Chapter 13
Orthopedics: Scoliosis

Joseph P. Cravero

A 16-year-old female with idiopathic scoliosis is coming for instrumentation and posterior spinal fusion. She has a history of asthma. Weight 60 kg. *P* = 92 bpm, BP = 108/62 mmHg, RR = 20/min, temperature = 36.7 °C.

J.P. Cravero, MD, FAAP
Department of Anesthesiology, Perioperative, and Pain Medicine, Boston Children's Hospital, Boston, MA, USA

Harvard Medical School, Boston, MA, USA
e-mail: joseph.cravero@childrens.harvard.edu

R.S. Holzman et al. (eds.), *Pediatric Anesthesiology Review*,
DOI 10.1007/978-3-319-48448-8_13

Preoperative Evaluation

Questions

1. When does idiopathic scoliosis begin, which sex is more likely affected, and at what age is it generally diagnosed? How does this differ from neuromuscular disease-related scoliosis?

2. Her curve is 75°. Is this cause for concern? How would you assess her pulmonary function? Do you need pulmonary function tests? What type of pulmonary dysfunction is most common with this level of scoliosis? Does it matter if her scoliosis is due to neuromuscular disease or is idiopathic?

3. Do you need more information on her cardiac status? What type of cardiac disease would she be at risk for, and how would you diagnose the extent of her cardiovascular compromise (if any)? How would your considerations differ in a patient with non-idiopathic scoliosis such as that associated with Duchene muscular dystrophy?

Preoperative Evaluation

Answers

1. Scoliosis is a complicated pathological problem that involves lateral curvature of the spine. Idiopathic adolescent scoliosis (AIS) is the most common form of scoliosis and is found in 1–3 % of children/adolescents between 10 and 16 years of age. This accounts for 70 % of all cases of scoliosis. Females are affected 3.6 times as often as males. Neuromuscular disease-related scoliosis can have many causes including neuropathic disease (cerebral palsy, syringomyelia), myopathic disease (muscular dystrophy, amyotonia congenita), neurofibromatosis, mesenchymal disorders (Marfan's syndrome, Morquio disease, Still disease), or trauma. Although variable in nature, neuromuscular scoliosis often begins at an earlier age and progresses faster. It is ultimately more likely to require surgical correction.

2. Yes, there is cause for concern because curvatures of 65° or greater can cause significant restriction of ventilation. The need for pulmonary function testing would depend on her exercise tolerance. If she has excellent exercise tolerance, I would not pursue testing. As scoliosis becomes severe, the rotation of the vertebrae causes the ribs to form a rib hump and restrict the thoracic cage. Vital capacity, forced expiratory volume in 1 s (FEV), and PaO are all decreased. The FEV-to-FVC ratio is largely unchanged. A preoperative vital capacity of less than 35 % is considered a significant predictor of respiratory compromise in the perioperative time frame. Lung function should be optimized prior to surgery. Any lower respiratory tract symptoms or signs (rales, rhonchi, wheezing) should prompt a thorough evaluation and postponement of surgery. In these cases 4–6 weeks should pass before administering general anesthesia for correction.

3. Patients with severe scoliosis are at risk for chronic hypoxia, pulmonary hypertension, and cor pulmonale. Hypoxic pulmonary vasoconstriction is an ongoing risk in patients with chronic hypoxia. Right ventricular hypertrophy and (eventually) cardiomyopathy can result. Any patient with known or suspected cardiac disease should have a preoperative cardiac evaluation. An ECG to evaluate for ischemia or axis deviation is indicated as is an echocardiogram to determine overall function and structural anomalies. Compromised patients will require intraoperative cardiac monitoring with consideration for transesophageal echocardiography during the operative case. A central line for trending of central venous pressures and administration of vasoactive medications would also be indicated. Patients with Duchene muscular dystrophy often have a dilated cardiomyopathy with compromised left ventricular function. In these cases, the cardiac compromise would be expected to be more marked than that with idiopathic scoliosis and accompanying cardiac dysfunction.

4. Her asthma is only a problem when she has a cold. She is maintained on beclomethasone (Qvar®) inhaler bid. She uses an albuterol inhaler when she has active wheezing. Do inhaled steroids require perioperative coverage with "stress steroids?" She was on oral steroids 2 months ago for 2 weeks. Will she need perioperative steroids? How will you prepare her for the operating room?

5. Should she receive erythropoietin preoperatively? What are the relative advantages/disadvantages to autologous donation of blood vs. acute isovolemic hemodilution? What other methods are available to avoid blood transfusion?

6. She is needle phobic; she is crying and keeps pulling her hand away as you try to look for an IV. Should you premedicate – with what medications? Would you use nitrous oxide to help start the IV?

4. Inhaled corticosteroids such as beclomethasone, budesonide, fluticasone, and triamcinolone are the cornerstones of therapy for persistent asthma. While the use of these drugs can result in undeniable improvement in overall symptoms, inhaled corticosteroids are suppressive rather than curative. No clinically important adrenal suppression has been shown to occur with the administration of these medications in their recommended doses. Patients who have been taking systemic corticosteroids for more than 2 weeks in the prior 6 months are considered at risk for adrenal suppression in the setting of major surgery. In this case she would need perioperative systemic steroids. If she were recently on systemic steroids, I would obtain a pulmonary consult to check her current pulmonary function and her responsiveness to bronchodilators. I would prepare her by placing her on oral steroids for 4–5 days preoperatively and continuing for the week after surgery. I would also have her take her bronchodilator therapy during the perioperative period.

5. The use of perioperative erythropoietin therapy has been shown to increase hematocrit levels before and after scoliosis surgery. On the other hand studies have not shown that the administration of the drug decreases the exposure to transfused blood for patients undergoing scoliosis surgery. I would not administer the medication to this patient, but it could be considered in specific cases where preoperative anemia is a major concern. Autologous donation can be performed if the patient is over 50 kg and she is not anemic. The blood can be harvested from the patient and stored for as much as 6 weeks. Donation can occur twice weekly and can be done up to 72 h prior to surgery. There is some evidence that this practice can decrease the exposure to allogenic blood. It is critical to consider the extent of the surgery and the overall likelihood of transfusion. If the correction is going to be large and transfusion is a certainty, then I would offer autologous donation as an option for the patient. Acute normovolemic hemodilution (ANH) is a technique in which blood is removed from the patient around the time of induction of anesthesia. Circulating volume is maintained with colloid or crystalloid. As opposed to autologous transfusion, there is less chance of clerical error and administration of the incorrect blood – since it does not leave the operating room. In addition, the blood that is returned to the patient is fresh and contains all of the factors, 2,3 DPG, and normal electrolyte components of the patient's blood.

6. If the patient is severely anxious, I will offer oral midazolam as a premedication, 0.5–1 mg/kg with a maximum dose of about 15 mg. Yes, if the patient would tolerate a mask on her face, the use of 70 % nitrous oxide in oxygen is an alternative to facilitate intravenous access.

Intraoperative Course

Questions

1. What are the surgical approaches to scoliosis repair and how would they change your anesthetic management?

2. What monitors do you need? Is an arterial line needed? Is CVP monitoring important? Would a TEE be indicated? What are the advantages and disadvantages? Does the underlying cause of the scoliosis change your opinion on this matter?

3. What are somatosensory evoked potentials (SSEPs)? What are motor evoked potentials (MEPs)? What do each they measure? Are both needed? If they are normal, does this assure normal neurological function postoperatively? What does a wake-up test measure? Is it necessary if SSEPs and MEPs are both normal during the course of a correction?

Intraoperative Course

Answers

1. Surgical correction of scoliosis involves the placement of screws and rods on the lamina of the vertebrae to segmentally straighten the spine. After the adjustment and tightening, the vertebral bodies are roughened in preparation for the placement of bone graft with is packed into the intervertebral spaces. The correction can be done exclusively from the posterior approach or from an anterior approach – or an anterior release combined with a posterior fixation. For the anterior approach, the patient is supine, and, depending on the level of the defect, the abdomen or thorax may be entered, generally from the lateral aspect. For the posterior approach the patient must be prone with particular attention to pressure areas since the surgery time is generally prolonged.

2. In addition to standard monitors of ECG, blood pressure, end-tidal carbon dioxide, and percutaneous pulse oximetry, I will use intra-arterial blood pressure monitoring. The arterial line will provide ready access for blood samples during the case, and it provides an accurate measure of blood pressure on a beat-to-beat basis. The arterial pressure tracing can also be used to estimate the intravascular volume by evaluating the difference in systolic blood pressure between inspiration and expiration. Finally the arterial line could be used with a minimally invasive cardiac output monitor to further delineate hemodynamic responses to anesthesia agents and blood loss. I don't expect to use a CVP monitor in most cases. CVP will not offer additional information beyond the monitors mentioned above and is not without potential risks of air embolism, hemopericardium, pneumothorax, and arrhythmias. If the patient has a significant cardiomyopathy, then I would use the CVP to deliver vasoactive medications for support and control of blood pressure. A TEE would be helpful in cases associated with cardiomyopathy (muscular dystrophies) since it can give an excellent estimate of cardiac filling and wall motion abnormalities associated with ischemia. The probe may be difficult to insert and/or maintain in the prone position in a posterior spinal fusion, so significant advanced planning must take place.

3. SSEP monitoring measures electrical activity in ascending sensory pathways. Intraoperative SSEP monitors the integrity of the sensorineural pathways from the site of sensory neuron stimulation (caudad to the surgical site) to a site cephalad to the surgical site such as the brainstem or the prefrontal sensory cortex. The principal goal of intraoperative monitoring is the identification of nervous system impairment at the operative site in the hope that prompt intervention will prevent permanent deficits. The surgeon is alerted to the possible damage, and corrective action is taken to prevent the damage. SSEPs measure evoked electrical wave configuration, peak-to-peak intervals, absolute and inter-peak latencies, and comparative latency delays between the ipsilateral and contralateral pathways. They

4. What agents will you use for induction and maintenance of anesthesia? Are some induction and maintenance agents more compatible with SSEP and MEP monitoring? Does it matter? What muscle relaxant will you choose? How will you place and secure the ETT? What will you choose for maintaining the anesthetic? Will this choice affect the SSEP monitoring? Do you need a baseline reading of SSEP or MEP before starting surgery? How will you assure amnesia? Is a BIS monitor helpful? What is the utility of antithrombolytics in spinal fusion surgery?

measure the proximal neural electrical responses (brachial plexus, spinal cord, brainstem, or cerebral cortex) to peripherally applied standard sensory stimuli (such as median or posterior tibial nerves), thereby testing the integrity sensory pathways' function. No, because of the potential for false-positive and false-negative results. No, because wake-up test evaluates the gross motor function. Yes, motor evoked potentials (MEPs). MEPs are performed by electrical stimulation of the motor neurons directly or indirectly by trans-osseous stimulation. MEPs are more specific test of descending motor pathways but are not more specific or sensitive than SSEPs in detecting spinal cord injury during surgery. The use of both MEP and SSEP monitors during spinal surgery provides the optimal sensitivity and specificity in detecting neurologic impairment of spinal cord during surgery. The wake-up test is a specific test for gross motor function of the spinal cord but has its own limitations. The wake-up test is warranted and a reliable test if MEPs are absent or SSEPs are abnormal. If simultaneous recordings of MEPs and SSEPs are normal during spine surgery, they are of sufficient sensitivity and specificity to negate the need for a wake-up test.

4. Planning for anesthesia must start with the appreciation that many anesthetics can interfere with the signals used to test SSEPs and MEPs. All of the inhaled anesthetics have significant effects on the amplitude timing of these potentials. Barbiturates, benzodiazepines, and propofol have less profound inhibition of these signals. Etomidate, ketamine, and opioids are not associated with significant diminution of the potentials. With this in mind, for induction of anesthesia, I would choose propofol and fentanyl. If MEP monitoring were planned, I would avoid muscle relaxants (as they obliterate this signal) and provide local anesthesia for the airway. If absolutely needed, I would use a relatively small dose of an intermediate-acting muscle relaxant such as rocuronium or cisatracurium with the idea that they would diminish in effect during the preparatory phase of the procedure and be gone by the time the procedure was actually starting so MEPs could be used. Induction with propofol has a slightly greater effect on SSEP readings than etomidate or ketamine, but this is usually not a reason to avoid the drug for induction as its effect would be diminished by the time testing of nerve conduction was started. Placement of an endotracheal tube via the nasal route will ensure that the tube can be more firmly secured against accidental dislodgement and less likely to kink than via the oral route in patients positioned prone during surgery. For maintenance, a low-dose, balanced technique including N_2O 50 %, inhalation agent at less than 0.25–0.5 MAC, and a combination of continuous infusion of propofol and infusion of a short-acting opioid such as remifentanil or fentanyl can be used. I would choose these because these agents in the above-described doses have minimal effect on suppressing both motor and sensory evoked potentials. It is critically important to obtain a reliable baseline recording after the induction of induction and prior to surgical manipulation. The BIS monitor uses a proprietary algorithm to interpret a limited number of EEG leads and derive a measure of depth of anesthesia. The monitor reading correlates with other measures of anesthesia depth but has not been proven to prevent awareness. It may be very useful

5. After labetalol is given to control hypotension, you notice that the peak inspiratory pressure, which had been 24 cm H_2O, has risen to 52 cm H_2O. Tidal volume (exhaled) is decreased to 200 mL from 450 cc. Oxygen saturation falls to 92 %. How do you determine and correct the problem?

6. You note copious bleeding. A hematocrit sample comes back 28 %. Does the patient need to be transfused? How do you determine when a transfusion would be appropriate? You are using a cell saver. What efficiency of blood salvage can you expect to obtain with this device? What are you giving back to the patient when you transfuse "cell saver blood?" What is the hematocrit on "cell saver blood?" When is DDAVP indicated and how does it work?

Postoperative Course

Questions

1. What are your criteria for extubation?

in avoiding "overshooting" the depth of anesthesia. While many anesthesiologists utilize the BIS for scoliosis repair surgery, use is not universal. The BIS monitor may be most helpful in cases where muscle relaxant is being used (since patient movement cannot be used to detect very light anesthesia) or patients who have physiology that prevents the use of significant amounts of anesthesia during the case. In most cases, attention to patient movement and vital signs can alert the anesthesiologist to light anesthesia levels that are associated with awareness. Antifibrinolytics such as tranexamic acid (TXA) and epsilon-aminocaproic acid (EACA) have been shown to decrease blood loss in posterior spinal fusion surgery. Their use is recommended during these surgeries.

5. The beta-blocker effect of labetalol may have caused bronchospasm. Other causes may include pneumothorax (asymmetry of breath sounds and shift of precordial apical pulse), blood transfusion reaction (hives, rashes, fever, darkening of urine, and direct and indirect Coombs test), endobronchial intubation (asymmetric breath sounds), obstruction of the endotracheal tube by secretions, or kinking of the endotracheal tube. If the head position correction fails to rectify the kinking of the endotracheal tube, the tube must be replaced.

6. I will transfuse when the Hct is between 20 and 25 %. The exact point of transfusion will depend on the rapidity of blood loss and the stability of the patient (cardiovascular parameters) as well as her blood gas (the presence or absence of acidosis). The amount of blood that can be salvaged with the use of the cell saver device ranges from 50 to 70 % of the shed blood. I would transfuse packed red blood cells unless there is autologous whole blood available. The hematocrit of the re-transfused shed blood ranges from 50 to 70 %. DDAVP is desmopressin, a synthetic analog of natural arginine-vasopressin. The difference in chemical structure enhances the pressor to antidiuretic potency (2,000–4,000:1), and prolongs the duration of action of the compound due to its resistance to enzymatic cleavage. As with arginine-vasopressin, desmopressin stimulates the endothelial cells to release factor VIII, prostaglandin I2, and tissue plasminogen activator but is more potent than arginine-vasopressin. It may also increase platelet adhesiveness.

Postoperative Course

Answers

1. The decision to extubate patient's trachea will depend on the following criteria: the patient is awake, is spontaneously breathing, is comfortable, and follows command, full recovery of muscle twitch response to nerve stimulation in the train-of-four and sustained tetanus at 50 Hz for 5 s or sustained double burst stimulation prior to administration of cholinesterase antagonists, ETCO <50 mmHg, head lift for >5 s, and the ability to generate maximum inspiratory pressure of greater than −25 mmHg.

2. How would you determine the postoperative disposition for this patient?

3. What would be your plan for postoperative analgesia?

Additional Topics

Questions

1. A patient with cerebral palsy (CP) needs a posterior spinal fusion. What are the anesthetic considerations for a patient with cerebral palsy and spastic quadriplegia? Can you use succinylcholine for rapid sequence induction?

2. A patient with Duchene muscular dystrophy needs an anterior/posterior (AP) spinal fusion. What is Duchene muscular dystrophy and how will it affect your anesthetic plans? Is this patient at risk for malignant hyperthermia?

2. This patient does not need the ICU if she maintains adequate spontaneous gas exchange, has stable hemodynamics, and produces adequate urine output. Moreover, she has other risk factors. Major concerns about postoperative care include moderate restrictive chest wall disorder due to a greater than 60° curvature, respiratory depression from large amounts of postoperative opioid requirements, the potential for flare-up of asthma, and low postoperative Hct – which can compromise tissue oxygenation

3. I would plan on multimodal analgesia for the postoperative period. This should include acetaminophen, gabapentin, and opioids (delivered by patient-controlled analgesia pump). If the surgeon agreed to allow NSAID use, I would add ketorolac. Muscle relaxation with benzodiazepines such as Valium is useful in treating the discomfort from muscle spasm.

Additional Topics

Answers

1. CP is a term that is applied to patients with static encephalopathy that is present at birth. Causes range from perinatal asphyxia to intrauterine infection or kernicterus. The signs and symptoms of the disorder become more obvious as the patient ages. The findings are varied and can range from minor spasticity (in one or two limbs) with normal intelligence to patients with severe spastic quadriplegia and limited intellectual development. There are many anesthetic implications of this disorder. Because of their spasticity, positioning patients with CP can be difficult. Simple supine or prone positioning may require extensive planning and padding. Gastroesophageal reflux disease (GERD) is a common problem and must be considered when planning induction. Seizures are a common problem. Many of these patients will be on multiple anticonvulsants as well as the antispasmodic baclofen. Spasticity in these patients can be severe and often leads to extensive scoliosis. This fact, together with the small size of many of these patients, leads to the need for careful attention to blood conservation and replacement as well as dilutional coagulation abnormalities. Vascular access can be very challenging. Postoperative pain control will depend on attention to behaviors that (sometimes) only close family members recognize as indicative of pain. Close communication and appreciation of these difficulties are critical for perioperative care. CP is not a denervation problem; thus these patients tolerate succinylcholine without difficulty.

2. Duchene muscular dystrophy is a hereditary muscle disease associated with skeletal muscle weakness and abnormal function of smooth muscles including cardiac muscles. It is due to defects in the dystrophin gene, on the X chromosome.

The dystrophin defect is inherited as X-linked recessive diseases. Therefore, only males are affected and female relatives of affected males may be carriers. The anesthetic plan must take into account that the defective skeletal muscles are at risk for breakdown (rhabdomyolysis) from succinylcholine and inhalation agents. Furthermore the defective heart muscles result in dilated and occasionally restrictive cardiomyopathy. Some patients may have RBBB and other rhythm defects. Later in adolescence, degeneration of the tongue and replacement with fatty infiltrate may pose difficult to direct laryngoscopy and glottis visualization. Also in adolescence, muscle weakness is moderate to severe, and patients usually require postoperative ventilatory control in the ICU. Scoliosis tends to be very severe in this patient population. Because of the extent of posterior spinal fusion surgery, these patients tend to lose a substantial amount of blood – ranging from 50 to 200 % of the circulating blood volume. While the patients are at risk for rhabdomyolysis with succinylcholine or inhaled agent exposure, DMD patients are not specifically at risk for MHS at a rate that significantly exceeds that of the general population.

Suggested Readings

1. Gibson PR. Anaesthesia for the correction of scoliosis in children. Anaesth Intensive Care. 2004;32:548–59.
2. Sloan TB, Heyer EJ. Anesthesia for intraoperative neurophysiologic monitoring of the spinal cord. J Clin Neurophysiol. 2002;19(5):430–43.
3. Zhang JG, Wang W, Qiu GX, Wang YP, Weng XS, Xu HG. The role of preoperative pulmonary function tests in the surgical treatment of scoliosis. Spine. 2005;30:218–21.
4. Zuckerberg AL, Yaster M. Anesthesia for Orthopedic Surgery (Chap 26). In: Smith's Anesthesia for Infants and Children. Davis P, Cladis PF, editors. Philadelphia: Elsevier-Mosby, 2011. 842–69