# 21 ANESTHESIA IN SPINAL SURGERY

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The role of anesthesia and the anesthetist in spinal (spinal cord) surgery is critical not only in the intraoperative period, but in the whole perioperative period through the duration of postoperative rehabilitation and eventual discharge. The anesthesiologist is responsible for providing appropriate surgical anesthesia during surgery together with maintaining the patient's normal respiratory and cardiovascular functions and providing sufficient pain control in the postoperative period. In the optimal fulfillment of this responsibility the compatibility between the surgical and anesthetic teams is of vital importance.

Especially before non-routine surgical approaches, information should be exchanged between the surgical and anesthetic teams about the patient and surgical plan and preparations need to be completed with this aim.

## Evaluation Before Surgery (Preoperative)

Before the patient is taken for spinal surgery *("preoperative")* evaluation by the anesthesiologist includes requesting necessary laboratory and imaging examinations, completion of consultations and preparations (preparing blood and blood products, organizing intensive care, etc.) to reduce possible life-threatening risks and prevent intraoperative and postoperative complications to the maximum degree.

Additionally, informing the patient and their family about the anesthesia and aftercare (venous/arterial catheters, foley catheter, possible duration of intensive care, postoperative pain control), answering any questions and obtaining written permission about these topics both solidifies the patient-doctor relationship and provides objective support for possible medico-legal problems.

## Premedication

Taken two hours before an operation 600 mg gabapentin has been shown to lower postoperative pain, and reduce opioid use and linked side effewctsw [1]. Our experience confirms these published findings. Before surgery, 300-600 mg oral gabapentin while helps postoperative pain control, while also providing a light sedation and strong anti-hyperalgesic effect.

Additionally for anxiety before surgery 0.5 mg alprazolam or 5 mg diazepam (0.05-0.2 mg/kg) taken the previous night is very effective. Midazolam, due to its amnesic effects and lack of oral formulation, is limited to intravenous (iv) administration immediately before the operation.

The anesthesiologist should check and confirm the patient's identity and type and level of operation before the patient is taken to the operating theatre to prevent confusion of individuals.

## Intraoperative Monitoring

Spinal surgeries, when compared to other surgeries, have characteristics that cause difficulty to the anesthetist, which include the long duration, the high possibility of hemorrhage during surgery, and the patient being in a face-down position and experiencing

severe pain after surgery. All spinal surgery patients, as with other surgery patients, undergo minimal standard monitoring as accepted by the American Society of Anesthesiology (ASA)[2]:

- Pulse oximetry
- End-tidal CO2 monitoring with capnograph
- Continuous ECG monitoring
- Arterial blood pressure
- Continuous body temperature monitoring if body temperature changes are expected

The use of monitoring choices other than those listed above (central venous pressure measurement, invasive arterial blood pressure monitoring, urine monitoring with foley catheter, BIS measurement, SSEP tracking) is decided by the anesthesiologist according to the patient's general situation, and the type and duration of the operation. In general use, invasive arterial blood pressure tracking for patients with cardiovascular instability and surgeries with expected blood loss-fluid shift, if there are no contra-indications, and in accordance with the patient's medical condition, is provided by a 20 G catheter, which is placed in the radial artery either before or just after induction. Central venous catheterization, especially when a massive transfusion is expected, is done in situations requiring a large and reliable venous entry. Central venous pressure measurements, while not frequently done due to misleading high readings linked to the face-down position, may be a relative marker for fluid balance changes.

During anesthesia induction, the choice of propofol (2-2.5 mg/kg), thiopental (3-5 mg/kg) or etomidate (0.1-0.4 mg/kg) administered through iv, is determined by the patient's general condition, together with their cardiovascular condition; if the patient has experienced trauma hypervolemia or cord pressure with perfusion, abnormalities are determined. To hold blood pressure changes at minimal levels after the anesthesia induction with etomidate or high-dose opioid use (fentanyl, 50-150 mcg/kg), the use of fentanyl (0.7-2 mcg/kg) as an adjuvant, in addition to other anesthetic agents, is a very effective method in suppressing the reaction of the sympathetic nervous system to the larygnoscopy. Routinely used during tracheal intubation, medium-term effective non-depolarizing muscle relaxants, rocuronium (0.6-1.2 mg/kg), vecuronium (0.08-0.01 mg/kg) and cisatracurium (0.15-0.2 mg/kg), have high reliability profiles. Especially for patients with spinal damage after acute trauma, the use of muscle-relaxant depolarizing agent succinylcholine is contraindicated for spinal surgeries within 3-180 days.

Denervation developing after trauma, together with the increased number of acetylcholine receptors at the neuromuscular junctions spreading to the muscle membranes, means the use of depolarizing medication may depolarize these receptors, releasing massive amounts of potassium from the muscles, which causes the development of hyperkalemia[3]. This situation can result in a very serious tableau, ranging from secondary arrhythmias to cardiac arrest.

Endotracheal intubation maintains a safe and open airway, and is essential in providing appropriate ventilation and anesthesia with anesthetic gases. In routine use,7-7.5 mm internal diameter spiral cuffed endotracheal tubes (ETT) are used for adult women, with a 8-8.5 mm internal diameter used for men. The spiral tubes are prevented from moving out of place by their internal coil, which provides a more reliable airway in the face-down position compared to classic ETT.

Especially with cervical trauma or with the presence of a narrow channel, conscious fiberoptic intubation allows minimal neck extension; or for anterior an approach thoracic instrumentation, and single-lung ventilation techniques which allow ease in viewing the surgical site, should be kept in mind. After induction, following the patient being turned from the supine to the face-down position, the ETT placement and equal ventilation of both lungs should be checked again as it is necessary to confirm the tube position has not changed.

## Face-down (Prone) Position

Another way in which the anesthetic approach to spinal surgery requires attention is regarding the patient's face-down position. In routine practice, after anesthesia induction and tracheal intubation on a stretcher, the patient is turned to a face-down position.

While the patient is being turned, it is important that the anesthesia is sufficiently deep, that no cough reflex or sympathetic response occurs, and that the patient maintains a stable cardiovascular course.

For patients with unstable cervical or thoracic spinal damage, a neck extension linked to intubation and positioning under anesthesia, may be a risk factor for the development of new neurological damage. In this case, conscious intubation, followed by conscious turning into face-down position and anesthesia, the induction may be started after neurologic evaluation.

In all prone position surgeries, it is necessary that the patient's bodily pressure points be softly supported. The neck and extremities should be in a neutral position with eyes, nose and genital organs protected from pressure. Regions and peripheral nerves that require special attention include; the elbow and ulnar nerve, the pelvis and lateral femoral cutaneous nerve, the lower lateral region of the knee, and the common peroneal nerve.

Additionally, it is necessary that the carotid-femoral and axillary artery and jugular veins are not left under pressure. The most definite cardiovascular effect of the prone position is the decrease in the cardiac index. The obstruction of the inferior vena cava lowers the cardiac output causing this effect. This situation brings increased surgical bleeding.

The obstruction of the venous return may cause blood to return to the heart via the vertebral column venous plexus. The distension of these veins and increased bleeding, may lead to a point where the view of the surgical site is obscured [4].

In terms of pulmonary function, the most significant change is the increase in the functional residual capacity (FRC) [5]. The cause of this is that the weight is on the knees and supports them, allowing the abdomen and lower chest to comfortably expand under low pressure.

While discussing the possibility of observing various complications in different systems due to the prone position, these complications can be listed in order: ETT falling out of the airway, upper airway edema, hyperextenion or hyperflexion of the neck, reduction in brain perfusion linked to cervical rotation, ischemic optic neuropathy linked to increased orbital pressure in the eyes, or blindness linked to central retinal artery occlusion, supraorbital nerve damage, corneal abrasion, brachial plexus damage linked to arm strain in the upper extremities, ulnar nerve damage linked to pressure, femoral vein occlusion – deep vein thrombosis – vascular graft kinking linked to hip flexion in the lower extremities, peroneal nerve damage linked to compression of the fibula lateral, and lateral femoral cutaneous nerve damage linked to pressure on the iliac crest [6].

Additionally local tissue damage linked to direct pressure and contact dermatitis linked to body contact with cushions are other potential complications to be aware of. Ischemic optic neuropathy and blindness linked to increased intraocular pressure have been associated with spinal surgery in the prone position [7]. The most common reason for sight loss after spinal surgery is anterior or posterior ischemic optic neuropathy (ION). Rarer reasons include central retinal artery or vein occlusion and occipital lobe infarction. Risk factors for ION include diabetes *("diabetes mellitus")*, hypertension, cigarette use and intraoperative anemia together with hypotension [8].

## Antibiotic Prophylaxis

After spinal surgery, the rate of surgical site infection (SSI) is accepted to vary between 0.4-12 % [9]. The most frequently isolated pathogens from surgical wounds are staphylococcus aureus and epidermidis. Risk factors for infection include patient age greater than 60, cigarette use, diabetes, previous surgical infections, high body mass index and chronic alcohol use [10]. Infection treatment after surgery if surgical debridement and appropriate antibiotherapy are sufficient, may require longer hospitalization, late wound healing and increased cost. Antibiotic prophylaxis for SSI is routinely used before spinal surgery due to its effectiveness and low cost of administration. Antibiotic prophylaxis administered to protect against SSI may vary from 5-7 day treatment to a single dose before surgery; no significant difference has been found in their prevention of infection [11].

According to a guide published by the Center for Disease Control and Prevention (CDC), a single dose of first generation cephalosporin effectively prevents development of an antibiotic-resistant bacterial infection after surgery. Cefazolin penetration of subcutaneous tissue and intervertebral discs, reached by an appropriate serum concentration, is more than sufficient. Additionally cefazolin has a wide safety band in terms of toxicity, is widely available, and has an optimal antimicrobial spectrum, making it an ideal agent. An antibiotic dose given 30 minutes before surgical incision, even when repeated for

operations lasting more than 4 hours or with more than 1500 ml blood loss, has equal scientific significance to more than 24 hours use.

Although rarely seen, for patients with a history of allergies to cephalosporin, vancomycin or clindamycin are suitable alternative antibiotics.

## Thromboembolism Prophylaxis

According to a guide prepared by the North American Spine Society (NASS) on antithrombotic treatment in spinal surgery, while no clear ratio is given for elective spinal surgery, the risks of venous thromboembolism (VTE) and linked deep vein thrombosis (DVT) and/or pulmonary embolism (PE) are very low [12]. Linked to this, taking into account the postoperative risk of hemorrhage, routine administration of low molecular weight heparin or low-dose warfarin is recommended.

In determining treatment, the thrombotic risk factors for patients, should be considered, including long duration surgeries and malignancy, paralysis, spinal cord damage, and a history of hypercoagulability. Also routine use of compression socks and mechanical sequential compression devices (SCD) are recommended.

## Reducing Surgical Bleeding

Serious blood loss can be experienced during spinal surgery, especially during osteotomy. While waiting for the hemoglobin concentration to fall to 7-9 g/dl, compensatory tachycardia to start, and blood lactate levels to increase before the blood and blood product transfusion begins; these limits should be raised for patients who cannot tolerate blood loss, especially from a cardiovascular point of view. Transfusion infections (HIV 1:1,900,000 units, Hepatitis C 1:1,600,000 units, Hepatitis B 1:220,000 units), bacterial contamination, immunosuppression, transfusion reactions and "graft versus host reactions" are side effects. There are various approaches the anesthesiologist can take to reduce intraoperative bleeding and keep perioperative blood and blood product transfusions to a minimum. The most frequently used approaches include autologous blood collection before surgery and intraoperative transfusion, controlled hypotensive anesthesia, and "cell saver" use and muscle relaxant use to reduce the intra-abdominal pressure preventing expansion of the epidural vein. Recently the intraoperative use of anti-fibrinolytic agents is becoming more common. Of these, two, tranexamic acid and aprotinin, have come to the fore.

Aprotinin (bovine pancreatic trypsin inhibitor) inhibits trypsin, chymotrypsin, plasmin and kallikrein and linked factor XIIa, inhibiting both the intrinsic coagulation pathway and fibrinolysis. Apotinin's wide use and intraoperative hemorrhage-reducing properties are very effective. Since 2006, the safety of aprotinin use has been questioned as it increases the risk of postoperative renal failure, myocardial infarction, cerebrovascular events and death [13] it was banned by the Food and Drug Administration (FDA) in 2007, and taken off the market in 2008.

Tranexamic acid (trans-4-aminomethyl-cyclohexane-1-carboxylic acid/TXA) is a synthetic analogue of lysine. It binds to the lysine receptors on plasminogen molecules, inhibiting the plasmin activation of plasminogen, thus inhibiting fibrinolysis, and preventing clot degradation. While the side effects of tranexamic acid include headaches, numbness-weakness, confusion, color-vision abnormalities and allergic reactions; contraindications to use include active intravascular clotting activity, acquired defective color vision, subarachnoid hemorrhage, and hypersensitivity [14].

The Tranexamic acid dose shows a wide range in different studies. Loading doses from 2.5 mg/kg to 100 mg/kg, doses from 0.25 mg/kg/hr to 4 mg/kg/hr and infusion intervals from 1-12 hours have been noted [15]. We have administered a protocol of 10-15 mg/kg IV loading dose with 1 mg/kg/hr infusion or repeated 10-25 mg/kg doses every three hours until incision closure. Tranexamic acid has been shown to reduce intraoperative hemorrhage by 30% in spinal fusion surgeries with thoracic/lumbar instrumentation [16].

Again in the same study, while no significant difference was noted in the need for perioperative blood/blood product transfusions; another study found 49% less blood loss in spinal surgeries with instrumentation and an 80% less need for transfusion [17]. Tranexamic acid, with a wide safety interval has not been reported to have any significant association with thromboembolic complications.

## Controlled Hypotensive Anesthesia

Spinal cord blood flow autoregulation is similar to brain blood flow autoregulation, and with mean arterial pressure (MAP) between 50-100 mg, Hg maintains a stable plateau. There is a linear relationship with $CO_2$ between 15-90 mm Hg, and above 50 mm the Hg $PaO_2$ values do not change. For spinal surgery, 60-65 mm Hg is the target interval for controlled hypotensive anesthesia (CHA). During controlled hypotensive anesthesia, normal/high end-tidal $CO_2$ values are important to maintain brain and spinal cord perfusion.

In the prone position, due to fluid sequestration to the lower extremities fluid, replacement is necessary until organ perfusion is maintained by normal cardiac output.

Agents frequently used for controlled hypotensive anesthesia include remifentanyl, sodium nitroprusside, esmolol, labetolol, and nitroglycerin. CHA in scoliosis surgery has been shown to reduce bleeding by 55%, transfusion requirements by 53%, and shorten the operation duration [18].

## Maintenance of Anesthesia

In spinal surgery, while there are no definite boundaries in approaching how to maintain anesthesia, *total intravenous anesthesia* (TIVA) and *inhalation anesthesia* are the two basic methods.

In *total intravenous anesthesia* (TIVA), after anesthesia induction anesthetic agents (generally propofol 100-200 mcg/kg/min) and analgesic medication (generally opioid derivatives, remifentanyl 0.2-0.5 mcg/kg/min, morphine 0.5-10 mg/hr, fentanyl 0.02-0.2 mcg/kg/min) are administered by IV infusion. Generally, TIVA is accepted as a more stable anesthesia from a hemodynamic point of view, and provides easy titration. Additionally, studies showing it has less effect than inhalation anesthesia on somatosensorial evoked potential (SEP) and motor evoked potential (MEP) have been published [19].

In addition, there are disadvantages such as much higher costs, and as with the MAC values for inhalation agents, each patient may not have a definite numerical value for an effective dose, a slower "wake-up" test, no reliable venous entry (iv coming out during patient positioning, or 3-way tap left closed, forgotten, etc.) which may lead to insufficient anesthesia, and the patient being aware during the operation.

The most frequently used volatile agents for *inhalation anesthesia* are isoflurane, sevoflurane and desflurane. These agents provide an ideal anesthesia, in combination with intraoperative opioid infusion. Intraoperative fluid replacement is a topic with no definite consensus in terms of both used fluid types and amount. In cases of insufficient fluid replacement, patients may experience complications such as hypotension, hemodynamic instability and the development of renal failure; excess fluid replacement may lead to complications such as pulmonary edema and the development of congestive heart failure, tissue edema, bad wound healing, dilutional anemia, coagulopathy, and the late return of gastrointestinal motility [20]. The classic approach involves the fast prior to surgery eliminated within 3 hours, and hourly basic needs together with the calculated blood and urine loss, with an added third cavity loss of up to 2-10 mg/kg/hr depending on the surgery, and especially in long duration surgeries a large amount of iv fluid is used. More recently, an approach involving 4 ml/kg/hr basal infusion, together with 250 ml crystalloid fluid loading depending on blood loss and urine outflow, with colloids given earlier especially 6% hetastarch in a balanced salt solution has gained popularity. This approach should not be used where there is concern that high volume colloid use may, or will definitely, cause the development of coagulopathy.

## Monitoring Depth of Anesthesia

Awareness during spinal surgery anesthesia is not as frequently observed as in cardiovascular and obstetric surgeries. Even if the monitoring of depth anesthesia is very important in maintaining the level of anesthesia appropriate to surgery; in adjusting the patients waking time if a waking test is necessary, and in making sure that the patient is in no way conscious during the surgery. The most common and easiest method is by monitoring the bispectral index (BIS). BIS monitoring is an algorithmic system developed by Aspect Medical Systems. A 4 electrode band is placed on the patient's forehead, the electroencephalogram (EEG) and electromyogram (EMG) signals are statistically analyzed, and a unitfree number appears on the screen.

According to this a measurement, above 80 shows the patient is awake, while the target values for surgical anesthesia are between 40-60. A BIS monitoring value of "0" is accepted as isoelectric brain activity. Bispectral index monitoring does not predict movement or hemodynamic responses to pain stimuli as it does not measure analgesic depth [21].

Various studies have shown that BIS monitoring has reduced awareness rates during anesthesia by 82%, and has reduced anesthetic medication use rates in TIVA, and the intubation duration and post anesthetic care unit (PACU) stay time. Additionally it has been shown to reduce perioperative respiratory complication rates and re-intubation rates in PACU [22]. However, a controlled, randomized study on the cost of BIS use, the effects of patient awareness on costs, reduction of anesthetic medication use, and the long-term effects on both cost and patient mortality and morbidity is necessary.

## Intraoperative Spinal Cord Monitoring

During spinal surgery, mechanical compression and/or the development of ischemia in neural structures linked to vascular tension may cause neurological damage to the spinal cord. To avoid this situation, intraoperative spinal cord monitoring allows early diagnosis, and can allow for early reversal of the events that lead to this situation.

Intraoperative somatosensorial evoked potential (SSEP) shows the motor function index as vascular damage that may affect the lateral corticospinal and dorsal spinocerebral pathways leading to motor dysfunction or loss [23]. During this process, peripheral nerves in the extremities are stimulated; the signals in the appropriate cortical regions are recorded and read by electrodes positioned on the scalp [24].

During intraoperative somatosensorial evoked potential (SSEP) measurements anesthetic stability and depth, hemodynamics, blood volume, autoregulation of spinal cord blood flow and temperature tracking are important as SSEP values show variations linked to many factors.

Inhalation anesthetic agents such as halothan, enflurane, isoflurane and sevoflurane increase SSEP amplitudes, and have been shown to also increase latency in dose-linked fashion [25]. Opioids used as inhalation agents, while having minimal effect on EEG amplitude, may increase SSEP latency. Intrathecal morphine, given for pain control during surgery, or used for long-term for chronic pain, has no effect on SSEP [26]. In addition to its anesthetic effects, cortical ketamine, an NMDA antagonist, and an effective analgesic agent definitively increases SSEP amplitudes [27].

Etomidate increases both amplitude and latency, thiopental reduces both and midazolam does not affect amplitude while increasing latency [28]. Muscle relaxants do not affect SSEP, and may even eliminate muscle-related artifacts reducing electric interference and providing optimal measurements.

Epidural or intrathecal (not IV) local anesthetics increase SSEP latency and are contraindicated as they directly affect spinal cord messaging [29]. While the patient's age and neurologic condition before surgery affect measurements: cerebral palsy, myelomeningocele, Friedrich ataxia and other peripheral diseases record high variability and weak amplitudes. During SSEP recording in a hemodynamically stable normo-thermic patient, amplitudes with a 50% decrease and/or 2 millisecond or 10% latency increase are accepted as indicating spinal cord damage [30].

## Ending Anesthesia

Where and how spinal surgery anesthesia will end is generally planned before surgery, depending on the patient's general condition, and type of surgery. Mostly patients are extubated in the operating room, and after a short follow-up in the recovery room, are brought to the ward. Generally, before surgery, patients with bad medical/cardiovascular conditions, and those with unexpected intraoperative events (lengthened surgery, massive hemorrhage, hypothermia) are taken to intensive care after surgery.

After patient recovery, maintenance of good analgesic control, effective discharge of secretions by coughing, and a quick start to rehabilitation are very important.

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