

REVIEW

Patient Positioning in Neurosurgery, Principles and Complications

Adrian Balasa^{1*}, Corina Ionela Hurghis², Flaviu Tamas², Rares Chinezu^{1,2}

1. George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, Romania

2. Neurosurgery Clinic, Emergency County Hospital, Targu Mures, Romania

Patient positioning is a crucial step in neurosurgical interventions. This is the responsibility of both the neurosurgeon and the anesthesiologist. Patient safety, surgeon's comfort, choosing an optimal trajectory to the lesion, reducing brain tension by facilitating venous drainage, using gravitation to maintain the lesion exposed and dynamic retraction represent general rules for correct positioning. All bony prominences must be protected by silicone padding. The head can be positioned using a horseshoe headrest or three pin skull clamp, following the general principles: avoiding elevating the head above heart more than 30 degrees, avoiding turning the head to one side more than 30 degrees and maintaining 2 to 3 finger breaths between chin and sternum. Serious complications can occur if the patient is not properly positioned so this is why great care must be paid during this step of the surgical act.

Keywords: positioning, complications, patient safety

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General principles

Correctly positioning the patient is a crucial step in neurosurgical procedures. This is the responsibility of both the neurosurgeon and the anesthesiologist. Patient safety is the most important factor, this is why when positioning the patient, blood pressure and pulse oximetry should be monitored and clamping chest tubes is not allowed [1] and also we must take into consideration surgeons comfort, especially for long interventions. A correct position should provide the optimal trajectory to the lesion and whenever possible we must use positions that maintain the lesion exposed via gravity and facilitate dynamic retraction; the use of spatulas and retractors should be avoided if possible. Another key factor when positioning the patient is ensuring that venous drainage is facilitated, this way avoiding brain tension.

In this paper we aim to assess the most important principles and risk factors associated to each of the six basic positions used in neurosurgical cranial interventions: supine, lateral ("park bench"), prone (three-quarter prone) and sitting positions.

Patient positioning always starts by positioning the body first. All bony prominences must be protected by silicone padding and the body must be secured to the operating table with special padded belts. When using a lateral position or "park bench" position, lateral supports must be used, this way permitting lateral tilting of the table with the patient secured.

The operating table must fulfill the following characteristics in order to properly position the patient: it has to be a table with at least 3 sections, it has to have sliding/tilting function, and it has to have range variability between the lowest and the highest position.

Head positioning and fixation

After securing the body, the head can be positioned. A general rule is to not elevate the head above the heart more than 30 degrees because this can lead to decreased cerebral perfusion pressure compromising cerebral blood flow. Every 2,5cm of head elevation above the heart decreases the mean arterial pressure by 2mmHg [2]. Another rule is that the distance between the chin and sternum shouldn't be less than 2 to 3 finger breaths, because hyperflexion can lead to cervical cord ischemia. The head shouldn't be turned more than 30 degrees to one side, especially when turning it towards the dominant jugular vein.

The head can be fixed using a three pin skull clamp (Mayfield fixator) or using a horseshoe headrest. When fixing the head with the three pin skull clamp, the imaginary line between the pins has to be under the equatorial line of the head; the pins must not interfere with the surgical field. Frontal sinuses, temporal squamous bone and venous sinuses must be avoided when inserting the pins. The risks associated to pin skull clamp fixation are bleeding, eye/scalp laceration and air embolism which can be prevented by using antibiotic ointment on the pins prior to insertion. El-Zenati et al. [3] reported one case of venous air embolism after removal of the Mayfield skull clamp to a 33 year male. The horseshoe headrest is used in trans-sphenoidal surgical approaches or for short time interventions. Long interventions can lead to pressure alopecia when using a horseshoe headrest [4].

Our experience shows that the Mayfield skull clamp is extremely versatile and use of the horseshoe headrest has limited use.

Supine position

Supine position can be used for approaching the frontal, temporal and parietal lobes, anterior, middle and even

* Correspondence to: Adrian Balasa
E-mail: adrian.balasa@yahoo.fr

the posterior cranial fossa, lateral and third ventricles and also the cervical spine for anterior approaches. The head shouldn't be rotated more than 30 degrees to one side. More rotation can be achieved by tilting the table or by using a roll under the ipsilateral shoulder. There are three variants of the supine position (Figure 1). The horizontal position is not well tolerated by the conscious patient for long periods of time so this is why it is not recommended. The lawn-chair position is a more natural position that can be well tolerated for long periods of time (Figure 2). The patient is positioned on the table with the head and thorax slightly elevated and the hips and knees slightly flexed. A pillow must be placed under the knees and a silicone pad must be placed under the heels. Bony prominences must be padded and ulnar nerve protected. This position has the advantage that the slight elevation of the head and legs improve venous drainage of the brain and venous return. Also elevating the head and thorax improves ventilation in the dependent zones of the lungs by displacing the abdominal organs away from the diaphragm [1]. Reverse Trendelenburg position is basically a horizontal position with the head slightly elevated.

Posterior fossa lesions can be operated through an adaptation of the supine position. Awad et al. [5] described the gravity dependent supine position used for infratentorial supracerebellar lateral approaches. The patient is positioned supine with a lateral roll under the ipsilateral shoulder and the head is flexed and rotated to the contralateral side. A lazy "S" incision is made over the transverse sinus and a

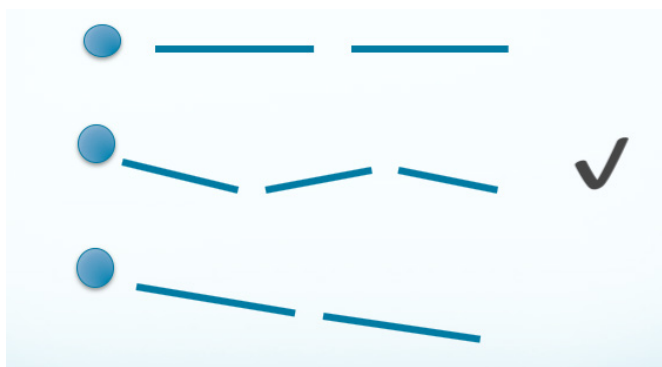


Fig. 1. Supine position variants: top-horizontal position; middle-lawn-chair position; bottom reverse Trendelenburg position



Fig. 2. The Lawn-chair position

lateral suboccipital craniotomy is performed in standard fashion. The dimensions of the craniotomy are reduced compared to operating in prone or lateral position because there is less need for a large exposure. The dura is cut in an "U" shape and reflected over the transverse sinus. Cisterna magna is opened and brain relaxation is achieved by removing CSF. Access to the quadrigeminal cistern is now easily obtained and more CSF can be removed if needed. The cerebellum falls and good access over the top of the cerebellum or to the postero-lateral midbrain is achieved. Using this position has the advantages of operating in sitting position but venous air embolism risk is reduced and the discomfort for the neurosurgeon is minimal. It has its limitations though, this position is not adequate for mid-line lesions or for patients with a stiff neck.

Our experience has showed that supine position and it's minor adaptations, represented by placing a roll under one shoulder can be used to successfully operate a myriad of pathologies of anterior skull base, through unilateral or bilateral frontal or subfrontal approaches and pathologies located in the Sylvian fissure.

Lateral position and park bench position

There are two variants of the lateral position: pure lateral and park bench position. Pure lateral position it's mainly used for temporal area surgery, and park bench for posterior fossa lesions.

The patient is positioned with the side of the lesion upwards. When a pure lateral position (Figure 3) is needed, the long axis of the head is parallel to the ground. In park bench position (Figure 4), the head is rotated towards the shoulder contralateral to the lesion, without exceeding 30 degrees of lateral rotation. The following steps for positioning are similar for both lateral and park bench positions: a roll is placed under the contralateral upper chest, we must avoid putting it directly under the axilla because the brachial plexus and axillary vessels will be compressed; all bony prominences must be protected; the depressed arm hangs over the end of the table on an arm support or suspended with a padded string; the ipsilateral hand is placed across the thorax with the elbow in slight flexion; the ipsilateral knee is positioned in extension and the depressed knee is positioned in flexion; a pillow must be placed between the knees; lateral supports are being placed in the sternal region and in the interscapular region and afterwards the patient is secured across the pelvic region with padded strings [4].

There have been described various complications following interventions with the patients positioned in lateral or park bench, starting from pressure sores to upper limb palsy to tongue swelling or delayed airway obstruction. Koizumi et al. [6] published a case report of a 43 year old man that has developed a massive tongue swelling 13 hours after undergoing a left suboccipital craniotomy in park bench position. In this case it seems that the cause of the massive tongue swelling was a malpositioned bite block that compromised the circulation into the left side of

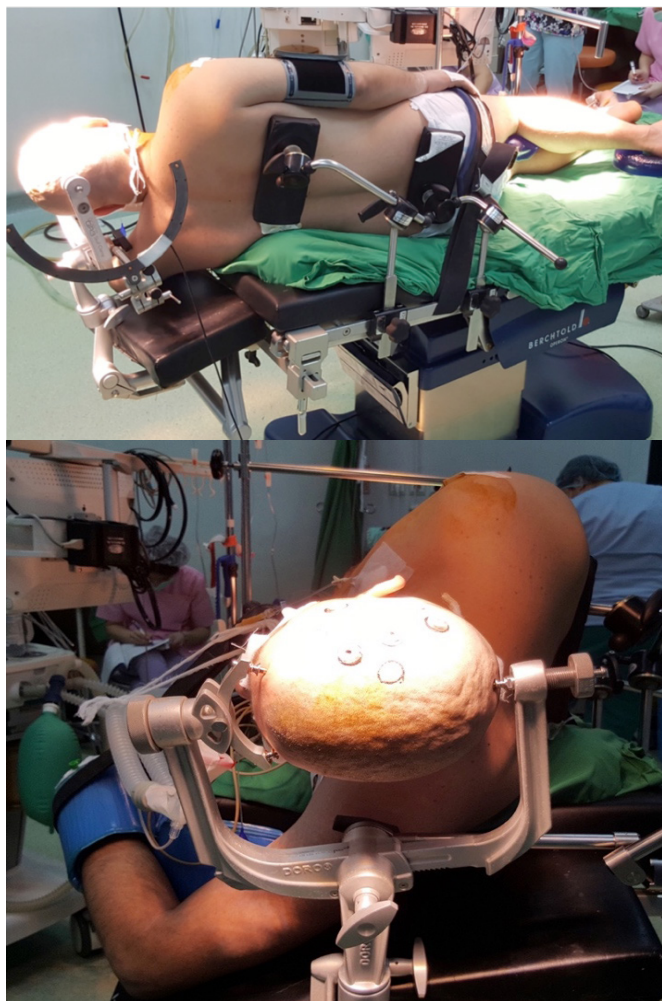


Fig. 3. The pure lateral position

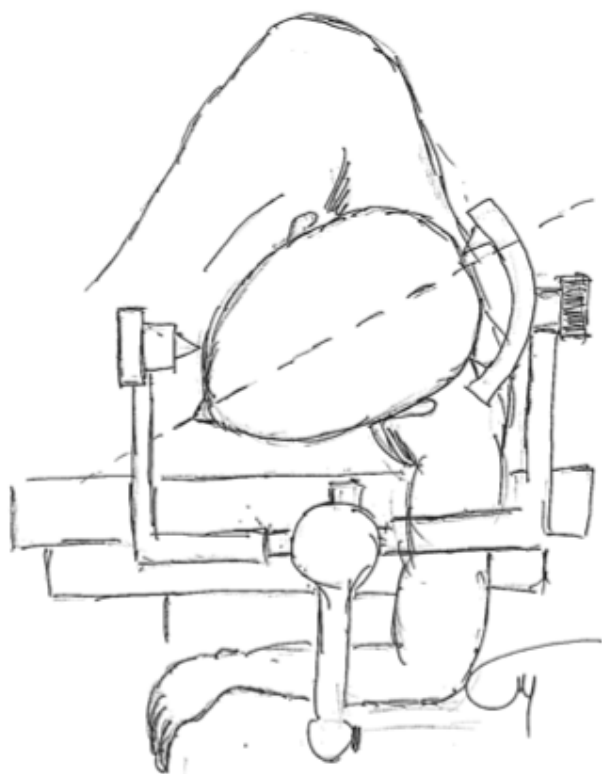


Fig. 4. The park bench position

the tongue during the intervention. The edema gradually improved after administration of intravenous steroids and no reintubation was needed. Yamaguchi et al. [7] reported two cases operated in park bench position that developed delayed airway obstruction postoperatively. They reviewed related articles written in English literature and found only five cases reported of delayed airway obstruction after craniotomy in lateral or park bench position, excluding the two cases reported by them in their case report. They concluded that excessive lateral flexion and rotation of the head (that is easily achieved especially in underweighted patients) kinks the internal jugular vein and therefore venous and lymphatic drainage from the head and neck is altered for many hours during long interventions. After the surgery is concluded, the soft tissue of the neck is reperfused causing face and neck edema that leads to airway obstruction few hours after surgery.

In our experience we have found that the lateral and park bench position are very good for treating pathologies located in the temporal, parietal or ponto-cerebellar fissure. Despite being more difficult to set up and requiring more time to do so, this time is well spent allowing for comfortable lengthy procedures for both the surgeon and the patient.

Prone position

Prone position is being used for posterior fossa lesions, fourth and third ventricle lesions or pineal region lesions. It can also be used for posterior approaches to the cervical, thoracic and lumbar spine. The patient is intubated in supine position and afterwards it is rolled in prone position on the operating table. Two rolls should be placed under the upper part of the thorax and pelvis for releasing pressure on the abdomen. When performing spine surgery a Wilson frame can be used. A roll is placed under the shins and the knees are flexed by elevating the leg segment of the operating table. When performing cranial or upper cervical spine surgery the arms are positioned adducted along the patient and when performing thoracic or lumbar spine surgery, the arms are abducted and placed on arm boards, and the elbows are flexed; care must be exercised not to hyperextend the arms because brachial plexus injury can occur. A padded belt is placed under the fesièr region to secure the patient in case afterwards the table is elevated in reverse Trendelenburg position [4].

The reverse Trendelenburg position, also known as Concorde position is mainly used for posterior fossa interventions or posterior approaches of the cervical spine. The head is then immobilized in a Mayfield head fixator and flexed, being aware to leave at least two finger breaths between the chin and sternum. A horseshoe head rest can be used for thoracic and lumbar spine interventions. Fixating the head after positioning the table in reverse Trendelenburg position prevents strain on the cervical spine. This position causes hemodynamic instability because the cardiac index and left ventricular ejection fraction decreases,

in contrast, oxygenation seems to improve because of the improved matching of ventilation-perfusion [1].

Kwee et al. [8] published a review of intraoperative and postoperative complications related to prone positioning. They analyzed 53 papers in English language literature and found 13 complications following prone position surgical interventions. The following complications were described: oropharyngeal swelling, nerve palsies (lateral femoral cutaneous nerve), postoperative vision loss, pressure sores, venous air embolism, increased intraabdominal pressure, increased bleeding, hepatic dysfunction, abdominal compartment syndrome, limb compartment syndrome, thrombosis and stroke, cardiovascular compromise and endotracheal tube dislodgement. The worst complication that can incur with the patient in prone position is cardiac arrest. A good measure of dealing with cardiac arrest is attaching the defibrillation pads before surgery. According to Nanjangud et al.[9] if a patient is diagnosed with cardiac arrest, cardio-pulmonary resuscitation must start as soon as possible with the patient in prone position, without wasting time turning the patient supine. Cardiac massage consists of manually compressing the middle portion of the thoracic spine. It seems that the systolic blood pressure generated when resuscitating a patient in prone position is higher than in supine position [10].

In our experience prone position is a very good position to do surgery in the occipital lobe, posterior fossa, cranio-cervical junction tumors and whole spine.

Three quarter prone position

This is a position mainly used for posterior fossa lesions or for lesions in the parieto-occipital region. When using this position, the operative site is downwards. Three quarter prone position (Figure 5) is best suited for occipital transtentorial approaches, as described in the year 1988 by Ausman et al.[11] He described the use of this position for pineal region tumors and concluded that the risk of air embolism is reduced compared with the sitting position and that because the operative site is down, there is less need for using brain retractors.

The patient is intubated in supine position and afterwards it is rotated on the operating table. A roll is placed under the contralateral hemithorax, elevating it approximately 15 degrees of the horizontal plane. A small roll is placed in the ipsilateral axilla. The contralateral arm is placed along the body and the ipsilateral hand is positioned behind the body. The superior leg is flexed and the inferior leg is extended. A pillow must be placed between the knees. The head is then fixed in the Mayfield device that is attached to the operating table. Usually the nose is positioned perpendicular to the ground (but the head can be rotated as much as 45 degrees) and the neck is slightly flexed. The body is secured with padded strings to the operating table. This position offers good comfort for the surgeon [4].

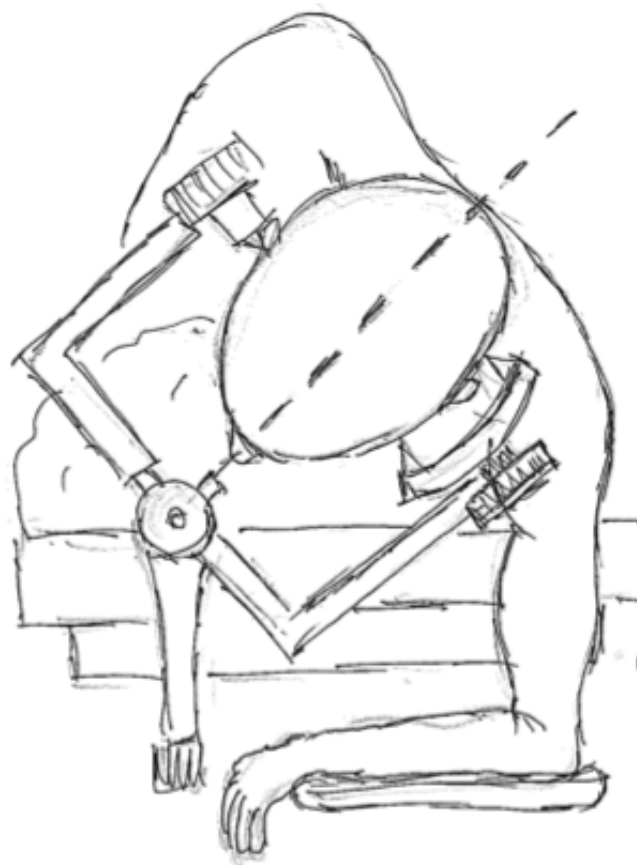


Fig. 5. The three quarter prone position

In our experience the three quarter prone position can be a good alternative to park bench in parieto-occipital of lateral posterior fossa tumors.

Sitting position

The sitting position (Figure 6) is less used nowadays because of the increased complication ratio related to it. It is mainly used for posterior fossa lesions that are approached through the infratentorial supracerebellar approach, suboccipital transtentorial approach, retrosigmoid approach or approaches to the superior cervical spine. Also patients that need implantation of deep brain stimulators are positioned this way because brain shift is minimized in comparison to other positions [12].

The patient is intubated supine and afterwards the operating table is flexed, elevating the thorax and body of the patient in sitting position. The hips are also positioned in slight flexion and the knees should be also slightly flexed. A crossbar that attaches to the first segment of the table is positioned anterior to the patient. The head is fixed in the Mayfield head holder that is attached to the crossbar. The head is flexed until the tentorium is as parallel as possible to the ground but hyperflexion of the head should be avoided [4].

Sitting position has the advantage that the cerebellar structures are gravity-retracted, leaving a good operating corridor to the pineal gland or the superior cerebellar area.

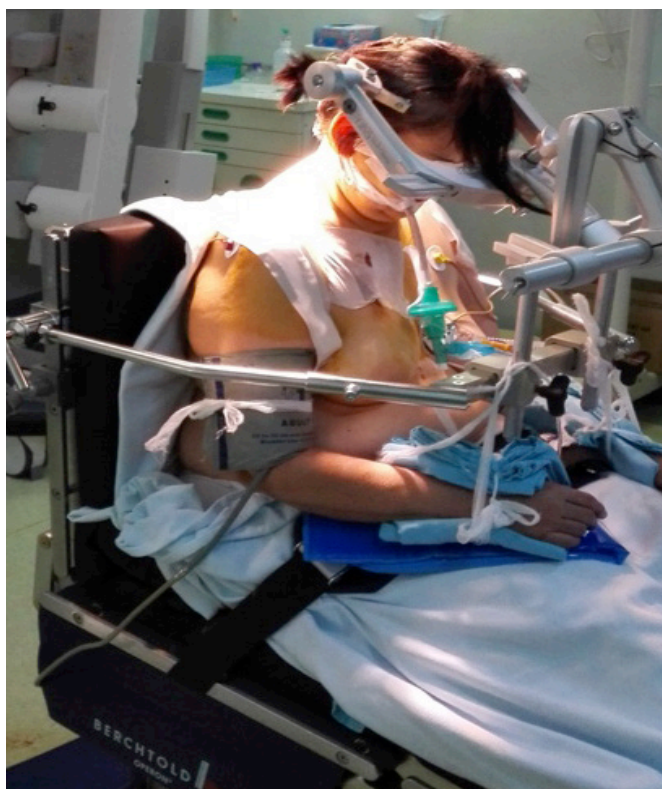


Fig. 6. The sitting position

Another advantage to sitting position is that the CSF and venous drainage improve, decreasing the cerebral pressure. The reason why this position is less used nowadays has to do with the increased risk of venous air embolism and hemodynamic instability. Dilmen et al. [13] published a retrospective study in the year 2011 of 692 cases (601 adults and 92 children) operated in sitting position and concluded that venous air embolism, diagnosed using capnography, has an occurrence of 26.3% in children and 20.4% in adults and that position induced hypotension occurs more frequently in adult population (37,6%) compared to pediatric population (18,6%). They also concluded that patients suffering of chronic obstructive pulmonary disease tolerate with great difficulty venous air embolism and recommend not using the sitting position in these patients.

Himes et al. [12] published a study of 1792 patients operated in sitting positions and reported a overall complication rate of 1,45%. The incidence of venous air embolism was 4,7%. Similarly with other studies, the incidence of venous air embolism seems to be the highest in cranial suboccipital interventions and intradural cervical spine interventions compared with cervical extradural interventions that had much lower incidence of venous air embolism. The reason why this is happening is not clear. Another complication that can appear is tension pneumocephalus that indeed in sitting position is more frequent than in other positions, but this complication frequently resolves by it's self. Subdural hematoma is a rare complication that has also been reported and the cause seems to be torn bridging

veins by the mechanical displacement of the cerebellum; nevertheless tension pneumocephalus and subdural hematomas are complications that can appear in every cranial procedure. Cervical quadriplegia is a devastating complication that is specific to sitting position and can be prevented by relieving the strain on the cervical spine by properly sustaining the patient's body, without leaving it hang by the patient's head which is firmly placed in the Mayfield head holder; this situation, combined with position related hypotension can lead to cervical spine ischemia leading to quadriparesis or quadriplegia. Sciatic nerve injury is another complication that can appear.

Sitting position is a relative contraindication to patients that are diagnosed with patent foramen ovale because of the risk of paradoxical air embolism. Echocardiography is the screening method recommended to every patient that is a candidate for a neurosurgical intervention in sitting position [12, 13].

Despite being proved as safe we have used the sitting position just a limited number of cases, mainly for infratentorial-supracerebellar approaches. We fell that the prone position allows for similar results in other lesions of the posterior fossa whilst allowing the operating surgeon more comfort and avoiding the intraoperative complications described by placing the patient in sitting position.

Conclusion

We can conclude that serious complications for the patient can occur if it is not properly positioned so this is why great care must be paid during this step of the surgical act. Also the surgeon's comfort is a very important aspect that has to be taken into consideration when positioning the patient.

Authors' contributions

AB (Conceptualization; Project administration; Supervision; Validation; Visualization)

CIH (Data curation; Investigation; Methodology; Resources; Writing – review & editing)

FT (Data curation; Formal analysis; Investigation; Methodology; Resources; Visualization; Writing – review & editing)

RC (Data curation; Formal analysis; Methodology; Project administration; Supervision; Visualization)

Conflicts of interests

The authors of this paper state that they have no conflict of interests to disclosure.

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