Positioning and Patient Effect

2

INTRODUCTION

Surgical procedures that require the use of anesthesia (both general and conscious sedation) render patients vulnerable to potential injury and unable to protect themselves fully or at all. Each position carries some degree of risk, which is magnified in the anesthetized patient. Accordingly, the operating room personnel must provide for total protection of the patient. Specific attention to bony prominences, joint position, and dependent portions of the patient's body are of utmost importance. Dependent portions at risk for compression injury include the following body parts:

- Eyes/ears
- Penis/scrotum
- Breasts
- Fingers
- Pendulous tissue (table-related injury)

The aim of optimal positioning for surgery is to provide the best surgical access while minimizing potential risk to the patient. However, there is an increased risk of nerve damage in *any* position if the surgery lasts more than 4 hours, if the patient's body mass index (BMI) is less than 20, or if the patient has diabetes or is a smoker.

Patient positioning can affect all systems, but especially the following areas.

Circulatory System

- Impaired autonomic/sympathetic nervous systems
- Loss of vasomotor tone
- Depressed cardiac output
- Gravity effects and redistribution of circulating volume
- Compression of extremities or great vessels
- Ischemia/decreased venous return

Pulmonary System

- Barriers to thoracic excursion
- Loss of hypoxic pulmonary vasoconstriction (HPV)
- Alteration in ventilation/perfusion (V/Q) ratio

Peripheral Nerves

Nerve injury risk is high; nerve injury is one of the most common causes of surgery-related lawsuits. Ischemia of the nerve sheath can be due to either direct injury (e.g., compression of the nerve) or indirect injury (e.g., compartment syndrome). The brachial plexus (C4–T2) may be stretched, resulting in potential injury, when any of the following manipulations occurs:

- Neck extension
- Opposite arm rotation
  - Ninety-degree abduction of an extremity
  - External rotation of the arm

Surgical Position and Effects on Functional Residual Capacity

When the patient is *supine*, the abdominal contents force the diaphragm toward the head and will decrease functional residual capacity (FRC). Lithotomy and use of Trendelenburg position further reduce FRC. In the *steep* Trendelenburg position, most of the lung may be below the left atrium (zone 3 or 4 condition) and the lung is susceptible to development of pulmonary interstitial edema.

The effects of the lateral decubitus surgical position on FRC vary:

- FRC is decreased in the dependent lung.
- FRC is increased in the nondependent lung.
- The dependent lung is prone to atelectasis and fluid accumulation because it is below the left atrium.

Not all surgical positions decrease FRC. The prone position may actually *increase* FRC.

Migration of Endotracheal Tubes: Potential Causes Related to Patient Position and Surgery

Always assess breath sounds for endotracheal tube (ETT) placement after changes in the patient position.

- Migration of the ETT can occur after head movement or repositioning of the patient.
- A tube that had been previously positioned in the trachea can enter a bronchus or exit the vocal cords.
- Flexion of the head causes caudad (deeper insertion) movement of the ETT.
- Extension of the head causes cephalad (pulls up and out) movement of the ETT.
- Trendelenburg position can cause a cephalad shift of the diaphragm and carina.
- Cephalad movement of the diaphragm and carina may follow insufflation.
- Endotracheal tube movement must be suspected after any sudden desaturation.

Cerebral Perfusion Pressure and Transducer Levels Associated with Patient Positioning

Cerebral perfusion pressure (CPP) and mean arterial blood pressure (MAP) are related as follows:

$$CPP = MAP - ICP \text{ (or CVP)}$$

where ICP is the intracranial pressure and CVP is the central venous pressure.

New research indicates that the lower limit of cerebral autoregulation should be maintained within the range of 70–93 mm Hg (with a mean of ± 80) and with 150 mm Hg as the upper limit. The old value cited for the lower limit (mm Hg 50) is simply too low and leaves no margin for error; severe cerebral perfusion compromise can result.

Cerebral perfusion pressure decreases by 15% in the sitting non-anesthetized patient and can further decrease during anesthesia due to vasodilation and myocardial depression. *MAP is uniform*

among the brain, heart, and arm in the supine or lateral patient but can change drastically in the patient in a heads-up position.

The arterial blood pressure transducer can be zeroed and calibrated at the *phlebostatic axis*: The stopcock is placed level with the phlebostatic axis, a common physical reference point; the phlebostatic axis is located at the fourth intercostal space and at half the anterior–posterior (AP) diameter of the chest. This approximates the location of the right atrium. After zeroing the transducer, it is raised and maintained at the level of the external auditory meatus to obtain a meaningful index of CPP.

Alternatively, the arterial blood pressure transducer can be zeroed at the level of the *external auditory meatus* and kept there to transduce at the brain level to obtain a meaningful index of CPP.

The MAP should be maintained at a minimum level of 60 mm Hg in healthy patients. This level is increased for elderly patients, patients with hypertension, and patients with known cerebral vascular disease.

If the sitting patient's pressure is measured by a blood pressure cuff, it is crucial to know the vertical distance between the brain and the blood pressure cuff (this difference is the hydrostatic pressure gradient between the heart and the brain). The blood pressure for *the base of the brain* should be calculated by decreasing the cuff MAP by *0.75 mm Hg for every 1 cm of vertical height* above the site of cuff measurement; this will be the mean arterial blood pressure the base of the brain "sees." Moreover, the pressure difference between the base of the brain (circle of Willis) and the very top of the brain can be as much as 9 mm Hg. If leg blood pressures must be used, a MAP less than 75–80% of preoperative values should be treated aggressively.

Maintaining adequate cerebral perfusion during surgery is critical. Keep in mind there may be a huge difference between the arterial blood pressure at the level of the brain and the blood pressure reading by cuff placed on a leg.

SUPINE POSITION

In the supine position (also called the dorsal position), the patient lies on his or her back; the knees are flexed on a pillow. *With the patient flat (either supine or lateral), the blood pressure is uniform throughout.*

- **Cardiac issues:** aortocaval compression may occur in obese patients.
- **Pulmonary issues:** the abdominal contents force the diaphragm toward the head and will decrease functional residual capacity.
- **Nerve issues:** ulnar nerve injury (ulnar groove at the posterior edge of the medial epicondyle) may occur. Laying the arm supine is the best prevention for ulnar nerve injury.

The *supine position with shoulder roll* may be used in anterior cervical, neck, and jaw surgeries. This position supports the head, and doesn't let it dangle.

PRONE POSITION

In the prone position, the patient lies face down with arms either flexed at the elbow or tucked at the patient's sides and shoulders at less than a 90-degree angle.

Following insertion of a peripheral IV (not in the antecubital fossa, unless the arms are to be positioned tucked at the patient's sides) and endotracheal intubation, the patient is turned onto the operating room table in the prone position. With the elbows flexed, the arms are extended on armboards angled toward the head of the bed with the shoulders less than 90 degrees and supported so they are not hanging, and the hands pronated ("swimmer's position"). Pillows are placed under the ankles. Padding is placed under the elbows and knees. A safety strap is secured across the

patient's thighs. The neck should be in a neutral position. The eyes and the tip of the nose should be checked at least every 15 minutes to make sure no pressure is applied to these areas and charted on the anesthesia record.

- **Cardiac issues:** Potential problems may include lower extremity/gut pooling of blood, inferior vena cava compression, and epidural engorgement.
- **Pulmonary issues:** Use chest rolls, as the lungs must have free excursion. The prone position may actually *increase* FRC. If the chest is not free, there is decreased compliance with high peak pressures and ventilation/perfusion problems.
- **Nerve issues:** Damage to the brachial plexus is possible. The arms should be in the swimmer's position or tucked at the sides, with the shoulders still at an angle less than 90 degrees.

Prone Position Checklist

- Eyes/ears
- Taped closed/padded eyes
- All extremities
- Penis/breasts in the clear;—move breasts inward medially
- Clear catheter tubing
- Chest rolls in good position, below the clavicle and below the inguinal space
- Brachial plexus checks
- Clavicle/mandible checks
- Check eyes and nose for no pressure every 15 minutes; document

Postoperative Visual Loss

Complete or partial blindness is a potentially devastating complication for a patient in the prone position; postoperative visual loss (POVL) is most often associated with long-duration spinal surgery with instrumentation. Commonly, these patients have surgery in the prone position lasting several hours and develop hypotension with considerable blood loss replaced only with crystalloid fluids with low urinary output.

POVL is thought to be due to multiple factors, including elevated central venous pressure from retarded drainage from the ophthalmic veins, and the head spending a prolonged period in the down-tilt position, causing decreased venous outflow from the cranium. Interventions to help prevent POVL include slight reverse Trendelenburg (head-up) position, transfusion of blood products to maintain preoperative hematocrit (HCT) levels, normothermia, euglycemia, and urinary output minimum of 0.5 mL/kg/h.

Prone Position on Andrews Frame

In this position, the patient is prone with the hips bent down and the patient kneeling. This position raises concerns for the following areas:

- Eyes
- Knee/ankles/toes (padding is needed)
- Penis/breasts (should be kept free)
- Chest excursion
- Venous pooling

TRENDELENBURG POSITION

In the Trendelenburg position, the head of the bed is lowered by 15 degrees or more.

- **Brain issues:** Trendelenburg position increases cerebral blood flow and intracranial pressure.
- **Cardiac issues:** Baroreceptors are activated and compensate with vasodilation. Increased pulmonary artery wedge pressures, mean arterial pressures, and mixed venous oxygen levels may occur. Stroke volume is decreased. Left atrial pressure is increased. Other potential cardiac problems include congestive heart failure, pulmonary edema, and facial engorgement.
- **Pulmonary issues:** Functional residual capacity decreases by 20%; abdominal contents shift cephalad. Vital capacity is decreased, as is pulmonary compliance. Pulmonary engorgement may occur. In the *steep* Trendelenburg position, most of the lung may be below the left atrium and the lung is

susceptible to the development of pulmonary interstitial edema.
- **Nerve issues:** There is no specific nerve risk with the Trendelenburg position.

REVERSE TRENDELENBURG POSITION

In the reverse Trendelenburg position, the head of the bed is raised by 15 degrees or more.

- **Cardiac issues:** Cardiac problems associated with this position include hypotension and venous pooling.
- **Pulmonary issues:** There is increased functional residual capacity and increased compliance. Oxygenation improved with adequate cardiac output.
- **Nerve issues:** There is no specific nerve risk associated with the reverse Trendelenburg position.

LITHOTOMY POSITION

In the lithotomy position, the patient is on his or her back, with hips flexed and legs apart. Strap-stirrups or boot-style stirrups (used to support the foot and the calf, thereby relieving pressure on the popliteal space) are used to support the legs and feet. After lithotomy, the feet are brought together and then lowered to decrease the lumbar torsion; check the patient's blood pressure after lowering the legs.

In the *exaggerated lithotomy* position, the hips are aggressively flexed so that bent knees are closer to shoulders than chest.

- **Cardiac issues:** These issues are minimal if the patient is not pregnant, does not have an abdominal mass, and is not obese. Approximately 600 cc auto-infusion of blood occurs when the legs are lifted into the lithotomy position. Cardiac output is decreased.
- **Pulmonary issues:** An abdominal shift occurs; FRC is decreased by 20%; vital capacity is decreased; and hypoventilation occurs in the spontaneously breathing patient.
- **Nerve issues:** Damage to the *peroneal* nerve is the most common injury in the lithotomy position, caused by nerve compression at the head of the fibula (i.e., the leg in a stirrup with the outer leg pressing against the stirrup); this injury causes foot drop and leaves the patient unable to dorsiflex the foot and with sensory deficits. Damage to the *sciatic* nerve may occur during the lithotomy position with thigh and leg external rotation causing traction; its symptom is foot drop. Damage to the *saphenous* nerve may occur when the nerve is compressed by the leg holder and the tibia, causing medial sensory deficits. Damage to the *femoral obturator* may occur because of calf pressure from the leg holder. Damage to the *femoral* nerve may occur when excessive thigh flexion causes the nerve to be pressured by the pubic ramus. Damage to the *popliteal fossa* may occur when pressure leads to development of compartment syndrome. Risk of nerve damage is increased for the patient in the lithotomy position if surgery lasts longer than 4 hours, the patient's body mass index (BMI) is less than 20, and/or patient is a diabetic or a smoker.

Patients in the lithotomy position are also at a higher risk of deep venous thrombosis (DVT). For this reason, it is important they have DVT prophylaxis (i.e., compression stockings, inflating stockings, and mini-dose heparin).

Special vigilance is needed regarding hand and finger positions when lowering or raising the foot of the bed.

SITTING OR BEACH-CHAIR (SEMI-FOWLER) POSITION

In the semi-Fowler position, patients are placed in a seated position with the head of the bed 30–90 degrees above the horizontal plane. The chin must be 1–2 finger breadths from the chest; otherwise, this position can strain the C5 vertebra.

- **Brain issues:** Advantages of the sitting position include facilitation of venous blood drainage

from the brain and decreasing ICP and CSF pressure.
- **Cardiac issues:** The patient may develop decreased mean arterial pressure (MAP) and central venous pressure (CVP), impaired venous return from a reduced stroke volume, and decreased cardiac output (by 20%). There is massive venous pooling in the lower extremities (especially in a head-up position greater than 60 degrees).
- **Pulmonary issues:** Functional residual capacity increases with increased compliance. Decreased pulmonary artery pressures with increased pulmonary vascular resistance.
- **Nerve issues:** Affected nerves may include the sciatic (lack of knee flexion in the sitting position), ulnar, and cervical nerves.

Pressure points in the sitting position include the occipit, scapula, elbow, sacrum, ischial tuberosities, and heels.

Advantages of Sitting Position

- Better surgical exposure
- Blood and cerebral spinal fluid drainage
- Potential advantage of improved hemostasis

Disadvantages of Sitting Position

- Hypotension, postural; decreased blood return to the heart (Avoid this by changing the patient's position gradually.)
- Decreased cerebral perfusion
- Venous air emboli (43%); especially with surgery involving bone (i.e., skull)
- Pneumocephalus (presence of air or gas within the cranium) because of the open sinuses and large veins
- Ocular compression
- Mid-cervical tetraplegia
- Edema or macroglossia
- Increased potential to lose airway

The risk of quadriplegia, paraplegia, peripheral nerve injuries, and facial/glossal edema have been reported to be increased when patients are placed in the sitting position.

Avoid use of nitrous oxide with a patient in the sitting position, as it increases the bubble size if venous air embolism (VAE) occurs.

JACK-KNIFE POSITION

In the jack-knife position, the patient lies in the prone position with the buttocks raised.

- **Cardiac issues:** These problems may include venous pooling, mesenteric/epidural engorgement, and decreased cardiac output.
- **Pulmonary issues:** Visceral shift occurs; FRC is decreased by 20% or more; decreased compliance occurs. Care should be taken to provide for free chest excursion. Hypoventilation may occur in a spontaneously breathing patient.
- **Nerve issues:** Guard against damage to the brachial plexus; arms should be placed in the swimmer's position or tucked at sides, with the shoulders still at an angle less than 90 degrees.

LATERAL DECUBITUS POSITION

The lateral decubitus position is a side-lying position.

With the patient on either the right or left side; clarify that the neck is in straight alignment with the spine and the head by placing folded towels or blankets under the foam head ring. There should be a two finger-breadths gap between the sternum and the chin. Check the "down" ear to make sure the pinna is flat and not folded. An axillary roll is placed under the dependent axilla; it is positioned slightly caudad to the axilla to provide an outlet and prevent compression of the brachial plexus. *Caution: An axillary roll can cut off circulation.*

The arm on the unaffected side (down side) is extended on an armboard with the shoulder at an angle less than 90 degrees, through use of a Velcro strap or taped to secure it. The arm on the affected side (up side) is supported on 1–2 pillows with the shoulder at an angle less than 90 degrees.

Two-inch tape can be used to secure the upper arm with pillows to the bed frame; protect the upper arm skin with a pad of gauze or a towel before taping it. The torso may be stabilized by kidney rests, pillows, or sandbags. The leg on the unaffected side is extended and the uppermost leg is flexed with a pillow placed between the legs. Adequate padding is needed for the ankles, feet, and knees. Protect and pad all bony prominences. This position is secured by use of wide adhesive tape at the shoulder, thighs, and legs, fastened to the underside of the table.

Equipment needed for this patient position includes beanbags, special hip pads, pillows, and overhead armboard for upper arm, and axillary rolls (blankets, foam).

- **Cardiac issues:** Minimal alterations are usually necessary unless the patient is hypovolemic. Check the pulse/capillary refill on the patient's lower arm/hand.
- **Pulmonary issues:** Ventilation/perfusion (V/Q) ratio mismatching may occur. The FRC is decreased in the dependent lung and increased in the non-dependent (upper) lung; the dependent lung is prone to atelectasis and fluid accumulation because it is below the left atrium. Lower lung excursion may be aided with axillary rolls, which lifts the chest and decreases pressure on brachial plexus.

Lateral Decubitus Position: Awake, Spontaneous Breather

- V/Q ratio is *not* greatly altered!
- Ventilation and perfusion are increased proportionately to the dependent lung.
- The distribution of the V/Q ratios of the two lungs is not greatly altered when the awake patient is in the lateral decubitus position.
- The V/Q ratio decreases from the non-dependent to the dependent lung, just as it does in upright and supine lungs.

Lateral Decubitus Position: Anesthetized Patient, Not Spontaneously Breathing

- The distribution of the V/Q ratios of the two lungs *is* altered when the anesthetized patient is in the lateral decubitus position.
- The dependent lung continues to receive more blood flow.
- The dependent lung receives significantly less ventilation because it is less compliant, has a lower FRC, and is weighed down by the abdomen and mediastinum.

- **Nerve issues:** There is a risk of brachial plexus injury or suprascapular nerve injury with the lateral decubitus position. Brachial plexus injury is a frequent complaint after lateral positioning. Traction and stretching of the brachial plexus comes from rotating the head away from the surgical field, elevating the ipsilateral shoulder and placing traction on the arm. Make sure the suprascapular neurovascular bundle is not stretching in the lateral position.

A patient in the lateral position is at increased risk for nerve damage and is at significant risk for injuries to neurovascular structures along with injuries to soft tissues. Pressure on the dependent eye, exacerbated by intraoperative hypotension, can cause retinal artery thrombosis, resulting in postoperative vision loss.

FLEXED LATERAL DECUBITUS POSITION

In the flexed lateral decubitus position, the patient is in a side-lying position with the bed flexed so that the head and feet are lower than the patient's mid-section. The break in the bed should be at the flat area of the iliac crest. This position spreads the thorax and costal margin to iliac crest distance.

- **Cardiac issues:** increased venous pooling.
- **Pulmonary issues:** similar to issues for the lateral decubitus position unless the patient is positioned incorrectly.
- **Nerve issues:** brachial plexus injury, suprascapular nerve injury.

PATIENT POSITIONING ON A FRACTURE TABLE

The fracture table is a special table used for reconstructive and reparative orthopedic surgeries; it contains radiolucent abductor bars and a perineal post (Figure 2-1). The patient is placed in the supine position; his or her feet are secured in foot boots with Velcro taping. Traction is applied to the affected leg, raised at an upward tilt of 10 degrees. The nonsurgical leg is relaxed and kept as low as possible. The perineal post is well padded to prevent pudendal nerve injury and skin necrosis, but fits snugly against genitalia to secure the patient's body. A C-arm machine is used to take X-rays intraoperatively.

For a male patient, the scrotum may need to be padded, pulled gently upward, and adhered to the abdomen to prevent lateral X-ray imaging.

- **Cardiac issues:** aortocaval compression with obesity.
- **Pulmonary issues:** decreased functional residual capacity.

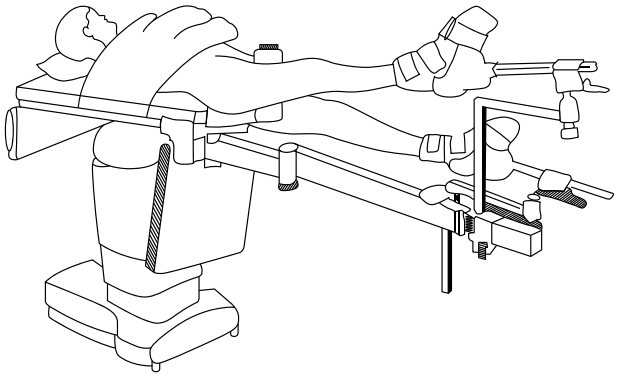

Figure 2-1 *Fracture Table*

- **Nerve issues:** vulvar or penile/testicular injury—can occur from the fracture table post placed between legs.