ОРИГИНАЛЬНЫЕ СТАТЬИ

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RISK AND BENEFITS OF PATIENT POSITIONING DURING NEUROSURGICAL PROCEDURES

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Patient positioning in surgical procedures has serious implications on clinical outcome. While surgical approach and exposure are considered by surgeons, frequently, the importance of properly positioning the patient, accounting for the clinical situation and co-morbidities, is overlooked. This is particularly true in many neurosurgical procedures, which require prolonged anesthesia and immobilization.
Traditionally, it is the anesthesiologists' responsibility to look after the well being of the patient, and maintain an adequate physiological environment, promoting full recovery. In this review, we analyze the different positions common in neurosurgery considering and balancing between surgical exposure, hemodynamic implications, patient comfort and neurological outcomes. The latter should be given particular attention, as it might be difficult to differentiate between neurological deficits which are a result of the patient's position, and those that are part of the underlying condition or surgical complication. Some positions interfere with standard monitoring or necessitate temporary interruption of or ventilation and continuous IV treatment. These as should be taken into account as well, reducing the interruption to the minimum. Finally, several complications are associated with specific positions and the approach to these complications is discussed. The review has been divided into two separate parts. In the previous issue of the journal we discussed the problems, related to head, neck and body positioning including supine and lateral position. Here we offer you the second part of the review, discussing benefits and problems related to prone and sitting position and specific complications including venous air embolism, blindness in prone position and pneumocephalus.

Prone Position

The prone position is commonly utilized for approaches to the posterior fossa, suboccipital region, craniosynestosis and posterior approaches to spine. Benefits: This is a good position for posterior approaches, lowering incidence of venous air embolism compared to the sitting position. Risks: Logistically, this is the most difficult position for the anesthesiologist, due to challenges associated with providing adequate

oxygenation, ensuring adequate ventilation, maintaining hemodynamics, and securing intravenous lines and the tracheal tube. Access to the patients' airway is poor. The loss of airway in this position may be life-threatening.

Reintubation or providing even non-definitive airway in this circumstance may be extremely difficult or even impossible. Excessive oral secretions may weaken tape adhesion securing the ETT in place, increasing the risk of unintentional extubation. If a lace is used for fixation of the ETT, face and neck edema should be sought after and readily noticed. Tight fixations may impair venous return from the brain. Pressure sores, vascular compression, brachial plexus injuries, air embolism, blindness, and/or quadriplegia can occur. Blood loss and transfusion rates, are reported to be higher in the prone position compared with the sitting position [1-2]. The risk of lower cranial nerve damage is increased as well [1]. Although the risk for venous air embolism during spinal surgery in prone position is diminished compared to sitting position, it is not completely avoidable, and should be considered when clinical suspicion arises. Lacking natural cushioning, the body front must be protected from pressure inflicted on vulnerable regions by body weight and the table surface. Gel overlay on top of the bolsters protects the lateral femoral cutaneous nerve that may be injured by compression of the thigh distal to the inguinal ligament [3]. Patient's knees should be slightly flexed and padded to prevent knee pain after the surgery.

Hemodynamics and Ventilation. Turning the patient prone from the supine position increases intraabdominal pressure, decreases venous return to the heart, and increases systemic and pulmonary vascular resistance [4]. Impairment of vena caval return diverts blood to the venous plexuses of epidural space, increasing the potential for bleeding during spinal surgery [5]. With the head-up tilt or in kneeling position where lower extremities are flexed, pooling of venous blood in the lower part of the body occurs, decreasing venous return and causing hypotension [6]. Although the cardiovascular responses to prone position have not been fully characterized, data suggest that left-ventricular ejection fraction and cardiac index may decrease, potentially caus-

ing hemodynamic instability [4, 7-8]. Oxygenation and oxygen delivery, however, may improve with prone positioning because of improved matching of ventilation and perfusion. The relationship between ventilation and perfusion may be improved for the following reasons: 1) Perfusion of the entire lungs improves, and previously underperfused regions become better perfused [9]. 2) Increase in intraabdominal pressure decreases chest wall compliance, which under positive-pressure ventilation, improves ventilation of the dependent zones of the lung. 3) Recruitment of previously atelectatic dorsal zones of lungs.

Characteristic challenges with prone positioning include disconnection of pulse oximetry, arterial line, and tracheal tube, leading to hypoventilation, desaturation, hemodynamic instability, and altered anesthetic depth. To prevent anesthetic catastrophes, the pulse oximeter and the arterial line should remain connected during the rotation, whenever possible. Monitoring of invasive blood pressure is particularly important in patients with heart or lung disease or those suffering from severe trauma.

Usually, the patient is anesthetized in the supine position, and is then turned prone on chest rolls or on a special frame. The head should be kept in the neutral position. All catheters, invasive monitors and the tracheal tube should be carefully secured before rotating the patient. Pressure sores (of breasts, penis, soft tissue at the bone points, ears, eyes) are the most frequent complications of prone positioning[10] Therefore, special frames (e.g. Wilson, Relton-Hall frame, Andrews frame, Jackson table and frame, which provide support to the chest but leave the abdominal wall and pelvis free, are often used. Chest rolls may be used to support the chest wall, and allow free movement of the chest and abdominal wall. Free movement of the abdominal is desirable for 3 reasons: 1) improved excursion of the diaphragm, and improved oxygenation ventilation, 2) a decrease in intraabdominal pressure and decreased surgical bleeding 3) and improvement of venous return from lower extremities and pelvis. The breast should not be exposed to pressure.

The effects of the prone position on hemodynamic stability and respiratory mechanics are frame dependent. Positioning on the Jackson table provides the most stable hemodynamics and does not increase dynamic lung compliance.

Eyes, nose, and ears should be protected against pressure, eyelids should be closed. If the head is positioned on a specially designed pillow (with holes for the eyes and nose), the eyes and nose should be periodically checked for lack of pressure (no less than once every 30 minutes) and head should be repositioned if needed. Blindness is a rare complication, (about 0.2% of cases), but it is a devastating complication of spine surgery during prone position, where prolongation of surgery and the magnitude of the blood loss may be risk factors [11]. Venous congestion may be avoided by positioning the head at body level or higher, but the other hand, elevation of the head for posterior fossa surgery or cervical spine surgery may increase the risk for air embolism. The incidence of air embolism has been reported to be 12% during neurosurgery in prone position when detected with precordial Doppler [12]. The upper extremities may be positioned along the body or abducted on to padded armboards. If abduction is used, great care must be exercised to avoid hyperextension of the arms to prevent brachial plexus injury.

Ventilation of the patient with pure oxygen, may prove to be beneficial, taking into account the relatively long time necessary for proper positioning and allowing a lax period for resolving unexpected difficulties. While positioning the patient, ETT should be disconnected from respiratory circuit and reconnected as soon as possible. The position of ETT has to be rechecked after positioning by auscultation. Following the rotation the ETT may dislodge or kink. All circuit connections should be rechecked, and, if possible, access to ETT and circuit should be assured.

Prone position procedures poses and additional risk for the tongue, pharynx and soft palate injury. Posterior cervical spine surgery and posterior fossa surgery require excessive head flexion for better exposure. This manipulation reduces anterior-posterior dimension of hypopharynx leading to ischemia of base of tongue, especially in the presence of a foreign body (ETT, TEE probe, oral airway). Edema may expand significantly after extubation leading to post-extubation stridor or airway obstruction. Gravity forces may cause the tongue to protrude forward between the teeth, leading to its swelling and edema. The use of bite protector may help to prevent this complication. The use of an oral airway is contraindicated in the prone position.

Attention should be given to the placement of the Folley catheter, avoiding pressure upon the skin of the thigh. ECG wires and electrodes should be placed dorsally.

Anterior tibial compartment syndrome may be a rare complication of the prone-sitting position for lumbar surgery [13-14].

Obesity may predispose patients to position-related palsies during thoracic spine procedures [15].

SSEP monitoring is a common monitoring mode neurosurgical operations (both craniotomies and spinal surgeries), and it may be useful utilizing this modality for detection of new peripheral nerve damage under general anesthesia. Recent peripheral nerve damage is detected by increase of latency or decrease of amplitude, and simple repositioning of the involved extremity mat prevent postoperative neurological deficit.[16-21] SSEP is very sensitive in detection of peripheral nerve compromise. Studies in healthy non-anesthetized volunteers, demonstrated that the SSEP signal was decreased even earlier then paresthesia appeared in volunteers [16]. SSEP changes related to peripheral nerves injuries occur in 5.2-6.1% of patients during spinal surgeries, mostly in brachial plexus (65%) and ulnar nerve (16%) and more often in lateral and prone position. These changes are relieved with repositioning [18-20].

The Concorde position is a modification of the prone position. This is the preferred position for surgical approach to occipital transtentorial and supracerebellar infratentorial area. The head is typically skeletally fixed and flexed, but may be laterally flexed if needed. The body is positioned in reverse Trendelenburg and chest rolls are placed under the trunk. The arms are tucked alongside to the trunk, and the knees are flexed. Specific complications include necrosis of the chin and an obstruction of cerebral venous outflow.

Knee-Chest Position

Neurosurgeons often prefer the knee-chest position for lumbar and thoracic laminectomies and discectomies. This position provides good exposure of the vertebral laminae and foramina in the posterior aspect of the spine and allows the patient's abdomen to remain free of mechanical pressure, easing ventilation, with minimal cardiovascular compromise. Other advantages of this position include reduced pressure on the abdominal viscera and vena cava and decreased bleeding because of the collapse of epidural veins. The anesthesiologist should position the patient's head, ensuring that the neck and spine remain aligned and the patient's spine is stable.

A flat-bottom gel should be bolstered horizontally above or below the chest to leave the abdomen free from compression. The breasts of female patients shall be checked to avoid excessive pressure. If the patient's breasts are large, the flat-bottom gel bolster needs to be placed above the breasts to support the chest and prevent neck compression by breast tissue; the bolster is placed below the breasts if the breasts are small. The patient's forearm, wrist, and hand are aligned in a neutral position and padded to protect the ulnar and radial nerves from excessive external pressure.

A sitting bracket with lateral supports provides support for the lower body and stabilizes the hips and buttocks.

A significant danger of the knee-chest position is impaired perfusion distal to the knees as a result of vascular kinking in the popliteal space. Excessive hip or knee flexion should be avoided and the pedal pulses should be checked of both feet to assess for adequate perfusion. Anterior tibial compartment has been reported as a complication in this position [13-14].

Sitting Position

This position is utilized for posterior fossa surgery and cervical laminectomy. The sitting position today is controversial as was when first introduced into clinical practice in 1913 by De Martel for brain tumor surgery performed under local anesthesia [22].

Benefits: This position provides optimal surgical exposure for posterior fossa surgery because tissue retraction and risks of cranial nerve damage are reduced, cerebral venous drainage is improved and bleeding is decreased. "Tight brain" condition and need for mannitol therapy is encountered less often in this position. The position provides an opportunity to observe the patient's face for signs of cervical stimulation of cranial nerves. Transfusion rate has been reported to be lower in the sitting position[1]. The patient's airway is accessible to the anesthesiologist. Risks: Venous air embolism (VAE), paradoxical air embolism, bradycardia or cardiac arrest due to brainstem manipulations may occur. Macroglossia, upper airway obstruction [23], pneumocephalus,[24] subdural hematoma, and quadriplegia [25] have been reported as well.

The most frequently damaged nerve in the lower extremities while maintaining the sitting position, is the common peroneal nerve [2]. Increased risk of sciatic nerve injury exists as well. Damage to the common peroneal nerve or compression and stretching of the sciatic nerve can lead to foot drop. Hyperflexion of the knees stretches the peroneal nerve and compresses it against the head of the fibula, and should therefore be avoided. Use of a buttock gel pad prevents excessive pressure on the sciatic nerve and coccyx. Patient's knees should be partially flexed to help minimize strain on the sciatic nerves and lower back [3].

Despite well described risks involved with the sitting position, there is no evidence of an increased mortality rate [26-28]. A recent national survey has demonstrated that the sitting position is still utilized for posterior fossa surgery in about half of practices in USA.[29] A recent publication in 2001 states that only 20% of craniotomies were performed in sitting position. Prevalence of the sitting position has decreased drastically in the pas 10 years [2]. Relative contraindications to the sitting position include: open ventriculoatrial shunt, signs of cerebral ischemia when upright and awake, right-to-left shunt as with patent foramen ovale (because of enhanced risk of paradoxal air embolism), and cardiac instability.

Hemodynamics and Ventilation The classic sitting position causes postural hypotension in approximately one third of patients, while 2-5% of patients suffer severe hypotension (defined as blood pressure decrease below half of baseline).30 The major hemodynamic consequence is a decrease in venous return, leading to decrease in cardiac output and hypotension. Therefore, hemodynamic instability and cardiac disease are relative contraindications for the sitting positioning. Measures which might be useful in avoiding hypotension include prepositioning hydration, wrapping of the legs with elastic bandages to counteract gravitational shifts of blood, and slow, incremental adjustment of table position.

Wrapping of the legs with elastic bandages (e.g. ACE bandage) from the toes to the groin prevents pooling of blood in the lower extremities and should be applied in every case. The use of pneumatic antishok trauses have been shown to attenuate the effects of assuming the sitting position [2, 31], however, this measure has not been widely applied.

Positioning of the patient with flexion of the hips, elevation of the knees to the level of the heart has also been shown to minimize position-associated hypotension [22]. In most healthy subjects, the hemodynamic changes are of nonthreatening magnitude. Moreover, the incidence of hypotension in sitting position has been shown not to be higher than in prone position for posterior fossa procedures [12, 22].

During procedures performed in the sitting position, MAP should be transduced at or corrected to head level (surgical field or interauricular plane) to provide a meaningful index of CPP. Specifically, CPP should be maintained at a minimum value of 60 mm Hg in healthy patients. The safe lower limit should be raised for elderly patients, for those with hypertension or known cerebral vascular disease, degenerative disease of the cervical spine or cervical spinal stenosis because they may be at risk for decreased spinal cord perfusion, and in the event that substantial or sustained retractor pressure must be applied to brain or spinal cord tissue [32] .

The modified sitting (semirecumbent) position provides better venous return and less hemodynamic instability. With head-up tilt, venous drainage via internal jugular veins is improved, resulting in decreased intracranial pressure. However, jugular veins may also collapse in the sitting position [33], and careful head positioning to avoid hyperflexion and hyperextension is required to prevent stretching or obstruction of the vertebral venous outflow.

Ventilation in sitting position is superior to the supine position due to downward shift of the diaphragm, which decreases intraabdominal pressure, improves ventilation of the dependent zones, and decreases ventilation-perfusion mismatch. However, low perfusion pressure secondary to decreased venous return may affect oxygenation. Therefore, preventing hypovolemia and maintaining normal pulmonary perfusion pressure are crucial for maintaining an adequate oxygen delivery in sitting position.

Venous Air Embolism (VAE)

The mechanisms involved in the appearance of VAE include negative venous pressure and exposure of veins and bony venous sinuses to air. When the site of surgery is exposed to air and located above the level of the heart, air may be entrained in the veins and bony venous sinuses, resulting in air entering the pulmonary circulation. A large VAE may decrease cardiac output by creating an airlock and decreasing left ventricular output. The incidence of VAE in sitting position may approximate 20-50% when precordial Doppler monitoring is used for detection [22] and 76% when transesophageal echocardiography (TEE) is used for detection [34]. The rate of VAE is apparently lower with cervical laminectomy (25% using TEE in the sitting position versus 76% for posterior fossa procedures).

Sensitivity of the different monitoring modalities, for detection of VAE varies, and follows the following order: TEE, precordial doppler, sudden drop of ETCO2, increase of CVP and PAP, hemodinamic instability.

Common sources of critical VAE are the major cerebral venous sinuses, in particular, the transverse, the sigmoid, and the posterior half of the sagittal sinus, all of which may be uncollapsible because of their dural attachments. Air may also enter through emissary veins, particularly from the suboccipital musculature, the diploic space of the skull (which can be violated by both the craniotomy and pin fixation), and the cervical epidural veins [32]. The incidence of clinically significant VAE, accompanied by drop of blood pressure is relatively low, and approaches 17% [12]. Patent foramen ovale should be excluded before every case as it is a source of paradoxical air embolism. Therefore, preoperative "bubble test" in awake patients using TEE or transthoracic echocardiography is advocated by some authors if the sitting position is considered [30].

In addition to standard monitoring, precordial transthoracic doppler is recommended for early detection of VAE[30]. Although TEE is more sensitive in detecting VAE, precordial doppler is inexpensive, readily available, easy to use, and noninvasive. Optimal placement of the precordial probe should be guided by recognizing the highest pitch over the right upper sternal border with the intravenous injection of agitated saline. When precordial doppler or TEE are unavailable, VAE should be clinically suspected when end tidal CO_2 suddenly drops in the presence of hypotension, unexplained by other causes. An atrial catheter (multiorifice or single orifice) placed at the highest point of the right atrium may be helpful for air aspiration. Correct positioning may be verified using intravenous electrocardiography, chest radiography, or TEE. However, the therapeutic value of the right atrial catheter may be limited. The most important treatment for VAE includes - irrigation of the surgical site with saline, applying external pressure on jugular veins in order to increase the venous pressure and limit air entrance [32], rescue head-down tilt or left lateral positioning, and cardiovascular support with administration of inotropes. Repositioing of the patient may be impractical in the sitting position when head holder is used. N_2O should be discontinued immediately if had been used.

Several prophylactic measurements were advocated for decreasing the risk of VAE including pneumatic compressive devices and PEEP (by increasing right atrial and jugular venous pressure) [2,31], fluid hydration and use of bone wax. On the other hand the use of PEEP may increase the risk of PAE and has been shown not to be effective in the prevention of VAE and proposed to be abandoned [35].

Other Complications

The incidence of postoperative pneumocephalus in sitting position may reach 100% [24], and may be due to negative cerebral spinal fluid pres-

sure and/or residual air during closure of the dura. Therefore, nitrous oxide should be discontinued 20-30 minutes before completion of the procedure. However, pneumocephalus can develop even without the use of nitrous oxide, raising the possibility that it does not play a major role in the development of this condition [24]. Moreover, the use of nitrous oxide up to the point of dural closure may actually represent a clinical advantage, due to it's superior diffusion capacity compared with that of nitrogen, and the quicker shrinking of the gas pocket [32]. Pneumocephalus may persist for weeks after surgery. If a repeated surgery is planned, N2O should not be used until the dura is reopened, because nitrous oxide may significantly increase the volume of trapped gas and lead to tension pneumocephalus.

Pneumocephalus can also develop de novo in the postoperative period in patients who have a residual dural defect and communication between the nasal sinuses and the intracranial space [32]. Tension pneumocephalus has been described as a rare complication after craniotomy in prone position [36].

Life-threatening tension pneumocephalus is rare (3%) [37]. Tension pneumocephalus should be suspected when one of the following sings is present: delayed awakening, non-awakening, severe headache, development of new neurological deficit after the surgery, and sings of brain herniation. The diagnosis of pneumocephalus is confirmed by a brow-up lateral radiograph or CT scan. The treatment is a twist drill hole followed by needle puncture of the dura.

Quadriplegia is a rare but devastating complication and results from cervical spine ischemia with neck and head hyperflexion. Elderly patients with cervical spine deformities and vascular pathologies have higher risk [38]. During positioning, sufficient distance betweeen chin and neck (at least 2 fingerbreadth) is recommended to avoid neck hyperflexion.

Three-Quarter Prone Position (Lateral Oblique, or Semiprone)

This position is used for posterior fossa and parieto-occipital surgery. Benefits: The risk of VAE is lower compared to the sitting position. Risks include bleeding, brachial plexus injury, pressure sores, and macroglossia. The issues with hemodynamics and ventilation in this position are similar to those with lateral and/or prone positioning.

The principles of three-quarter positioning resemble those for lateral position, but the head may be placed on the table and the dependent (lower) arm may be placed behind the body (coma or sleeping position). If a suboccipital approach is required, the nondependent (upper) shoulder should be taped down towards the foot. However, this can cause additional stretching of the brachial plexus (maneuvers to prevent brachial plexus injury are discussed in "Lateral Position" section).

Summary

Positioning of the patient for neurological surgery is an important part of anesthesia care and poses many technical and physiological challenges. As discussed, recognition of the physiological changes with positioning and careful and meticulous positioning may decrease unwanted complications.

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ТҰЖЫРЫМ

Нейрохирургиялық ем-шараны орындау үшін, науқасқа ынғайлы жағдай жасалуы емдеу жетістіктеріне бірталай әсер етеді.

Хирургиялық жету хирургтің айрықша ісі болса, анестезиолог дәстүрлі түрде науқастың дұрыс орңықтыруына, клиникалық ахуалына және бірге болатын ауруларына байланысты, науқастың тұрақты күйін сүйемелеу, тез және толық оянуын қамтамасыз етуде, жауапты болып табылады. Бұл әрине, көп уакыт жансыздандыру және жылжымаушылықты талап ететін нейрохирургиялық операцияларда маңызы зор.

Бұл талдамада , нейрохирургияда қолданылатын әр түрлі позицияға сараптама жасалынады, хирургиялық жетудегі ыңғайлық, гемодинамика мен вентиляцияға позицияның әсер етуі , науқас үшін жайлылық арасындағы баланстауға назар аударылады. Науқастың жайлы жағдайына ерекше көңіл аудару керек, өйткені операциядан кейінгі науқастың дұрыс емес жайғасымынан болған неврологиялық тапшылық хирургиялық әдіс нәтижесінде болған неврологиялық тапшылықтан қиын ерекшеленуі мүмкін.

Кейбір жайғасымдар стандартты мониторингті қолдануға кедергі жасайды, немесе мониторды, өкпенің жасанды вентиляция аппаратын немесе көк тамырға жіберілетін инфузияны және анестетиктерді уақытша сөндіруді талап етеді. Сондай жағдайларда жоғарыда аталған манипуляциялардың уақытын ең аз уақытқа дейін қысқартуға әрекет жасау керек. Науқастың арнайы жайғасым-қалпына байланысты болған асқынулар, олардың диагностикасы және ем тәсілі осы талдамада айтылады.

Осы талдама екі бөлімге бөлінген. Бірінші бөлімде бас, мойын және денеге байланысты мәселелер талқыланады, сонымен қатар, нейрохирургиялық операцияларға тән арқамен жату, бүйірмен жату жайлары кіреді. Осы жерде, сіздердің назарларыңызға шолудың екінші бөлімі ұсынылады, ішпен жату жағдайы және «отыру» жағдайына байланысты венозды эмболия, ішпен жатқанда көру қабілетін жоғалту және пневмоцефалюс сияқты мәселелер мен басымдылықтар талқыланады.

РЕЗЮМЕ

Придание правильного положения больному для выполнения нейрохирургических процедур, имеет значительное влияние на успех лечения.

В то время как хирургический доступ является прерогативой хирурга, анестезиолог традиционно несёт ответственность за правильное положение больного в соответствии с клинической ситуацией и сопутствующими заболеваниями, так же как поддержание стабильного состояния больного и обеспечения быстрого и полного пробуждения. Это особенно важно для большинства нейрохирургических операций, которые требуют длительного наркоза и иммобилизации.

В данном обзоре мы анализируем различные позиции, используемые в нейрохирургии, принимая во внимание балансирование между удобством хирургического доступа, влиянием позиции на гемодинамику и вентиляцию, удобство для пациента. Последнее заслуживает особого внимания, поскольку послеоперационный неврологический дефицит, как следствие неправильного положения больного, может быть трудно отличим от неврологического дефицита, являющегося следствием хирургического вмешательства.

Некоторые позиции препятствуют адекватному использованию стандартного мониторинга или требуют временного отсоединения пациента от монитора, аппарата ИВЛ или внутривенных инфузий и анестетиков. В этих случаях следует стремиться сократить время вышеперечисленных манипуляций до минимума.

Осложнения, связанные со специфическими положениями больного, их диагностика и лечение также дискутируются в этом обзоре.

Данный обзор разделён на две части. В первой части обсуждались проблемы, связанные с положением головы, шеи и тела, включающие положения на спине и на боку специфичные для нейрохирургических операций. Здесь Вашему вниманию предлагается вторая часть обзора, в которой обсуждаются достоинства и проблемы, связанные с положением на животе и «сидячее положение», включая венозную эмболию, потерю зрения на животе и пневмоцефалос.