Chapter 1: PREOPERATIVE EVALUATION

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Case Study: – A five-day-old male infant has had abdominal distention and vomiting since birth. He was born at term in a small village by a midwife and had Apgar scores of 8 and 9 at 1 and 5 minutes of life. He never had a bowel movement. After 24 hours of life he refused feedings and began vomiting green bilious material. Further attempts to feed him were unsuccessful. After a 16-hour trip to the hospital, he was found to be dehydrated and near death and thought to have a bowel obstruction. The following is a discussion of the preoperative evaluation of this and all patients.

Preoperative evaluation is the most important part of any anesthetic! Failure to properly evaluate patients before anesthesia and surgery and to clearly understand any preoperative problems and potential intraoperative complications increases the incidence of intra and postoperative complications, including cardiac arrest and death. Information gained from the patient’s history and from the physical and laboratory examinations allows the anesthetist and surgeon to correct preoperative problems, appropriately plan the anesthetic, and take steps to avoid complications. It also allows for proper planning for postoperative relief of any pain the patient will have. It only takes a few minutes to do an effective preoperative evaluation, especially if the history is obtained while the physical examination is being done.

Obtaining Information

There are multiple sources of patient information available to the anesthetist, including chart notes and discussions with the nurses and the physicians. Discussions with the patient’s nurse(s) are very important because they spend most of their day with the patient and often understand the patient’s problems better than anyone else. The patient’s nurses often is aware of such things as the effects of changes in body position on arterial blood pressure and heart rate (e.g., does the patient become hypotensive and/or tachycardic with changing his position?) and of problems associated with drug administration (e.g., hypotension, tachycardia, allergic reactions)? After discussions with the nurse(s), information is sought from the physician(s) caring for the patient. The anesthetist must be aware of and understand the effects of all drugs being administered to the child and the interaction(s) of these drugs with anesthetics and other drugs administered during surgery.
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Evaluation of the Hospital Chart

The purpose of the hospital chart (record) is to store patient information that is both readable and readily available to other people who will care for the patient. Consequently, written notes should be clear, concise, and informative. There should be no doubt about the meaning of information written in the chart. Information obtained from the chart preoperatively should include the birth history, especially prenatal or neonatal complications that occurred. Hypoxemia or asphyxia before (e.g., fetal bradycardia, decreased fetal movement), during, or immediately after birth (e.g., cyanosis, apnea, delayed onset of breathing, bradycardia, and/or hypotension) can be associated with intracranial hemorrhage, tricuspid valve insufficiency, myocardial damage, decreased cardiac output, renal failure, and necrotizing enterocolitis. These abnormalities may persist for days-to-months and occasionally may be permanent. It is important to determine if there was pre- or intrapartum bleeding due to premature placental separation. If there was, the patient may well be hypovolemic and anemic and require a blood transfusion prior to anesthesia and surgery to prevent her/him from becoming severely hypotensive and suffer a cardiac arrest with the induction of anesthesia. Finally, was the umbilical cord wound so tightly around the fetus’ neck or body at the time of birth that it was necessary to cut the cord to deliver the baby? Having to do so can leave 25-40 percent of the fetus’ blood volume in the placenta, causing severe neonatal hypovolemia.

Appendix 1 provides the normal heart rates, arterial blood pressures, and central venous pressures of infants and children.

Hydration

Babies live in a sac of water for nine months before birth. Consequently, they have excess total body and of lung water at birth. The kidneys excrete this excess water over the first 3 - 4 days after birth, which causes a 10% - 15% decrease in body weight. Babies born by cesarean section often have more excess water (especially lung water) than babies born vaginally. Thus, transient tachypnea of the newborn, which consists of tachypnea and oxygen desaturation (SpO₂ <90% when breathing room air), develops more often in babies delivered by cesarean section than in vaginally delivered babies and often persists for several days. The combination of the fluid loss and insufficient fluid intake during the first few days of life can lead to volume depletion (dehydration). Babies born in a hospital are often more likely to be dehydrated because physicians caring for them often limit their fluid intake to 65ml/kg/day (rather than 120-150ml/kg/day) to help the babies loose their excess fluid more quickly. If such babies require surgery, they are likely to develop hypotension with the induction of anesthesia. In hot climates they may be more dehydrated. Infants born outside a hospital may be very dehydrated upon arrival at hospital if fluid intake was inadequate (as it was in the case described above). Thus, determination of fluid intake (oral and I.V.) and output (urine, blood, vomiting, diarrhea), the state of hydration, and the need to replace all volume deficits is important to prevent hypotension and decreased tissue perfusion during the induction of anesthesia.
The volume status of patients can usually be determined from the history and physical examination. Changes in the child’s weight are important, especially if they occurred over a short period of time. For instance, if a baby weighed 5kg three days ago and now weighs 4.5 kg, this weight loss is almost certainly due to fluid loss and dehydration. But it must be remembered that some patients can have excessive loss of fluid into tissues (third space losses) and still have inadequate intravascular volume without a change in body weight. This occurs when fluids are sequestered in the bowel, peritoneum, plural cavities, or in the extremities (edema). In this instance the weight will not have changed, but the intravascular volume may be inadequate.

Urine output is another useful sign of hydration. Most infants and young children produce at least 0.75 ml/kg/hr. of urine; failure to urinate during the previous 4 hours is associated with hypotension (>30% decrease in systolic blood pressure from preoperative values) in approximately 70% of neonates during the induction of anesthesia. Because neonates cannot concentrate their urine for the first weeks of life, their urine specific gravity is often 1.005 or less. The concentrating ability of the kidneys increases to near adult levels by about two years of age. The urine pH is usually equal to or greater than five, due to loss of bicarbonate in the urine. The concentrating ability of the kidneys increases when the child’s protein intake increases. If the urine specific gravity is exceeds 1.011, 70% of infants will also become hypotensive when anesthesia is induced. Older children with a preoperative urine specific gravity ≥1.035 are usually dehydrated and often develop hypotension during the induction of anesthesia.

If the child has a fontanel, the skin position over the fontanel is a useful guide to his or her volume status. Skin covering the fontanel of a well-hydrated baby is even with the bone of the outer skull. If the fontanel is sunken to the inner level of the skull bone, the intravascular volume is reduced by 5%. If the fontanel is below the inner level of the skull, the volume deficit is at least 10%. Crying or excessive ventilation pressures cause the fontanel to bulge outward and invalidates the use of fontanel skin position as an aid in determining intravascular volume. Since, the head and fontanel are usually in front of the anesthetist during surgery, the anesthetist can use the position of the skin over the fontanel to evaluate intravascular volume during surgery.

Decreased skin turgor and slow capillary refill are additional signs of dehydration. The skin of normally hydrated infants returns immediately to its normal flat position when it is lifted and released. However, the skin of a hypovolemic baby remains “tented up” for several seconds before returning to its normal position (Figure 1). After the skin is blanched, the capillaries of normally hydrated babies and young children refills with blood in less than three seconds. That of older normally, hydrated patients refills in less than two second. The capillary filling times of severely dehydrated infants and children often exceeds five seconds. The mucus membranes of the mouth should be moist. If they are dry, this too is a sign of dehydration.
Peripheral pulses and skin temperature are also useful guides when determining the intravascular volume of infants and children (Fig. 1-1). The examiner should use her/his non-dominant hand (left hand for right-handed persons and visa versa) to feel for pulses because the fingers of the non-dominant hand have fewer calluses and better sensation. Excessive pressure on the skin over a baby’s artery can easily collapse the artery and lead to the false conclusion that the pulses are absent. Diminished or absent dorsalis pedis or radial artery pulses usually indicate a 5% reduction in intravascular volume. Diminished or absent popliteal and brachial artery pulses indicate a 10% reduction in intravascular volume, while diminished or absent axillary and femoral artery pulses are consistent with a 15% or more reduction in intravascular volume.

The heart rate of sick neonates and young children may be fixed at about 150 beats per minute (BPM) and not change with increases or decreases in blood pressure, indicating that the baroreceptor response is depressed or non functional. The heart rate of older children usually changes when the arterial blood pressure changes. If the blood pressure is more than two standard deviations below the normal mean blood pressure for age (See Appendix 1), the child is hypotensive.

In a warm environment (e.g., in an infant warmer or a warm climate), examining the infant’s skin temperature is also a useful sign of whether the intravascular volume is adequate or not. The
examiner should place her/his hand on the patient’s chest and move the hand outward along the skin of the chest, shoulder, and arm to the patient’s fingers. Under normal circumstances, the patient’s skin temperature will be warm all the way to the fingertips. A sudden decrease in temperature in the forearm is associated with an approximately 5% decrease in intravascular volume, while a sudden decreases in temperature in the upper arm or leg usually indicates a 10% reduction in intravascular volume. A decrease in temperature from the axilla or groin outward to the end of the extremity is indicative of a 15% or more reduction of volume.

The position of the liver relative to the right costal margin is another useful aid when determining intravascular volume. In infants and young children, the size of the liver is an index of how well the right ventricle is functioning and can be used as a surrogate for central venous pressure (CVP), which under normal circumstances is 2-8cmH₂O. An acute increase in central venous pressure or the presence of a pneumothorax decreases blood return to the heart and causes the liver to rapidly enlarge. Sudden liver enlargement is usually indicative of a failing right ventricle and inadequate ejection of the blood returning to the heart. Reduced ejection of blood from the right ventricle is often due to fluid overload, pulmonary hypertension, left ventricular failure, or disease of the cardiac valves. Failure of the right ventricle to adequately eject the returning blood increases right atrial and central venous pressures, which causes rapid enlargement of the liver. The liver edge of infants and young children can enlarge from its normal position two cm below the right costal margin to the pelvis in less than five minutes. Correcting the cause of right ventricle failure and liver enlargement leads to a rapid reduction in liver size and to return to its normal position in less than 5 min.

The position of the liver in the abdomen can be determined in several ways. The first is to gently run one’s fingers back and forth across the right abdominal wall, without exerting excessive pressure, until the liver edge is felt. If excessive pressure is applied, the liver may be pushed up under the right costal margin and make the liver seem smaller than it really is. If the abdomen is distended or painful, a stethoscope can be gently placed on the abdomen and a fingernail can be gently scraped from the lower abdomen upwards towards the rib cage. The tone made by the fingernail scraping will suddenly become duller when the liver edge is encountered. Because the liver of hypovolemic children is smaller than normal, its edge may be up under the ribs. During abdominal surgery, the liver edge is usually visible to the surgical team and can be used by the anesthetist to both evaluate the intravascular volume of the child and to guide fluid administration. When adequate fluid has been administered and the heart is functioning normally, the liver edge will be approximately 2 cm below the right costal margin.

While any one of the above signs may not be indicative of the patient’s intravascular volume status in all cases, taken together they give an accurate indication of the patient’s intravascular volume. This examination takes only a couple of minutes to complete and should be part of every preoperative evaluation. With the exception of the liver edge and the fontanel, the above can be used to determine the volume status for patients of all ages.
Respiratory System

The respiratory system begins its development very early in gestation but is not completely developed at birth. The larynx, trachea, bronchi, and lungs arise as outgrowths of the ventral wall of the foregut; failure of any of the steps required for normal organ development leads to airway anomalies, including laryngeal clefts, agenesis of the lung, and tracheal-esophageal fistulae. Surface-active material (SAM) prevents lungs from collapsing at the end of expiration and is usually secreted into the developing alveoli at 35-36 weeks gestation. Failure to secrete SAM, as often occurs in premature babies, results in hyaline membrane disease, a major cause of neonatal death worldwide.

Before birth the lungs are filled with about 30ml of fluid per kg of body weight that must be removed immediately after birth and replaced with approximately 30cc of gas per kg of body weight. Clearance of fluid from the lungs begins during labor and continues during both the birth process and breathing after birth.

Before birth the partial pressure of oxygen (PaO2) in blood perfusing the heart and brain is only 30-to-40mmHg. Despite this low PaO2, there is sufficient oxygen available for fetal growth because the concentration of hemoglobin is high (approximately 18g/dl) and the oxygen dissociation curve is shifted to the left (Figure 1-2).
Figure 1-2. Fetal and Adult Oxygen Dissociation Curves for Hemoglobin.

Note that the fetal curve is shifted to the left, which allows hemoglobin to take up oxygen at lower oxygen concentrations than adult hemoglobin. The PaO₂ associated with 50% hemoglobin oxygen saturation is 27mmHg in adults and 18mmHg in fetuses and babies less than about 3 months of age. From: Lissauer and Graham, 2002. With permission

This left shifted oxygen dissociation curve allows fetal hemoglobin to carry more oxygen at lower PaO₂s. Due to the left-shifted oxygen dissociation curve and a higher hemoglobin concentration, fetal blood contains the same amount of oxygen as that of normal children and adults (20cc O₂/100ml of blood). If there is a decrease in umbilical cord blood flow, severe hypoxemia occurs very rapidly because there is no oxygen reserve in the lungs, as there is in older children. All of the fetus’ oxygen is in the blood and tissues. Immediately after birth the baby breaths room air (21% oxygen), but his oxygen saturation (SaO₂) does not immediately increase. It takes approximately 10 minutes for the SaO₂ of normal babies to rise from about 70% at birth to 90%. The rapid respiratory rate of infants (30-60 breaths per minute) helps them maintain their functional residual capacity (FRC) because at these respiratory rates there is not enough time for more than their normal breath (tidal volume) to escape from the lungs during exhalation. Slowing the respiratory rate with narcotics or mechanical ventilation increases the time for exhalation and often causes atelectasis and hypoxemia, especially in premature babies.
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Over the first three months of life, the hemoglobin concentration decreases from about 18g/dl at birth to about 9-10g/dl, due to destruction of fetal red blood cells. New red blood cells produced contain adult hemoglobin; the hemoglobin concentration in blood rises to adult levels by about one year of age.

Visual examination of the child’s chest and listening to her/his breath sounds must be part of every preoperative evaluation; these examinations provide important information about how well the lungs and the chest are functioning. A rapid respiratory rate (>60 breaths/min in babies and 20 breaths/min in young children) can be caused by lung injury or lung anomalies, hypercarbia, or hypoxemia. Intubation of the trachea frequently reduces FRC and causes atelectasis, which worsens oxygenation and acidosis, unless a positive pressure of 4-5cmH₂O is applied to the tracheal tube during expiration. Inward movement of the suprasternal notch, the spaces between the ribs, and the sternum during inspiration (retractions) are signs of increased respiratory work and are often due to bronchospasm, atelectasis, pulmonary edema or secretions, pneumonia, or congenital anomalies of the lungs. Grunting respiration (breathing out through partially closed vocal cords) is a sign of reduced FRC and is an attempt by the child to increase her/his FRC.

Listening to the chest provides useful information. Normally, the breath sounds are clear and equal bilaterally. “Dry rales” often indicate the presence of atelectasis. Wet rales, on the other hand, indicate fluid in the lungs, either within the alveoli or within the interstitium of the lung.

About one percent of babies have a pneumothorax immediately after birth, but most of these pneumothoraces are clinically insignificant. If the pneumothorax is clinically significant (i.e., difficulty breathing, decreased oxygen saturation, cyanosis, hypotension), the pneumothorax can often be detected by standing at the end of the bed and observing how the chest moves during breathing. If a pneumothorax is present, the affected side of a young child’s chest will be elevated and move little or not at all with inspiration. The “normal” side of the chest will move more normally with inspiration. If a cold light, such as a surgeon’s headlight or a small bright flashlight is available, it can be used to diagnose a pneumothorax in babies and young children. (This does not work in fat children.) When the light is placed on the non-affected “normal” side of the chest in a darkened room, a small amount of light is seen around the edges of the light source. If a pneumothorax is present, the involved hemi thorax will glow brightly when the light is applied (Figure 1-3).
Figure 1-3: Use of a Cold Light to Diagnose a Pneumothorax in a Baby

A light applied to the right chest of the infant causes the entire chest “light up”, demonstrating the presence of a pneumothorax. In the absence of a pneumothorax, only a small arc of light would show around the light source. With permission from http://www.NICU-pedia.com

A pneumothorax that is causing distress must be treated immediately by inserting a needle or chest tube into the affected chest. If the air leak is continuous, a chest tube should be inserted and connected to three-bottle suction. (Figure 1-4)
Figure 1-4. The Three-Bottle System Used for Removing Air and/or Fluid From the Pleura.

The bottle on the right is connected to the patient’s chest tube and is used to collect blood, fluid, and air. The bottle in the middle is an underwater seal that prevents air from being drawn back into the lung during spontaneous breathing. The difference in liquid height between the bottle on the left and the bottle in the middle determines the amount of suction applied to the pleura. In addition to tubes entering and exiting the bottle on the left, this bottle also has a third tube that open to air. How far this tube is located below the fluid surface determines the amount of suction applied to the lung. With permission from: The Trauma Professional's Blog - http://www.thetraumaapro.com

Cardiovascular System

Both ventricular contraction and heart rate contribute to cardiac output and tissue perfusion. The heart rates of babies are normally between 120 and 160 beats per minute (bpm) and 80-to-100bpm in young children. Before six months of age, increases in cardiac output are primarily due to increases in heart rate, not to increases in ventricular contraction. This is due to the fact that the ventricles of young infants are “stiff” because their myocytes have fewer contractile elements. This may cause difficulties for sick children who are less than six months of age because their heart rates are often “fixed” at about 150 beats/min. As their condition improves, their heart rate varies. Consequently, a heart rate of 150 beats/min is not always a sign of a healthy infant.

Knowledge of how the patient’s cardiovascular system is functioning and of their intravascular volume are important for preoperative planning and for reducing the incidence of hypotension
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and hypoperfusion with the induction of anesthesia. While there is no good way to measure cardiac output and tissue perfusion clinically, the presence of normal arterial blood pressures, normal peripheral pulses, and a normal capillary refill times are suggestive of adequate tissue perfusion. Appendix 1 shows the normal arterial blood pressures and heart rates versus age.

Cardiac murmurs are usually caused by turbulent blood flow and are common in infants and young children. Some murmurs are functional (innocent) or due to anemia; they are usually clinically benign. Functional murmurs are usually the result of physiologic conditions outside the heart and are not caused by defects in cardiac structure. However, functional murmurs must be differentiated from those produced by abnormal myocardial structures; the latter are often associated with significant cardiovascular problems before and during surgery, especially if the anesthetics and other drugs administered during surgery reduce cardiac function further (See Chapter 12). The murmur associated with a ventricular septal defect (VSD) is a systolic ejection murmur that is best heard along the patient’s left sternal boarder. If the pressures in the right and left ventricles are equal, no VSD murmur will be heard, even though the child has a large VSD. This is because the right and left ventricular pressures are similar, which prevents blood from flowing across the defect; this is an ominous sign if the elevation in right ventricular pressure is caused by pulmonary hypertension. During anesthesia and surgery, hyperventilation-induced alkalosis may decrease the pulmonary vascular resistance and allow significant left-to-right shunting of blood through the VSD. This can cause a murmur and congestive heart failure. Positioning a stethoscope over the heart throughout surgery allows the anesthetist to detect a new or worsening murmur. If this occurs, ventilation is reduced to correct the alkalosis.

Abdomen

Abnormalities of the gastrointestinal tract are common reasons for surgery in infants and young children (See Chapter 13). Most young children have a protuberant abdomen because their liver and other intra-abdominal organs are relatively larger than those of older patients. If a baby’s abdomen is flat or sunken, there is usually a less than normal amount of bowel within the abdominal cavity, due to a diaphragmatic hernia, bowel atresia, gastroschisis, or omphalocoele. Enlarged peri-umbilical veins suggest abnormalities or infections of the liver. Increased intra-abdominal pressure from intra-abdominal fluid, gas, or infection often turns the normally pink, well-perfused neonate’s abdomen blue or grey. The abdomen of patients born with an imperforate anus is often distended. Therefor, patency of the anus should be determined at birth.

Infants and young children normally have a soft, non-tender abdomen on palpation. If palpation causes pain, its source should be determined. If the pain worsens on release of the abdominal pressure (rebound tenderness), the patient may have peritonitis. Localization of the pain to a certain area of the abdomen suggests an abscess. If the examiner’s fingerprints are visible on the abdominal wall after he/she applies modest pressure, this too is indicative of peritonitis.
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“Fingerprinting” only occurs if the baby’s abdominal wall is edematous, even though the edema is otherwise difficult to detect. The young child’s liver edge is normally 1-2cm below the right costal margin. Cirrhosis, hepatitis, amyloidosis, hemochromatosis, glycogen storage disease, liver cysts, cancerous and non-cancerous tumors, and an inadequate number of bile ducts (biliary atresia) can enlarge the liver. Right heart failure is also a common reason for liver enlargement in infants and small children. Enlargement of the spleen is usually not due to primary splenic disease but is a sign of hepatic failure, cirrhosis of the liver, beta thalassemia, biliary atresia, or cystic fibrosis, among others. Applying undue pressure to an enlarged spleen may rupture it.

The kidneys of young children can be palpated by placing one hand behind the upper abdomen and the other on the anterior abdomen. By pressing up with the posterior hand and down with the anterior hand, and gently moving the fingers of the upper hand, it is possible to feel the kidney as a globular mass. Urethral obstruction or a kidney tumor can enlarge the kidney. The presence of renal abnormalities and renal injury must be detected before surgery because perioperative mortality and poor clinical outcomes are more common when abnormal renal function is present preoperatively. The baby should make at least 0.75ml of urine per kg/hr. Well-hydrated infants and children usually make 2-4ml/kg/hr. of urine.

Auscultation of the abdomen also provides useful information. Absence of bowel sounds is associated with torsion or distention of the intestine, peritonitis, trauma, bowel obstruction, and hypokalemia. All of these conditions cause ileus, which is a condition in which the bowel smooth muscle fails to normally contract and move food and liquid forward. When ileus is present, the infant is more likely to vomit, regurgitate, and aspirate gastric contents during the induction of anesthesia. Measures should be taken to prevent aspiration (oral gastric tube, cricoid pressure). Children who are sleeping and those who have had abdominal surgery, anesthesia (general or spinal), opiate administration, anticholinergic drugs, and phenothiazines often have hypoactive bowel sounds. Hyperactive bowel sounds, on the other hand, occur with diarrhea, gastrointestinal bleeding, infectious enteritis, and bowel obstructions. If “rushes” (bowel sounds that increase in intensity over a few seconds) are heard, one should suspect the presence of a bowel obstruction.

Extremities

Trauma or congenital anomalies are common reasons for abnormalities of the extremities of infants and young children. If abnormalities are found, the reason(s) for them should be sought. If trauma is the cause, the anesthetist should search for other injuries, especially for intra-abdominal injuries (liver or spleen) because hemorrhage, severe anemia, and reduced intravascular volume often accompany these injuries. Young children seldom have extremity edema unless their serum protein concentrations are low. Lack of visible veins in the extremities is common, especially in young children who are chronically ill or are dehydrated and intravascular volume depleted. Finding a vein large enough to permit rapid transfusion of blood or large volumes of fluid can be a problem. The
saphenous or external jugular veins are usually adequate for this purpose. Placing the child in a slight head down (Trendelenberg) position often distends the external jugular vein, making insertion of an I.V. catheter easier. If intra-abdominal bleeding is suspected, the I.V. should be placed in an upper extremity or the neck when possible because administering blood and fluid through a lower extremity I.V. often causes the fluids to be lost into the abdomen and never reach the central circulation.

The skin of young children is looser and less well fixed to the subcutaneous tissue than it is in older patients. To make inserting an I.V. easier, the skin should be pulled moderately taught to prevent it and the vein from moving while the I.V. is being inserted. If skin tension is not maintained, the vein will often be pushed away from the needle tip, and the needle will not enter the vein. If the tension on the skin is released before the needle or catheter is securely positioned in the vein, the skin and vein may retract off the end of the catheter or needle. Care must be taken to prevent air from entering the intravenous line or I.V. connector because it only takes 0.1-0.2cc of air to cause a cardiac arrest and death if the bubble of air passes right-to-left through a foramen ovale and lodges in a coronary artery. Once the I.V. is connected to the fluid source and is taped securely in place, the arm or leg should be secured on a board to reduce the possibility of accidentally dislodging the I.V. In some instances, it may be necessary for a surgeon to insert a central line to measure central venous pressure, for blood and fluid administration, and to permit blood withdrawal for laboratory tests during and after surgery (See Chapter 2).

As part of the preoperative evaluation, the patient’s skin should be carefully examined because skin infections are common and reduce the number of available sites for I.V. insertion. Skin infections may also make it unwise to use a spinal, caudal, or an epidural anesthetic because inserting a needle or catheter through an infected area may lead to meningitis or a spinal abscesses. The skin of normal patients is usually pink and warm. If it is grey, blue or cold, the cause(s) should be sought before anesthesia is induced.

Laboratory

All necessary laboratory results must be reviewed and understood before anesthesia is induced. Appendix 2 lists normal values for hemoglobin, hematocrit, clotting factors, and electrolytes in young children. While these are the generally accepted values for young patients, anesthetists must know what the normal values for her/his population of patients and for their hospital’s laboratory. Knowledge of the patient’s preoperative hemoglobin concentration is very important, especially for infants and young children, because they consume at least two times as much oxygen per minute as adults. (Anesthesia reduces the infant’s and young child’s oxygen consumption by about 50% and that of adults by about 15%.) Since approximately 98% of oxygen in blood is in red blood cells (RBCs), the hemoglobin concentration of blood must be high enough to provide sufficient oxygen to meet the patient’s tissue oxygen requirements. Understanding
two important concepts (oxygen content and oxygen delivery) are necessary when trying to decide if the hemoglobin concentration is adequate. Oxygen content \(= (1.39 \times [\text{Hb}] \times \text{SaO}_2) + 0.003 \times \text{PaO}_2\). \text{SaO}_2 is the saturation of oxygen on hemoglobin; 1.39 is the cc of \text{O}_2/g of hemoglobin; [\text{Hb}] is the hemoglobin concentration; and 0.003 is the cc of oxygen dissolved in plasma (i.e., <1% of oxygen in blood). Multiplying 0.003 X \text{PaO}_2 gives the cc of oxygen dissolved in plasma. Because most oxygen is in hemoglobin, it is far more effective to increase the hemoglobin concentration than to increase the inspired concentration of oxygen (FiO\textsubscript{2}) when attempting to raise the oxygen content of blood. For example, if the hemoglobin concentration is 4g/dl, the oxygen content of hemoglobin is 5.4cc of oxygen/100 ml of blood. If the \text{PaO}_2 is 100mmHg, the amount of oxygen dissolved in plasma is 0.3 cc of oxygen/100 ml of blood. Thus, there is 162 times more oxygen in hemoglobin than the plasma/100ml of blood. If the baby is transfused to a hemoglobin concentration of 10g/dl, the oxygen content of hemoglobin will increase to 13.4cc/100 ml of blood, but the amount of oxygen dissolved in plasma will remain at 0.3cc/100 ml if the \text{PaO}_2 remains at 100mmHg. An oxygen content of 5.4g/dl is very close to the lower limit for survival and leaves little room to compensate for oxygen desaturation or blood loss during surgery. Preoperative transfusion of blood will increase the patient’s margin of safety. If little or no blood loss is expected (cleft lip repair, closed reduction of a fracture), a hemoglobin concentration of 7-8g/dl is sufficient.

Oxygen delivery is the second important concept. Oxygen delivery = the oxygen content of blood \times the cardiac output. While it is not possible to measure cardiac output clinically, it is probable that cardiac output and tissue perfusion are adequate if the arterial blood pressure and capillary refill times are normal. When the hemoglobin concentration of a 3kg infant is 4g/dl and the cardiac output is normal (300ml/kg/min), oxygen delivery is only 5.4cc/dl \times 0.9l/ min or about 4.9cc of oxygen delivered per deciliter of blood delivered to the tissues each minute. However, the oxygen consumption of normal babies is about 6cc/kg/min. Survival of a patient with this hemoglobin concentration depends on his ability to increase and maintain greater cardiac output. However, increasing the cardiac output further increases oxygen consumption, which further reduces the margin of safety. If hypoxemia occurs or the anemia worsens during surgery, the patient may suffer a cardiac arrest. If at all possible, the hemoglobin concentration of such a patient should be raised by blood transfusion before the induction of anesthesia. At times this may not be possible, but hopefully these times would be rare.

Appendix 3 gives the normal serum electrolyte concentrations for infants and children. Abnormal electrolyte concentrations are common in children who have had diarrhea, vomiting, losses of fluids and electrolytes into their tissues (bowel, peritoneum, pleura [third space losses]), or inadequate fluid intake. During the first week of extra uterine life, renal tubular acidosis (RTA) occurs; this is caused by loss of bicarbonate from the infant’s immature kidneys. Potassium is also lost. RTA usually self corrects when intake of food and protein are adequate. World wide, vomiting and diarrhea are the most common causes of fluid and electrolyte abnormalities in
young children. Interestingly, rehydration of dehydrated patients may worsen their serum electrolyte abnormalities by unmasking the presence of low total body electrolyte stores. Commonly used diuretics also increase bicarbonate and potassium loss from the kidneys and increase serum chloride concentrations. Severe electrolyte abnormalities, (e.g., potassium and calcium) may give rise to dysrhythmias and myocardial dysfunction, especially during anesthesia. Therefore, electrolyte abnormalities should be corrected prior to the induction of anesthesia when possible.

Since glucose is the brain’s main energy source, it is important to assure that the blood glucose concentration is normal for age before, during, and after surgery (Appendix 3). Under normal conditions, blood glucose concentrations are maintained by glucose intake (oral or I.V.), glycogenolysis, and gluconeogenesis. Glycogen is stored mostly in the liver and muscle and is deposited in these tissues, primarily during the last trimester of pregnancy. Infants born before the last trimester of pregnancy or those who had poor intrauterine nutrition or were stressed before or during the birth process may have low glycogen stores and difficulty maintaining normal serum glucose concentrations. If the glycogen stores are adequate, the stress of surgery may increase serum glucose concentrations, which may also be a problem. If a cardiac arrest occurs when a patient’s blood glucose concentration is greater than 200mg/dl, it is less likely he/she will be resuscitated from the arrest and more likely that he/she will have central nervous system injury if resuscitated.

If the patient had X-rays done before surgery, they should be evaluated for the presence of lung abnormalities, infections, or a pneumothorax or pneumomediastinum before inducing anesthesia.

**Transport of Patients**

Transport of patients to and from the operating room can be dangerous. To reduce the danger, enough people must be available to push the patient’s bed, monitor the patient’s condition, administer drugs and fluids, and ventilate the patient’s lungs if necessary. The minimum monitoring during transport should include SaO₂ and continuous auscultation of the breath and heart sounds with a stethoscope that is taped to the chest. Measuring arterial blood pressure during transport is also helpful. Covering the child with plastic bag and warm blankets helps maintain a normal body temperature during transport. If the patient required mechanical ventilation before surgery, her/his lungs should be ventilated during transport, usually with a bag connected to an endotracheal tube. The respiratory rate used during transport should be the same as the rate used before transport and one that is appropriate for the patient’s age and lung condition. Very rapid respiratory rates can interfere with exhalation and result in gas being trapped within the lungs. This causes over expansion of the lungs, decreased lung compliance, decreased ventilation, hypoxemia, and on occasion, a pneumothorax. A respiratory rate that is too slow can result in atelectasis and hypoxemia. If before surgery the inspired oxygen
concentration (FiO₂) exceeded that of room air (21%), the same oxygen concentration should be used during transport to and from the operating room (if possible) to prevent hypoxemia or hyperoxia. The chest should expand normally with each inspiration. Excessively large tidal volumes will over expand the lungs and may cause a pneumothorax or pneumomediastinum.

Sick patients should go directly to the operating room from the ward, ICU, or emergency room and not be left outside the operating room while the room is being prepared for surgery. Nurses and doctors should be waiting for the patient; a sick patient should never wait for them. All equipment, drugs and a functioning suction should be readily available before the patient arrives in the operating room. If possible the operating room should be warmed before the patient enters the room to reduce the likelihood of her/him becoming cold. Hypothermia increases the pulmonary vascular resistance of neonates, which causes hypoxemia as poorly oxygenated venous blood is shunted right-to-left through a patent foramen ovale. Anesthesia induced under these circumstances is a formula for disaster.

Summary

Preoperative evaluation is very important because it makes existing problems known and allows the anesthetist and surgeon to correct the problems pre-operatively, which reduce the risks of anesthesia and surgery. It is important to have an adequate number of people who understand the patient’s problems available; this helps prevent complications of anesthesia and surgery. Transport of sick patients can be dangerous for patients and requires the same level care provided pre- and intra-operatively.

References