



**Pediatric Anesthesia  
& Pain Management**

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**Guidelines for the Anesthetic Management of Spine Fusions and SSEP Monitoring**

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## Guidelines For The Anesthetic Management Of Spine Fusions And SSEP Monitoring

### Preoperative Assessment

- A. Determine the location and degree of spinal curvature, the etiology of the scoliosis, the patient's history of exercise tolerance, respiratory symptoms, and the presence of coexisting diseases.
- B. A physical exam of the cardiorespiratory system should evaluate the presence of tachypnea, crackles, wheezing, and signs of right heart failure.
- C. Preoperative neurologic deficits, if any, should be recorded.
- D. Based on the severity of the curve and the degree of respiratory impairment, the following preoperative laboratory studies should be ordered:
  1. Chest radiograph
  2. Electrocardiogram
  3. Echocardiogram
  4. Pulmonary Function Tests
  5. Arterial blood gases
  6. Spirometry (FVC, FEV1, FEV1/FVC)
  7. Lung Volumes (TLC, FRC, RV, FRC/TLC, RV/TLC)
  8. Coagulation Studies: Platlet count, Prothrombin time (PT) and Partial thromboplastin time (PTT)
  9. Electrolyte panel
  10. Liver function test

### Respiratory sequelae

- A. Two main factors significantly affect respiratory function in scoliosis patients: the degree of the curve and the association of neuromuscular disease. When the scoliotic curve exceeds 65 degrees, respiratory function is compromised. Pulmonary function tests demonstrate the characteristic pattern of restrictive lung disease (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 become chronically hypoxemic, hypercapnic, and at risk for developing pulmonary hypertension and respiratory failure.

### Cardiovascular Sequelae

- A. Mitral valve prolapse is found in 25% of patients with scoliosis as compared to less than 10% of age matched controls.
- B. An increased association of scoliosis in children with congenital heart disease is well documented.
- C. Right ventricular hypertrophy and pulmonary vascular hypertensive changes are frequent findings at the postmortem examination of patients with long standing scoliosis.

***Neurological exams as essential preoperatively in order to see if any adverse sequelae have occurred postoperatively.***

## **Positioning and Monitoring Devices**

- A. In addition to the monitors routinely used in conducting a pediatric general anesthetic, an indwelling arterial catheter and central venous cannula are essential. A pulmonary artery catheter may be substituted for a central venous catheter if significant myocardial dysfunction is found during the preoperative cardiac evaluation.
- B. An indwelling urinary catheter (Foley) is essential to monitor urinary output and to assess the adequacy of the circulating blood volume.
- C. Aggressive strategies are required to avoid intraoperative hypothermia. Body temperature can fall significantly during the spinal procedure due to the large surface area exposed and due to the administration of blood products.
- D. Extreme care must be taken when positioning these patients since brachial plexus injuries and retinal artery occlusions will occur with hyperextension of the shoulder or compression of the globes.

## **Neurologic Monitoring**

- A. Postop paralysis and/or sensory loss are devastating complications of scoliosis surgery. Neurologic injury may occur from direct injury to the spinal cord or nerves during instrumentation, from excessive traction during distraction, or from compromised perfusion of the spinal cord. To minimize the risk of these neurological injuries various methods of intraoperative monitoring have been used.
  - 1. Intraop wake-up test: patients are awakened intraoperatively to assess spinal cord motor function. The wake-up test requires an anesthetic that allows rapid recovery of consciousness and motor function. If the patient is unable to move his feet but can move his hands, spinal cord compromise is presumed, and the spinal rod instrumentation is removed immediately. The wake-up test has its limitations, however. It tests only the anterior spinal cord (motor function) and not the dorsal column (sensory), and it requires patient cooperation so it cannot be used in patients with cognitive impairment. Also, spinal injury may be missed because it occurred after the wake-up test was performed.
  - 2. Somatosensory evoked potentials This technique allows continuous assessment of spinal cord function and does not require patient movement, arousal or cooperation. The cortical and subcortical responses to peripheral nerve stimulation are monitored.
    - a. Various pharmacologic and physiologic variables affect the latency and amplitude of SSEP and have been estimated to account for up to 44% of intraoperative SSEP changes.
    - b. Pharmacologic factors: The potent inhalation agents tend to increase latency and decrease amplitude in a dose-dependent fashion. In general, up to 0.5 to 1.0 MAC of the inhaled agents in the presence of nitrous oxide is compatible with the monitoring of cortical SSEPs. N<sub>2</sub>O alone or in combination with an opioid or inhalational anesthetic, causes a decrease in amplitude without changes in latency. Although opioids have a similar effect on the SSEP as the inhalation agents, higher doses of opioids can be used with reliable and reproducible SSEP monitoring.
    - c. Physiologic factors: Various factors including blood pressure, PaO<sub>2</sub>, pH, hematocrit, and temperature, can influence SSEPs. A decrease in mean arterial pressure below the autoregulation level, can result in a progressive decrease in amplitude. Hypoxemia adversely affects SSEPs. A hematocrit below 15%

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- causes increase in latency and variable changes in amplitude. Hypothermia increases latency and decreases amplitude and hyperthermia decreases amplitude.
- d. Pathologic factors/Instrumentation: Injury along pathways involved in the generation of evoked potentials or impairment of their blood supply will result in abnormal SSEPs.
  - e. Throughout the actual surgical procedure a physiologic and pharmacologic steady state must be maintained to effectively use SSEPs as monitors of spinal cord function. By maintaining a steady state of anesthesia any intraoperative changes of increased latency, decreased amplitude, or complete loss of waveform can be attributed to spinal cord injury rather than pharmacologic effects.
  - f. Surgical manipulation and induced hypotension may in concert produce neurologic injury. Normalization of the SSEPs may occur spontaneously, with relaxation of the distraction instrumentation, or by improving spinal cord perfusion (increasing blood pressure, arterial carbon dioxide blood levels, etc).

## Anesthetic Management and Postoperative Care

- A. Most older children prefer IV induction of anesthesia. Thiopental 1-2 mg/kg or propofol 2 mg/kg are commonly used for induction of anesthesia along with a nondepolarizing muscle relaxant to facilitate tracheal intubation. Vecuronium in a dose of 0.1 to 0.15 mg/kg IV, rocuronium in a dose of 1 mg/kg or pancuronium in a dose of 0.1 mg/kg can be used for tracheal intubation and any of these muscle relaxants can be used for maintenance of muscle paralysis. It is important to maintain adequate muscle relaxation during the operation because increases in muscle tone can raise venous pressure and increase bleeding.
- B. Younger children prefer an inhalational induction which can easily be provided with halothane or sevoflurane. A muscle relaxant is again given to facilitate tracheal intubation after securing IV access.
- C. Two popular techniques for maintenance of anesthesia are
  1. Opioid/propofol/nitrous oxide/oxygen/relaxant technique and
  2. Halothane or isoflurane in oxygen ( $\pm$  nitrous oxide)/relaxant/opioid. The opioid can be given IV, or in the intrathecal space. Continuous IV infusions of an opioid (fentanyl, alfentanil or remifentanil) have been used to provide optimal conditions for anesthesia, surgery and SSEP monitoring. Alternatively, intermittent injections of opioid can be given. If intrathecal morphine sulfate is given then usually no adjuvant IV opioids are administered. A typical dose of intrathecal morphine would be 5-10mg/kg. A low dose of volatile agent may be used with the opioid even when SSEPs are being monitored.
- D. Deliberate Hypotension: see below
- E. Post-op pain management including patient controlled analgesia and epidural opioids  $\pm$  bupivacaine have been used with success after scoliosis surgery. The epidural catheter is often placed by the surgeon, under direct visualization after a posterior fusion, and by the anesthesiologist, using loss of resistance, in an anterior fusion. The epidural solution is usually a combination of hydromorphone 3mg/cc with bupivacaine 0.1%. The epidural infusion is run at a rate between 0.1-0.5 cc/kg/hr. If the child is able to comprehend the concept of a PCA often a PCEA (patient controlled epidural analgesia) can be used. With a PCEA the solution used is hydromorphone 25 mg/cc with bupivacaine 0.1%. A basal rate is delivered and the dose is dependent on the patient's weight and the location of

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the epidural catheter. A PCA dose of 1-3 cc is given with a lockout interval of 30 minutes.

- F. After scoliosis correction all children should be cared for in an intensive care environment.

### Blood Loss

- A. Due to the large area of decorticated bone exposed in spinal surgery, there can be extensive blood loss. Because blood loss can be difficult to accurately assess (blood on gowns, drapes, on the floor, sponges, third space losses, etc.) it is important to measure the hemoglobin concentration frequently and to follow filling pressures via the CVP line. A urinary catheter can also be used to closely monitor urine output as another means of assessing volume status.
- B. A coagulation profile should be measured to determine whether FFP, cryoprecipitate, or platelets are required after the replacement of one blood volume.
- C. Multiple techniques have been described to minimize blood loss and need for blood transfusions. Predonation of autologous blood is occurring more frequently. Isovolemic hemodilution can substitute for or augment autologous blood donation. Deliberate hypotension can be used in any patient who is otherwise healthy. Blood salvaging techniques have also been used effectively but are usually practical only in children weighing over 10 kg.
- D. Isovolemic hemodilution: the main physiologic advantage that results from this process is a reduction in blood viscosity by withdrawal of a calculated volume of the patient's blood, after the anesthetic induction, and is then accompanied by simultaneous replacement of crystalloid or colloid to maintain near-normal blood volume. The patient's own fresh blood is reinfused near the end of the surgical procedure after major blood loss has ceased.
  - 1. Contraindications: when there is evidence of end-organ dysfunction (pulmonary, cardiac, renal, neurologic, or hepatic diseases), when there are significant hemoglobinopathies (sickle cell or sickle-C disease), and in clotting disorders.
  - 2. Indications: useful for infants and older children in whom the anticipated blood loss is expected to exceed 15% of their blood volume, patients who refuse blood transfusion (i.e., Jehovah's Witnesses), and patients who have a rare blood type and are therefore difficult to cross-match.
  - 3. Protocol for Hemodilution: 1) the parents must be fully informed about the risk of hemodilution and 2) a complete preop history, with particular attention to a history of decreased cardiorespiratory reserve and impaired neurologic and renal function, should be obtained. To maximize the preop hemoglobin concentration, oral iron therapy and recombinant erythropoitin should be considered.

The volume of blood to be removed during hemodilution can be estimated by the following formula

$$V = EBV \times (H_O - H_F) / H_{AV}$$

V= volume of blood to be removed, EBV= estimated blood volume, H<sub>O</sub>= initial hematocrit, H<sub>F</sub>= minimal allowable hematocrit after dilution, and H<sub>AV</sub>= average of initial and minimal hematocrits.

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- E. Controlled hypotensive anesthesia: main purpose is to decrease blood loss, thereby improving operating conditions or decreasing the need for blood transfusions.
1. Indications: it is appropriate for most surgical procedures that require a "bloodless field", a reduction in blood loss, and possibly a shortened operating time. Examples of cases include neurosurgical, orthopedic, and craniofacial reconstruction cases. This procedure is also indicated when religious beliefs preclude blood transfusion.
  2. Contraindications: a physician's lack of understanding of the technique or lack of technical expertise, inadequate postoperative care, focal or generalized decreased organ blood flow, elevated intracranial pressure, anemia/hemoglobinopathies, polycythemia, or an allergy or sensitivity to the hypotensive agent.
  3. Drugs commonly used:

Volatile anesthetic drugs: Isoflurane is probably the volatile anesthetic of choice for controlled hypotension because studies with isoflurane-induced hypotension indicate that the decrease in cerebral blood flow is less than or equal to the cerebral metabolic rate for oxygen.

Sodium nitroprusside (50 mg/bottle) is reconstituted in 5% dextrose in water (500 ml) to give a 0.01% solution. The infusion rate should begin at 0.1 m g/kg/min and can be increased up to a maximal rate of 8 to 10 m g/kg/min. The maximal recommended dosage of nitroprusside is approximately 2 to 3 mg/kg/day.

Esmolol is a good agent because of its rapid onset, its short and titratable action and its cardioselectivity. A loading dose of 500 m g/kg/min for 2-4 minutes is given and then it is followed by a constant infusion of 300 m g/min. Propranolol can be given in slow incremental doses up to a total dosage of 0.06 mg/kg.

Clonidine is an alpha<sub>2</sub> agonist that has been used to decrease blood pressure. 30-60 minutes is needed in order to see an effect. In children a dose of 5-25 m g/kg/24 hours divided q6 hours can be given.

Nicardipine is an intravenously administered calcium channel blocker. Its primary physiologic actions include vasodilation with limited effects on the inotropic and dromotropic function of the myocardium. A loading dose of 5 to 10 m g/kg/min is needed to obtain a mean arterial pressure of 50-65 mmHg and then a constant infusion of 1 to 7 m g/kg/min is needed in order to maintain this pressure during the case. The advantages of nicardipine over sodium nitroprusside include lack of toxic metabolites, limited reflex increases in heart rate, and no rebound hypertension.

- F. Autotransfusion (Cell Saver): the benefits of using cell saver is that the salvaged RBCs are immediately available, type-specific, compatible, and normothermic, without the risks of homologous blood transfusion. The shed blood is aspirated from the surgical field, mixed with anticoagulant and stored in a reservoir. When enough blood has been collected it is spun down and the RBCs are separated from the other blood components and can be used for transfusion.
1. Indications: the child must weigh more than 10 kg, the anticipated blood loss should be 20% or more of the estimated blood volume, and it can also be used for procedures in which more than 10% of patients are transfused with more than one unit.
  2. Contraindications: infants and small children less than 10 kg since an anticipated blood loss of 1 to 1.5 times the estimated blood volume is

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required before currently available blood salvage procedures are practical.

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