



**Guidelines for the Anesthetic Management of Patients with Scoliosis
Undergoing Posterior Spinal Fusion Surgery**

I. Definition of scoliosis: **Lateral deviation of the normal vertical line of the spine by > 10 degrees**

II. **Classification of scoliosis:**

- A. Idiopathic
- B. Congenital: (Hemivertebrae; often associated with cardiac and urinary tract anomalies)
- C. Neuromuscular (Duschenne Muscular Dystrophy)
- D. Neuropathic (Spinal Cord Pathology (Spinal Dysraphism, Sequelae of Poliomyelitis, Spinal Cord Injury), Brain Pathology (Cerebral Palsy))
- E. Myopathic (Muscular Dystrophy, Amyotonia Congenita, Friedreich's Ataxia)
- F. Neurofibromatosis
- G. Mesenchymal and Connective Tissue Disorders (Marfan Syndrome, Ehlers Danlos Syndrome, Dwarfism, Rheumatoid Arthritis, Osteogenesis Imperfecta)
- H. Trauma

III. **Degree of Curvature:**

Cobb Angle: As the scoliosis severity worsens, the Cobb angle increases

- A. >40° surgery indicated
- B. >65° may have restrictive lung disease >100° patient may experience exertional dyspnea >120° alveolar hypoventilation

IV. **Respiratory Sequelae**

Two main factors significantly affect respiratory function in scoliosis patients: the degree of the curve and the association of neuromuscular disease. When the Cobb Angle exceeds 65 degrees, respiratory function is likely compromised. Pulmonary function testing may demonstrate the characteristic pattern of restrictive lung disease (decreased vital capacity, functional residual capacity, and total lung volume). The greatest reduction is in vital capacity. The alterations in lung volumes are caused by changes in chest wall compliance and the resting position of the thoracic cage, rather than parenchymal changes or lower airway obstruction. The primary abnormality in pulmonary gas exchange is ventilation-perfusion maldistribution. As the scoliotic deformity progresses, the work of breathing increases and alveolar hypoventilation predominates. Therefore, these patients may develop hypoxemia, hypercapnia, secondary electrolyte aberrations, and progress to pulmonary hypertension and respiratory failure.

V. Cardiovascular Sequelae

Right ventricular hypertrophy and pulmonary vascular hypertensive changes are frequent findings at the postmortem examination of patients with long-standing scoliosis.

VI. Preoperative Assessment

- A. Evaluate the location and degree of spinal curvature, the etiology of the scoliosis, the patient's exercise tolerance, respiratory function, and the presence of any coexisting diseases.
- B. A physical exam of the cardiorespiratory system should determine the presence of dyspnea, increased work of breathing, tachypnea, râles, wheezing, or signs of right heart failure.
- C. Preoperative neurologic deficits, if any, should be carefully sought and recorded.
- D. Based on the severity of the curve and the degree of respiratory impairment and other organ involvement, the following preoperative laboratory studies should be considered:
 1. Chest radiograph
 2. Electrocardiogram
 3. Echocardiogram
 4. Pulmonary Function Testing

5. Arterial blood gases
6. Coagulation Studies: Platelet count, Prothrombin time (PT) and Partial thromboplastin time (PTT)
7. Electrolyte panel
8. Liver function test

VII. Intraoperative Management

A. Positioning and Monitoring Devices

1. In addition to standard ASA monitors, an arterial catheter for blood pressure monitoring, lab draws and pulse pressure variation monitoring is important. This is ideally placed in the upper extremity to allow for easy access to the cannula during surgery.
2. Central access may be useful for administration of vasoactive infusions, fluid administration, to trend central venous pressure (although the absolute central pressure is always inaccurate due to positioning of the patient), and for postoperative care. Patients who are anticipated to require intensive care unit admission postoperatively should have a central line inserted for surgery.
3. A urinary catheter is used to monitor urine output.
4. Two forced air warming blankets are used to maintain normothermia. One is placed on the upper extremities and one on the lower extremities below the buttocks.
5. Extra care is taken when positioning these patients in the prone position to compulsively avoid compression of eyes/face and abdomen/genitalia, and to maintain neutral extremity position, particularly avoiding hyperextension of the shoulders. Pressure points should be well padded (elbows, pelvis, knees, ankles).

B. Neurologic Monitoring

Neurologic injury may occur from mechanical injury to the spinal cord or nerves during instrumentation, excessive distraction of the cord during rod insertion, or compromised perfusion of the spinal cord. To monitor spinal cord integrity during surgery, the neurophysiology team monitors intraoperative somatosensory evoked potential (SSEPs) as well as motor evoked potentials (MEPs). Good communication between the neurophysiology team, anesthesiologists and surgeons is critically important, tailoring the administered anesthetics to those known to least affect the quality of electrophysiological monitoring. Obviously, during intrathecal drug injection (see below), local anesthetics should never be injected into the subarachnoid space.

1. Somatosensory Evoked Potential monitoring allows continuous assessment of the integrity of the ascending/dorsal spinal cord columns by extracting and averaging the very low amplitude signal (microvolt range) of EEG activity in response to electrical stimulation of the upper extremity (control signals) and lower extremities (monitoring dorsal cord integrity and function).

2. Motor Evoked Potentials monitor the ischemia-sensitive ventral gray matter of the descending/anterior columns of the spinal cord, by electrically stimulating the motor cortex trans-cranially, and recording the induced motor activity distally. MEPs are checked intermittently by the neurophysiologist throughout the case, but have the advantage of providing instant feedback, as no averaging is required. Additionally, the amplitude of MEPs is much higher than those of SSEPs (in the millivolt range as compared to the microvolt range).

3. Anesthetic agents and physiologic perturbations may interfere with SSEP and MEP signals:

4. Anesthetic Effects on SSEPs

Volatile anesthetics produce a dose-dependent increase in latency and decrease in amplitude. Up to 0.5-1 MAC of a volatile anesthetic in the presence of nitrous oxide is compatible with *adequate* monitoring of SSEPs. However there is a high degree of inter-individual variability of response, and the overall quality of the SSEP is superior in the absence of volatile anesthetics and nitrous oxide.

Intravenous agents have minimal effects on cortical SSEPs, except etomidate and ketamine, which actually increase SSEP signal amplitude. Continuous infusion of propofol 100-200 mcg/kg/min is well-tolerated. Muscle relaxants improve SSEP recording because they suppress EMG activity and provide a “cleaner” background, however NMB will of course obliterate MEPs. High doses of continuously infused opioids are compatible with SSEP monitoring, but bolus doses of opioids and other sedatives should be avoided during critical stages of surgery to eliminate transient effects on the SSEP that may be confused with spinal cord compromise.

5. Anesthetic Effects on MEPs

a) MEPs are extremely sensitive to the inhibitory effects of volatile anesthetics. Doses as low as 0.25-0.5 MAC can suppress synaptic transmission. Nitrous oxide, although less suppressive than other inhaled agents, demonstrates a synergistic effect on amplitude depression when combined with other anesthetics.

b) During the spinal fusion, a physiologic and pharmacologic steady state should be maintained as best as possible to effectively use SSEPs and MEPs as monitors of spinal cord function. Any intraoperative neurophysiologic changes (increased latency, decreased amplitude, or complete loss of waveform) should be immediately reported to the anesthesiologist and surgeon. The team (anesthesiologist, surgeon and neurophysiologist) should then decide how to address the changes.

Alterations in physiologic parameters that alter the sensory and motor EPs	
Parameter	Effect
Hypothermia or Hyperthermia	↓
Anemia	↓
Hypotension	↓
Hypoxia	↓
Hypocarbica	↓

Anesthetic agents that alter the sensory and motor EPs		
Agent	Amplitude	Latency
Halothane	↓	↑
Desflurane	↓	↑
Isoflurane	↓	↑
Sevoflurane	↓	↑
Nitrous oxide	↓	↔
Barbiturates	↓	↑
Etomidate	↑	↔
Ketamine	↑	↔
Midazolam	↓	↔
Opioids	↔	↔
Propofol	↔	↔

C. Surgical Distraction of the Spine

1. After surgical exposure and placement of anchoring hardware the surgeon will begin to distract, or straighten, the spine. This is a high-risk time for neurophysiologic compromise. The surgeon should notify the anesthesiologist approximately 15 minutes prior to distraction to allow ample time for physiologic optimization (Reversal of induced hypotension and normalization of MAP, hemoglobin, temperature, etc.). Although patient characteristics and anatomy differ, a general guideline for this stage of the procedure is that the MAP should be maintained between 65-75 mmHg in standard risk cases and 75-85 mmHg in high-risk cases.

2. What to do if Neurophysiologic Signals Change

- a) Announce the change to the surgeon and OR staff
- b) Determine by asking the electrophysiologist:
 - (1) When did the change occur?
 - (2) What was the change?

- (3) Increased latency? Decreased amplitude?
Complete loss?
 - (4) Change in MEPs, SSEPs or both?
 - (5) Where is the signal change?
- c) Determine if anesthetic management (change in anesthetic gas administration, bolus IV drug administration) was coincident in time and therefore might be responsible. If so, try to correct (reduce gas concentration, etc.).
- d) Determine if a change in hemodynamics, specifically hypotension, is coincident with the change in monitoring. If so, correct.
3. Management of Neurophysiologic Signals Change. While surgeons address their contribution to new spinal cord dysfunction:
- a) Administer 100% oxygen
 - b) Increase the spinal cord perfusion pressure using a mean arterial pressure of at least 75 mmHg. Initiate infusion of dopamine if required to do so.
 - c) Optimize hemoglobin/hematocrit and coagulation status.
 - d) Turn off volatile anesthetics and nitrous oxide, if administered, and convert to TIVA.
 - e) If signals do not improve, discuss the following options with the surgeons, cognizant that after the anesthetic and physiologic parameters have been optimized, the ultimate management is their responsibility:
 - (1) Wake-up test, in which the patient is allowed to arouse to demonstrate neurologic function, then the surgery is resumed.
 - (2) Aborting procedure, in which the distracting rods are removed and the back is closed as expeditiously as possible.
 - (3) Administration of methylprednisolone 30 mg/kg IV (limited data to support efficacy).

- (4) Imaging of the spine under the same general anesthetic to rule out spinal cord compression due to an epidural hematoma. Note that this can only effectively be accomplished with a CT myelogram.

VIII. Planning for Postoperative Pain Management

- A. We have developed an intraoperative spinal fusion pathway for idiopathic scoliosis patients in order to decrease anesthetic management variability (see attached pathway below). The pathway calls for multimodal analgesia, with preoperative administration of celecoxib and pregabalin, administration of intrathecal morphine by the anesthesiologist after induction or by the surgeon after exposure of the spine, an anesthetic based on TIVA using infusions of propofol and remifentanyl, and intraoperative administration of intravenous acetaminophen at the onset of the case and every 6 hours.
- B. The Pediatric Pain Management Team manages patients postoperatively. The post-op pain regimen includes patient controlled analgesia with hydromorphone, oral pregabalin, intravenous acetaminophen, and ketorolac if drain output is as expected. The inpatient pain team should be notified by the anesthesia team at the end of the case as closure of the back begins.

IX. Blood Loss

Due to the large area of decorticated bone exposed in spinal surgery, there can be extensive blood loss. The healthy teen with idiopathic scoliosis usually will not require transfusion in the operating room, but case-end hemoglobin is usually as low as 7–8gm/dl. Children with other etiologies of scoliosis will almost always require intraoperative blood transfusion.

- A. Aminocaproic acid (Amicar) is used for most cases.
- B. Red blood cell scavenging (“Cell Saver”) is used for all patients undergoing spinal fusion surgery who do not have malignancies. Cell Saver red blood cells may be returned to the patient when the collection reservoir contains 2L of blood and saline; usually this is at the end of the case. Be cognizant that Cell Saver blood contains heparin, and significant volumes of retransfused blood may induce a coagulopathy.
- C. There must also be Blood Bank blood available for the patient in the room at all times. Patients who are transferred to the PICU from the OR postoperatively should be accompanied by one unit of PRBCs (similar to transplant and cardiac patients).

****See below for attached Perioperative Pathway for Idiopathic Scoliosis Patients****

LPCH Perioperative Pathway for Idiopathic Scoliosis Patients Undergoing Posterior Spinal Fusion Surgery

Pre-operative

- **Pregabalin** (max dose 300 mg):
 - 2 mg/kg PO (suspension or capsules)
 - Dose rounded up to nearest 25 mg
- **Celecoxib**:
 - If 10-24.9 kg: Celecoxib 50 mg PO
 - If 25-49.9 kg: Celecoxib 100 mg PO
 - If ≥ 50 kg: Celecoxib 200 mg PO
- Consider IV or oral **midazolam** for premedication
- Team Communication: Number of levels, neuromonitoring plan (MEP, EMG, SSEP), anticipated blood loss, use of cell saver, blood availability, is this a “high risk” case, postoperative disposition?

Intraoperative

- Secure airway, cover eyes, place bite block, temperature probe, forced-air warming blankets
- *Consider* using processed EEG to monitor anesthetic depth or ask neuromonitoring team to provide input on anesthetic depth
- Antibiotic prophylaxis as ordered by surgeon (verify before administering)
- Unless a contraindication exists, preoperative antibiotic prophylaxis consists of:
 - **Cefazolin** (30 mg/kg IV q 3hrs), and
 - **Gentamicin** (1 mo-17 yrs: 2.5 mg/kg IV, no re-dose; ≥ 18 yrs: 5 mg/kg IV, no re-dose)
- **Aminocaproic acid**: 100 mg/kg IV bolus over 15 min (max 5 g), then 10 mg/kg/hr IV¹
- Line Placement- usually 2 large bore IVs and arterial line. For high-risk pathway patients going to PICU, consider a central line.
- **Acetaminophen** 15 mg/kg IV at start of case and redose at 6 hours if still in OR
- **Intrathecal (IT) preservative-free Morphine 5 mcg/kg^{2,3}**
 - Use the 0.5 mg/mL concentration PF morphine vial, maximum dose 500 mcg
 - Consider administering pre-incision via spinal (especially if surgeon does not plan to expose low lumbar segments)
 - If not feasible, request that surgeon administer IT morphine as early as possible in the case

- Call to notify Acute Pain Service 650-724-6000 regarding patient, dose, and time of administration and document in chart
- **If contraindication to IT Morphine Exists**
 - Administer long-acting opioid if appropriate

Anesthetic Maintenance

- Intravenous anesthetic maintenance:
 - **Propofol** (Suggested dose range 100-250 mcg/kg/min)
 - **Remifentanyl** (Suggested dose range 0.05-0.25 mcg/kg/min)
- Use up to 0.5 MAC **isoflurane** to titrate MAP to desired level
- Check regular blood gases
- The surgeon may decide to administer **Liposomal Bupivacaine** to patients (typically \geq 15 yrs old) near the end of the procedure
 - Consider the implications of local anesthetic administration and (potentially) reduced postoperative pain

Transfusion Management

- Calculate Estimated Blood Volume
- Calculate Allowable Blood loss
- Discuss indications for transfusion with your attending early in the case
- Have unit dose of PRBCs in the OR cooler
- Cell saver: Call anesthesia tech # 10246 to spin cells
- Transfuse when clinically indicated or when Hgb \leq 7.0

Incision Closure/Emergence

- Check ABG 1 hour prior to transport
- If EBL \geq 1 blood volume, check coagulation labs
- **Ondansetron** 0.1 mg/kg IV (up to 4 mg) during incision closure

Transport to PICU (if applicable)

- Bring 1 unit PRBCs to PICU in cooler
- If **vasoactive medications** used to support blood pressure within 1 hour of transport, notify PICU attending/fellow (#78850) and bring infusion (even if infusion discontinued)

References:

1. Florentino-Pineda I, et al. The Effect of Amicar on Perioperative Blood Loss in Idiopathic Scoliosis: The Results of a Prospective, Randomized Double-Blind Study. *Spine* 2004, 29(3):233-8
2. Gall O, et al. Analgesic Effect of Low-dose Intrathecal Morphine after Spinal Fusion in Children. *Anesthesiology* 2001; 94:447-52

3. Eschertzhuber S, et al. Comparison of high- and low-dose intrathecal morphine for spinal fusion in children. *BJA* 100(4): 538-43 2008

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