 The schema is showing the semi-sitting position which allows for the fixation of the head at a lower position and for a reduction of the difference in the height between the surgical field and the heart

the patient to be returned to the supine position, a U-shaped support head fixation device is fixed to the backplate to allow for the procedure to be performed immediately. The neck is positioned in slight anteflexion. A gap of about two fingerbreadths must be present between the sternum and the mandibular bone. For safety, in some cases, fixation of the body's position is conducted while monitoring the regional cerebral oxygen saturation (rSO_2) and somatosensory-evoked potentials [18]. When there is concern for hypotension, fluid is loaded by infusion, and the lower extremities are wrapped with elastic bandages beforehand. The use of G-suits for wrapping the lower extremities up to the pelvis, as well as the wearing of shock pants, should also be taken into consideration.

26.3.4.3 Physiological Effects

This may potentially promote venous return, decrease intracranial pressure, and reduce the amount of bleeding. At the time of the estimation of the cerebral perfusion pressure (CPP), the level of the external acoustic meatus is determined as a reference for the monitoring of the mean blood pressure and venous pressure in the surgical field. The CPP should be maintained at 60 mmHg or higher. Placing a patient in a sitting position while they are under anesthesia puts them at risk for developing a decrease in cardiovascular function and, particularly, hypotension. Vasopressors may also need to be administered in some cases. In a previous report, the mean arterial pressure was relatively unaffected, but the wedge pressure, stroke volume, and cardiac index decreased [19]. The absence of a change in mean arterial pressure, which is associated with a decrease in cardiac index, signifies an increase in systemic vascular resistance. In elderly people or patients with a history of valvular heart disease or coronary artery disease and those who are unable to tolerate an increase in vascular resistance, an indwelling pulmonary artery catheter should be put into place, and alternative body positions should be taken into consideration.

26.3.4.4 Complications Associated with the Sitting Position

An air embolism is the most feared potentially life-threatening complication of surgery in a sitting position. When dural venous sinuses in the posterior cranial fossa are left open after a surgical procedure that is performed in the sitting position, the fact that they adhere to the surrounding bones keeps them from collapsing even when the venous pressure becomes negative. As a result, leaving them open allows air to flow in. For the monitoring of venous pressure in the surgical field in the posterior cranial fossa, the catheter is inserted in a retrograde manner from the internal jugular vein or from a vein in the upper arm. Then, the catheter tip is pushed forward under fluoroscopic guidance up to the level of the external acoustic meatus. In the presence of a sudden decrease in SpO_2 or $ETCO_2$, an air/pulmonary embolism is suspected. Air inflow inside veins must be detected rapidly with cardiac

auscultation, Doppler ultrasound examinations of the chest wall, and transesophageal echocardiography. Monitors that are used for the detection of venous air embolisms should have high sensitivity, good specificity, and a hair trigger, allow for quantitative evaluations of venous air embolisms, and be indicative of the process of recovery from a venous air embolism. These requirements are met by $ETCO_2$ and chest wall ultrasonography/Doppler, which are currently the standard monitors. Transesophageal echocardiography is more sensitive than chest wall Doppler; however, its safety for long-term use has not yet been established. Once air flow is detected inside veins, the operator should be informed immediately, and the surgical field should be covered with gauze that has been soaked in physiological saline solution. The anesthesiologist should rotate the operating table toward the right and upward, stop the inhalation of nitrous oxide, and attempt to aspirate the air from the indwelling central venous catheter or pulmonary artery catheter that had initially been put in place.

Other complications of surgery in the sitting position include macroglossia, quadriplegia, pneumocephalus, and sciatic nerve paralysis. Macroglossia is due to an impairment of venous return, and it is caused by indwelling devices in the oral cavity or excessive anteflexion, like that found in the prone position. Transesophageal echography may also be listed among the causes. Quadriplegia is often due to impaired blood flow and spinal cord compression that is caused by latent spinal diseases. Caution is needed when there are indications of the presence of diseases of the cervical spine. Pneumocephalus may cause delayed awakening, and it should be prevented by filling the cavity with artificial cerebrospinal fluid or physiological saline solution after the suture of the dura mater has been completed. Sciatic nerve paralysis is particularly frequent in obese individuals, and therefore, caution is needed.

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