WHAT THE PEDIATRICIAN SHOULD KNOW ABOUT PEDIATRIC TRAUMA

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TRAUMA HAS REMAINED one of the leading causes of death and disability in children. This category is responsible for 20% of all pediatric deaths.[1]

To study incidence and cause-and-effect relationship in pediatric trauma, we reviewed all accidental deaths which occurred in children under the age of 13 years from 1968 to 1972 in Brooklyn. An analysis of this data showed that the child most likely to die a violent death in our urban society is the impoverished young male, belonging to a minority group, in activity-related accidents (71%).[2]

As shown in Table 1, vehicular accidents were the most common cause of death, followed by fire and falls. The causes of death were usually violent in nature leading to multisystem in-

TABLE 1.—DEATH DUE TO TRAUMA IN CHILDREN UNDER 13 YEARS OF AGE: BROOKLYN, 1968–1972

NUMBER OF DEATHS: 729	
CAUSE:	
Vehicular	25.6%
Fire	21.2%
Fall	12.4%
Assault	8.6%
Poison	2.3%
Miscellaneous	29.9%
RACE: Black 55.2%; Hispanic 25.2%; White 19.6%	
AGE: under 1 year: 16.2%; under 4 years: 55%	
SEX: male: 65.9%; female: 34.1%	

juries, a finding supported by our clinical experience with surviving trauma victims.

The important role trauma plays in the treatment needs of children is further illustrated by a review of the clinical activity of the pediatric surgical service at Kings County Hospital. In the Pediatric Surgical Emergency Room an average of 25,000 children are seen yearly by the pediatric surgical staff. During the summer months, with a seasonal peak of trauma, 20% of all operative procedures and 37% of all pediatric surgical admissions were related to trauma.

The incidence of the "battered child syndrome" appears to be increasing in spite of renewed attention to cause and effect.

Since the publication of the first Pediatric Surgical Textbook by Felix Wurtz in the 16th century, describing "the harm befalling suckling children inadvertently or advertently by their wet or dry nurses" few reports have appeared dealing with "iatrogenic medical trauma." Advances in diagnosis and therapy, however, have led to an increase in medical trauma as demonstrated by the soaring number of malpractice suits.

Although most serious accidents in childhood will eventually require surgical care, both prevention and primary care usually involve the pediatrician. Our basic goal, to save every child arriving alive in the Emergency Room, can only be accomplished if pediatrician and surgeon work as a team. The surgeon must be familiar with the particular problems of infancy and childhood, and the pediatrician with the surgical aspects of trauma.

As a team they can provide not only the best technical care but the understanding and reassurance the frightened pediatric trauma victim will need, to prevent minor injuries from becoming major trauma.

I. TRAUMA: DIFFERENCES BETWEEN CHILD AND ADULT

There are distinct differences between the child and the adult having undergone trauma which range from the cause to the effect of trauma.[3] While major injury may produce only minor symptoms in children, on the other hand minor injury, such as contusion of the abdominal wall, can lead to symptoms ordinarily seen in adults only with major injury, such as ileus and abdominal distention. The child's anxiety can both exaggerate or mask findings. A precise history of the trauma incurred, especially in battered children, is often unavailable and information given by parents may be intentionally misleading.[4] The presence of preexisting lesions such as hydronephrosis, horseshoe kidney, Wilm's tumor or hydrocephalus can lead to unexplainable major

symptoms after what appears to be only minor trauma. Fractures, especially in the young child, are not only more difficult to diagnose but in the growing child may lead to either growth retardation or overgrowth, introducing factors not seen in the adult.

"Industrial-type injuries" limited to children can occur both at home or in public places, such as wringer injuries or extractor injuries in laundries. The child's body, with its pliable chest cage, may incur injuries different from those of the adult at the same anatomical location. Extensive intrathoracic injury, such as pulmonary contusion, hemorrhage or hemopneumothorax can be present without rib fractures in contrast to the adult. Psychological reactions vary; the child, already frightened from either accident or abuse, is suddenly thrown into a buzzing emergency room. While medical treatment may be adequate, too often too little time is spent to reassure the child and the parent. Bleeding, which may appear to be minor when the child is seen in an adult emergency room, can be disastrous in children with a relatively small blood volume. Evaluation of vital signs on admission, such as tachycardia, may be difficult since it may be either an expression of hypovolemia or the excitation of an apprehensive child.

While many of the differences may appear to be unfavorable to the child, the child has one positive asset: associated disability or diseases are rare; the healthy child is often able to cope better with major injuries than an adult. The child's ability to recover quickly may not be necessarily the result of adequate medical care but, paraphrasing an old saying, "God is kind to fools and pediatric surgeons."

II. EXAMINATION OF THE INJURED CHILD

Look, Listen, Feel

Look.—The general appearance of the child, completely undressed, will give the first clue to the extent of the injury. Labored respiration, sternal retraction, alar flare or cyanosis is usually suggestive of injury to the respiratory system, although respiratory interference can also result from intraabdominal or central nervous system injuries. The child should be examined for injuries of the upper airway, including the mouth to detect oropharyngeal injuries, possible dislocation of orthodontic devices or evidence of recent traumatic loss of teeth which may suggest aspiration and upper airway obstruction.

The patient's alertness or state of anxiety may reveal central nervous system (CNS) injury, although impending shock may

mimic CNS involvement. Abnormal position or the child's inability to move the extremities may suggest fractures, dislocations, or central nervous damage. Observation of the pupils, their response to light, the appearance of eardrums are all essential to evaluate the patient's central nervous system. The presence of marked swelling with pelvic or femoral fractures may indicate blood loss at the fracture site and alert the physician before shock occurs.

Neck vein distention in hypotensive children can be the earliest sign of cardiac tamponade. The shift of the cardiac impulse can suggest an underlying tension pneumothorax as cause for respiratory distress or hypotension. Often overlooked, but equally important, is the observation of the child's genitalia; not only are genital or anal injuries occasionally overlooked in battered or abused children, the presence of a drop of blood at the urethral meatus may be the only sign of a serious urethral injury.

LISTEN.—Auscultation should include the evaluation of breath sounds, comparison of both thoracic cavities and a check for the presence or absence of stridor. Muffled heart sounds may be present in tamponade; murmurs can suddenly appear due to injury of the cardiac valves, septum or the chorda tendinae.[5] Abdominal examination includes the evaluation of bowel sounds and percussion to elicit gaseous distention or free air over the liver in a patient with a ruptured viscus. In patients with suspected fractures of long bones, osteophony may confirm the clinical impression of the fracture before x-rays have been taken.

FEEL.—The entire trunk, abdomen and extremities should be palpated and checked for tenderness, pain and swelling. Abdominal palpation should include the evaluation of local and referred pain, distention, guarding and rigidity. The presence or absence of subcutaneous emphysema is looked for over chest, neck and abdomen. Motion, sensation, peripheral pulses and temperature of all extremities are carefully checked. No attempt should be made, however, to demonstrate crepitation or a false point of motion in patients with apparent fractures.

MONITORING OF VITAL SIGNS

In all children blood pressure, pulse, respiration and temperature should be checked and recorded at regular intervals. Since the initial vital signs may be normal even in patients with major injury, or the pulse rate abnormally increased in children with anxiety and only minor injury, the change of vital signs is

usually more significant than the original vital signs on admission. In all patients with major injury, urine is obtained for microscopic examination through an indwelling bladder catheter; in patients with minor injury, through a urinary bag. In children with major injury a central venous pressure catheter is inserted to monitor central venous pressures, and an additional intravenous catheter is inserted into an upper extremity for the administration of fluid.

In all patients with major injury, or apparent gastric dilatation even with minor injury, a nasogastric tube is inserted to decompress the stomach to prevent aspiration. The nasogastric tube has to be irrigated with isotonic saline not only to assure patency and location, but also to dilute gastric contents to allow aspiration.

History

When, Where and How.—The basic rules of obtaining a patient's history also apply to children with trauma. Description of the trauma should be obtained and changes of the patient's condition in the interval between trauma and admission, such as alertness, should be determined. If the history does not appear to be compatible with the injury, either preexisting pathological conditions or the intentional misleading history given for abused children may be responsible for the discrepancy. The review of the history should be related not only to the current trauma but also to the past medical history, preexisting diseases and past immunizations. A confusing history, repeat admissions to various institutions or obvious omissions of pertinent facts may be the first indication of a "battered child syndrome."

III. PREPARATION OF THE CHILD WITH MAJOR TRAUMA

As in adults, the "ABCD rule" (airway, breath, cardiovascular, definitive therapy) is followed.

The patency of the airway is carefully checked and, depending on the type of injury, respiratory support is given. In most children requiring respiratory support, breathing with a mask or mouth-to-mouth respiration is preferable to endotracheal intubation unless both experienced personnel and adequate instrumentation are available. Prior to attempts of endotracheal intubation the stomach should be emptied to avoid aspiration during intubation. With rare exceptions, such as major oropharyngeal injuries, emergency tracheostomy is rarely indi-

cated. A tracheostomy in an awake child is a complicated procedure and should be attempted only in the operating room and after the child has been intubated.

Routine vital signs, such as blood pressure, pulse, respiration and temperature are monitored. A central venous catheter is inserted into the upper extremity or the jugular vein and an additional intravenous line is inserted in an upper extremity. The patient's blood type and cross match, hematocrit, WBC count and values for blood gases are determined. Suspected fractures of extremities are splinted. In patients with suspected cervical injury, the head is supported and no attempt is made to make a clinical diagnosis until x-rays have been obtained.

If thoracic or intraabdominal injury is suspected an anterior-posterior and lateral chest film, upright and supine of abdomen and chest should be taken. In patients in whom the injury may make an upright film impossible, cross table lateral or lateral decubitus films should be obtained. If extremity fractures are suspected, films of the contralateral extremities should be taken for comparison. In patients with microscopic or gross hematuria an intravenous pyelogram should be obtained simultaneously. Renal scan or angiogram are occasionally necessary.

Throughout the work-up the patient's temperature, especially in infants, should be maintained. In children without shock or central nervous injury but with anxiety, mild sedation is usually indicated not only to keep the child more comfortable but to allow the physician a more thorough examination, especially if abdominal injury is suspected. Throughout the examination and preparation of the child, a member of the team should inform the parents of the suspected diagnosis and the necessary diagnostic and therapeutic procedures to be undertaken.

IV. SHOCK AND RESUSCITATION

Although hypotension occurs in children with marked blood loss, it can be a late sign. Unexplained tachycardia, especially in children without obvious anxiety, should suggest hypovolemia. The general appearance of the child, the presence of pallor and the child's irritability and complaint of thirst may be an early sign of acute hypovolemia, even in the presence of a normal blood pressure. A change from tachycardia to bradycardia is an ominous sign, often leading to rapid death unless successful countermeasures have been taken.

Hematocrit reading and WBC count are obtained. The presence of a normal or only slightly lowered hematocrit does not rule out acute hypovolemia due to hemorrhage. In patients with

impending or actual shock crystalloid solutions are given before typed and cross-matched blood has been obtained. Although the presence of a metabolic acidosis is often found in shock, the emphasis and selection of intravenous fluids should be placed on *isotonic* solutions to restore vascular perfusion. Crystalloid infusions are followed by blood transfusions or plasma or both as indicated, with continuous monitoring of blood pressure, pulse rate and central venous pressure to check the adequacy of blood infusion and to avoid overtransfusion. As a rough estimate, if the acute blood loss is unknown, 20% of the estimated blood volume can be rapidly infused without leading to cardiac failure in children without preexisting cardiopulmonary disease. The signs of restored perfusion are: improved general appearance, increased alertness, disappearance of pallor, return of vital signs to normal and beginning urinary output. Overtransfusion or overinfusion is to be avoided; either one may add to the development of a "shock lung."

Patients who fail to respond or who develop cardiac arrest may require the following drugs as part of the resuscitation regimen: epinephrine (0.05 mg/kg body weight/min) or intracardiac epinephrine (1:10,000 dilution: 2–4 ml for body weight under 4 kg, 3 ml for 4–18 kg body weight and 4 ml for body weight over 18 kg); intravenous sodium bicarbonate (3 mEq/kg body weight); calcium gluconate (100 mg/kg body weight). Other drugs, such as Isuprel, may be indicated.

While the use of sodium bicarbonate may be necessary to combat metabolic acidosis, repeat infusions of sodium bicarbonate, because of its hypertonicity, may lead to a rapid expansion of the intravascular volume and lead to cardiac failure. Since sodium bicarbonate is broken down into H_2O and CO_2, it is obvious that sodium bicarbonate is contraindicated in patients with respiratory acidosis and increased P_{CO_2}.

In patients with cardiac arrest without chest injury, an attempt of closed heart massage should be initiated. The pulse rate to be achieved depends on the child's age. Too rapid massaging can lead to inadequate ventricular filling and therefore inadequate perfusion. It can also interfere with respiratory support; ventilation and cardiac massage should be synchronized. Continuous awareness of the location of both liver and spleen are necessary to avoid injury to either of these organs. In patients not responding to closed external massage or with suspected intrathoracic injuries open heart massage may be necessary. The left chest is opened through the 4th or 5th intercostal space and open heart massage is performed by manually emptying both right and left ventricle simultaneously. A continuous recording of the peripheral systolic blood pressure serves as an

indication whether either closed or open massage is efficiently performed.

The continuous determination of blood gases, including $P_{A_{O_2}}$, P_{CO_2} and pH, is essential for the rational administration of intravenous fluids and ventilatory support. In patients with either cardiac failure or overexpanded intravascular volume, the restoration of a normal pH may require the use of agents such as tromethamine (THAM, TRIS).

V. PERINATAL TRAUMA

Perinatal trauma can be classified as follows:

1. *Combined trauma* involving both mother and child.[6] In car accidents the "belt injury" can lead to uterine rupture and trauma to the fetus. Intrauterine injuries following stabbing or gunshot wounds of the mother have been reported in increasing frequency, presenting a diagnostic and therapeutic problem. While the mother's life should be considered first, with advanced pregnancy both the child's suspected injury and its estimated gestational viability become criteria for the consideration of a cesarean section. The evaluation of maternal and/or fetal injury demands a joint approach by obstetrician, pediatrician and pediatric surgeon to assure prompt resuscitation and treatment of both mother and infant.

An example of combined maternal-fetal injury is shown in Figure 1. The mother was shot in the abdomen during her 8th month of pregnancy. X-rays indicated the presence of an intra-abdominal bullet, possibly located in the fetus. Although maternal and fetal signs were stable, a prompt cesarean section was performed since the gestational age was compatible with survival. The infant sustained a maxillofacial injury; the bullet entered the oral cavity and was swallowed by the infant. Within 8 hours after the gunshot wound the bullet had advanced through the small intestine and was lodged within the ileocecal area. Both infant and mother recovered uneventfully.

2. *Fetal medical injury.* With increasing use of amniocentesis and intrauterine transfusions, a variety of fetal injuries have been reported, ranging from fetal intraabdominal to intrathoracic trauma.[7]

VI. BIRTH INJURIES

The most common birth injury consists of clavicular fractures with or without associated brachial plexus paralysis of either the Erbs or Klumpke type.[8] A chest x-ray should be obtained to evaluate involvement of the phrenic nerve with diaphragmatic

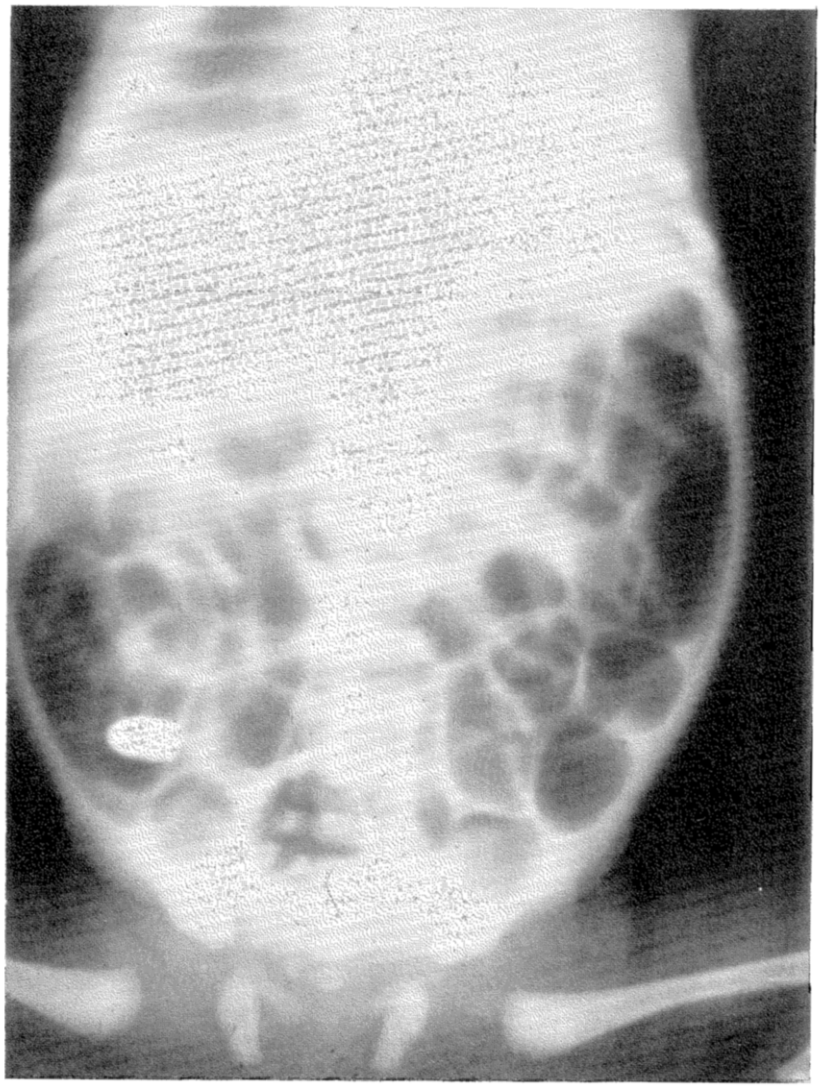


Fig. 1.—Newborn with a .38 bullet at the ileocecal junction. The infant sustained an intrauterine maxillofacial gunshot wound and swallowed the bullet. Transit time from mouth to ileocecal valve was 8 hours.

elevation. While paradoxical motion is usually seen with phrenic nerve paralysis, it may be difficult to differentiate from diaphragmatic eventration. In most infants with phrenic nerve or brachial plexus paralysis, function will be restored within several months. Permanent nerve damage is present if function has not been restored within six months.

Therapy of skull fractures, cerebral or subgaleal hematomas will depend on the extent of the injury and the involvement of the central nervous system.

Rupture of liver and spleen, either combined or isolated, has been reported in numerous instances, as well as the occasional rupture of the bile duct.[9, 10] In infants with liver or splenic ruptures, sudden hypotension and evidence of decreased peripheral perfusion, drop of hematocrit value associated with abdominal distention or ileus constitute the presenting signs. In infants with suspected intra-abdominal injury abdominal paracentesis may prove the existence of either hemoperitoneum or bile peritonitis. The presence of either noncoagulating blood or bile is an indication for prompt laparotomy. In infants in whom a splenectomy was performed, subsequent coverage with penicillin appears warranted throughout childhood and adolescence, in view of increasing reports of septicemia after splenectomy even in healthy children.

VII. IATROGENIC INJURIES

1. Vascular

The most common iatrogenic trauma in infants is related to invasive arterial or venous techniques.[7] Thrombus formation following the insertion of venous or arterial catheters is common and catheter embolization after inadvertent transection or tear of the umbilical arterial catheter has been observed in two premature infants in our institution. In older children embolized catheters can be retrieved through the use of a basket catheter; in infants operative removal is necessary. Embolization of venous catheters has also been reported in many instances.

The use of intravenous administration of hypertonic fluid, combined with the use of pumps, has led to numerous instances of extravascular infiltration and subsequent tissue slough including the loss of extremities. Arterial occlusion, especially of the femoral artery, is not uncommon after arterial catheterization. Venous thrombosis, leading to swollen and often cyanotic extremities, can usually be treated nonoperatively; heparinization may occasionally be indicated. In contrast, arterial occlusion with cold extremities, absent pulses and ischemic, patchy discolorization should be immediately evaluated for operative intervention. The longer the interval between arterial occlusion (extrinsic or intrinsic) and operative repair, the poorer the results. Not all arterial occlusions warrant operative repair and spontaneous development of collateral vessels can prevent the loss of extremities. Late sequelae, such as reduction of growth

of the involved extremity or limitation of function due to ischemic pain, are common if arterial continuity has not been satisfactorily restored.

2. Gastrointestinal Perforations

Barium enema perforations can lead to serious intraperitoneal sepsis. If barium enema perforations occur, an immediate laparotomy with removal of the barium is necessary. After a delay of several hours between perforation and operation, the barium is densely adherent to peritoneal structures and cannot be removed completely. While the barium per se is not toxic and only sets up dense adhesions, the combination of barium and fecal matter leads to an overwhelming sepsis unless it can be removed early.

A common injury, the breaking of rectal thermometers, is usually harmless. Unless there are signs of peritoneal irritation, unexplained temperature or considerable rectal bleeding, proctoscopy is not indicated for removal. The half of a thermometer will usually lodge in the area of the sphincter and can be removed manually without complication. If perforation of the rectum has occurred, either intraperitoneal perforation with peritonitis or subperitoneal perforation leading to ischiorectal abscess, repair or colostomy, or both, are warranted.

Enemas, frequently used, can represent a potential danger. While the use of isotonic enemas, usually saline, is well tolerated, the use of tap water enemas can lead to extreme mucosal damage, fluid loss, absorption of "nonabsorbable" medication and water intoxication. Only isotonic solutions should be used when the intestinal tract is irrigated; both hypotonic and hypertonic solutions lead to mucosal damage. It should be emphasized that "nonabsorbable medications," such as Kantrex, will be absorbed by the intestinal tract when the mucosal barrier has been damaged. While an accurate estimation of the absorption is impossible, medication administered in the enema in children with colonic mucosal damage should not exceed the usual systemically administered dose.

The careless use of hypertonic radiopaque material, such as gastrografin, can also lead to major complications. Due to its high osmolality, whether it is administered in the upper intestinal tract or the colon, it will pull fluid into the intestinal lumen to equilibrate the osmolality. The sudden loss of fluid into the intestine, especially in children with preexisting debilitating diseases, can lead to acute hypovolemia and shock unless carefully controlled.

3. Respiratory Complications

Oropharyngeal and laryngeal injuries due to intubation are seen with increased frequency since more infants with respiratory distress syndromes are salvaged. Subglottic stenosis or injury to the vocal chords is usually immediately apparent; perforation of either the nasopharynx with dissection into the chest or esophageal perforations may be more difficult to diagnose.[11, 12] Another common complication consists of the insertion of endotracheal tubes into one of the main stem bronchi, usually the right, with simultaneous occlusion of the other main stem bronchus. The insertion of the endotracheal tube in one main stem bronchus and subsequent failure to ventilate the other lung will lead to a rapid deterioration of gas exchange, since the continuous perfusion of the nonventilated lung represents a large arteriovenous shunt. Extensive cartilaginous injury can be caused by prolonged nasotracheal intubation, leading to alar necrosis, which is difficult to repair.

Complications following tracheostomy may include pneumothorax and emphysema. Prolonged insertion of metal tracheostomy tubes can cause perforation of the posterior wall of the trachea and the formation of a tracheoesophageal fistula. Stenosis of trachea and tracheomalacia are late complications.

VIII. SYSTEMIC TRAUMA

1. Respiratory Injuries

Respiratory emergencies can be caused not only by direct injury to the respiratory tract or chest, but also by CNS or intra-abdominal injuries. Abdominal trauma with secondary diaphragmatic irritation or elevation can interfere with diaphragmatic movement which constitutes the major part of respiratory muscular function in the young infant. Both neurological and intra-abdominal injuries should therefore be considered in patients with respiratory distress.

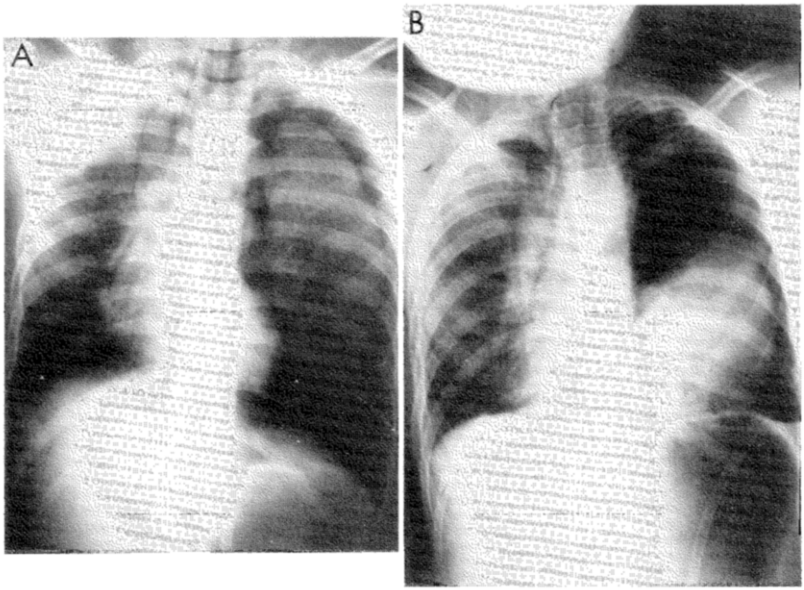
Oropharyngeal and cervical injuries.—In the presence of major oropharyngeal injuries mouth-to-mouth or mask ventilation, even with the insertion of an airway, may be inadequate. Immediate endotracheal intubation or tracheostomy may therefore be indicated.[13] In patients with cervical injuries, especially with penetrating injuries, prompt intubation and operative exploration of the neck may be the only way to restore an efficiently functioning airway. These patients constitute a small minority, however, and an immediate transfer to an appropriate facility is indicated.

BLUNT CHEST INJURY.—The most common intrathoracic injuries following blunt trauma consist of pulmonary contusions, pneumothorax, tension pneumothorax, hemopneumothorax, mediastinal emphysema, cardiac tamponade, flail chest and diaphragmatic hernia. [14, 15]

Pneumothorax.—In simple pneumothorax the cardiac impulse is at its normal site, and breath sounds are absent or diminished over the involved side. Most patients are only in moderate respiratory distress and can be evaluated radiologically to confirm the clinical diagnosis of pneumothorax or combined hemopneumothorax (Fig. 2). After the diagnosis has been confirmed, a chest tube is inserted and the lung expanded.

Tension pneumothorax.—Patients with tension pneumothorax are usually in severe respiratory distress, often with associated signs or symptoms of shock. The cardiac impulse is frequently shifted to the uninvolved side. Breath sounds are absent over the involved side; they may also be diminished on the contralateral side due to the marked mediastinal shift, which occurs

Fig. 2.—A, 10-year-old boy sustained a pneumothorax following blunt vehicular chest injury. On the supine film only a simple left pneumothorax without mediastinal shift is recognizable. **B,** in the upright position the collapsed left lung has moved downward, indicating a loss of fixation as seen with severance of the mainstem bronchus. The left mainstem bronchus was repaired and the child recovered uneventfully.



especially in children where the mediastinal fixation is relatively unstable. When the diagnosis of tension pneumothorax is suspected, a syringe with a #18 short beveled needle should be inserted into the intercostal space on the involved side and air withdrawn. If the air escapes under pressure, a chest tube should be immediately inserted with underwater drainage. In contrast to patients with simple pneumothorax, radiologic confirmation in patients with tension pneumothorax is rarely justified since valuable time may be lost and the patient may rapidly deteriorate on his way to x-ray or within the x-ray unit.

Mediastinal emphysema.—Anterior and posterior mediastinal emphysema can occur in blunt trauma with or without pneumothorax. Although the majority of patients with isolated mediastinal emphysema will show only mild respiratory distress, an occasional patient may require mediastinal decompression.

Hemothorax.—The physical findings may be identical to those seen in patients with simple pneumothorax. The presence of fluid on x-rays, including anteroposterior upright, lateral films and lateral decubitus, confirms the diagnosis. A low-lying chest tube should be inserted into the 6th or 7th interspace in the midaxillary line. In most patients with pulmonary injury the bleeding will cease after the lung has been expanded following the insertion of the chest tube. If hemorrhage continues, major vascular injury should be suspected and the patient immediately prepared for exploratory thoracotomy. In patients with uncontrollable chest hemorrhage emergency thoracotomy in the emergency room may be justified to establish control of major vascular or cardiac injury.

Cardiac tamponade.—Blunt injuries direct to the sternum can cause cardiac tamponade with reduced cardiac inflow and output. The characteristic signs are hypotension with a small blood pressure amplitude, distended neck veins and occasionally distant heart sounds. The presence of normal heart sounds, not muffled, does not rule out a cardiac tamponade. The treatment consists of pericardial aspiration either substernally through a point below the xyphoid or through the 4th intercostal space.

Pulmonary contusions.—The physical findings of pulmonary contusions may be minimal on admission and resemble the findings of a mild pneumonia if present at all. Chest x-rays on admission may show minor areas of pulmonary hemorrhage or may be perfectly within normal limits until radiological changes appear after approximately 24 hours. The treatment consists of adequate ventilation, intermittent positive pressure breathing aid and antibiotic coverage to prevent the development of pneu-

monia. As in all respiratory emergencies, repeat monitoring of blood gases is essential to determine the response of the patient and the adequacy of the treatment.

Diaphragmatic hernia.—Diaphragmatic herniation can occur with blunt or penetrating thoracoabdominal injury with herniation of abdominal viscera into the chest.[15] The most common site for a symptomatic diaphragmatic hernia is the left side of the diaphragm. The stomach, and occasionally intestine, can herniate through a traumatic tear and lead to either respiratory distress or gastrointestinal symptoms due to torsion of the stomach, gastric or intestinal obstruction. The presence of a gas-filled viscus in the thoracic cavity with a history of preceding injury should alert the physician to the existence of a diaphragmatic hernia which will require operative repair.

PENETRATING CHEST INJURIES.—In contrast to adults, only approximately 10% of all chest injuries in childhood are of the penetrating type.[16] Diagnostic work-up is similar to that for patients with blunt thoracic injuries. Pneumothorax, tension pneumothorax and hemothorax are the most likely complications with major catastrophies related to either cardiac or large vessel injuries. The treatment depends on the symptomatology and is identical to major blunt injuries of the chest. It should be emphasized that the presence of a penetrating thoracic injury, including the presence of bullets within the thoracic cavity, does not constitute an indication for operative treatment unless complications occur such as: uncontrollable bleeding, bronchopleural fistula formation, esophageal perforation, mediastinitis, emphysema or retained blood in the thoracic cavity.

2. ABDOMINAL INJURIES

The vast majority of intra-abdominal injuries in childhood, like chest injuries, are caused by blunt trauma, in contrast to adults where penetrating trauma is more common.[17] Trauma of the abdomen may lead to injury of the abdominal wall, intra-abdominal organs or retroperitoneal structures. In addition to the general examination of the child, including central nervous system, respiratory system and extremities, the abdominal examination should include the following observations: presence or absence of abdominal distention, external signs of injury such as abrasions, lacerations, hematomas, tire marks or periumbilical hematoma suggesting the presence of intra-abdominal blood.[18-20] Palpation of the abdomen should elicit localized, diffuse or referred tenderness, the presence or absence of localized guarding or rigidity. Bowel sounds should be evaluated to detect the

presence of an adynamic ileus, keeping in mind that even minor abdominal wall or CNS injury may lead to the disappearance of bowel sounds. In patients with suspected multisystem injury or with vague abdominal findings, especially if unconscious, abdominal paracentesis and/or lavage should be performed. A nasogastric tube should be inserted to decompress the stomach and prevent aspiration. X-ray evaluation should include supine and upright films, including the chest, to detect ileus pattern, free air, or free fluid in the abdomen. The urine should be examined and if either microscopic or gross hematuria is present an intravenous pyelogram should be performed. WBC count and values for hematocrit, serum and urinary amylase should be obtained. In all patients with signs of peritonitis, laparotomy is indicated after the patient has been prepared for operation by restoring vital signs to normal with the administration of isotonic crystalloid solutions, followed by plasma and blood transfusions if major bleeding is suspected. A positive abdominal paracentesis or lavage constitutes an absolute indication for laparotomy. The presence of a "negative tap or lavage" does not represent a contraindication for laparotomy, however, if peritoneal signs develop. The most likely structures involved in children with hemoperitoneum are liver and spleen. Liver injuries, usually a part of a multisystem injury, are accompanied by injuries to other structures such as spleen, kidneys, intestine and pancreas in 80% of all patients. In contrast, splenic injuries are usually isolated injuries and associated injuries occur only in 20%. The hemorrhage from the spleen is usually self-limiting and exsanguination prior to operation is rare. Massive liver injury, on the other hand, can lead to rapid exsanguination, especially if associated with major vessel injury such as inferior vena cava, hepatic veins or portal veins. In view of the increased incidence of fatal septicemias after splenectomies, even without associated hematological diseases, long-term postsplenectomy coverage with penicillin appears justified. Repair of the fractured spleen rather than removal is performed by an increasing number of surgeons.[21-23]

INTESTINAL INJURY.—Perforation of the intestine following blunt trauma usually occurs in the upper jejunum as a result of direct compression of the jejunum against the vertebra. Free intraperitoneal air may be present. Duodenal perforation or hematoma rarely presents with free intraperitoneal air, symptoms may develop slowly and unless associated with acute abdominal signs and symptoms may only be demonstrated by radiological examination.[24-26]

PANCREATIC INJURY.—Pancreatic injury is usually seen as a

component of multisystem injury associated with either splenic, hepatic or intestinal injury such as to the duodenum. Isolated pancreatic injury may range in symptomatology from a mild ileus in patients with mild pancreatic contusion to a marked peritonitis if pancreatic transection or hemorrhagic pancreatitis has occurred.[27-29] Serum and urinary amylase levels are usually elevated; the absence of an elevated amylase level, however, does not rule out acute pancreatic injury. In all patients with major pancreatic injury abdominal exploration is indicated. In an occasional patient the acute pancreatic injury may not have been diagnosed and only the development of a pseudocyst post injury with the appearance of a mass may indicate the previous injury. In contrast to adults, internal drainage via gastroenterostomy or duodenoenterostomy is usually not indicated and tube drainage of the pseudocyst usually suffices.[3]

RETROPERITONEAL HEMORRHAGE.—In patients with massive blunt abdominal injury retroperitoneal hemorrhage can occur with or without intra-abdominal and renal injury. The retroperitoneal hemorrhage may be related to injuries of the kidney or retroperitoneal structures and vessels, often seen in combination with pelvic fractures. The blood loss can be marked and lead to exsanguination especially if major vessel injury has occurred. While major pelvic fractures or major renal injuries are usually evident on physical examination or IVP, scan, or angiogram, retroperitoneal hemorrhage can occur without association of pelvic or renal injury and may not be suspected since the peritoneal tap may be negative. The presence of unexplained blood loss, development of abdominal distention and ileus without intra-abdominal blood may be a clue to the underlying hemorrhage. Not all of these patients will require operative exploration but close continuous monitoring of vital signs, blood replacement and prompt radiologic work-up, which may have to include angiography, are indicated.[3, 30]

PENETRATING ABDOMINAL INJURIES.—The presence of a penetrating injury without symptoms of peritonitis or intra-abdominal blood loss requiring prompt intervention does not constitute an indication for exploration per se. Abdominal paracentesis and lavage are indicated, however, to rule out intra-abdominal bleeding or free intraperitoneal intestinal contents. In the absence of peritoneal signs and a negative tap nonoperative treatment with continuous careful observation will reduce unnecessary operative exploration. If signs of peritoneal irritation occur, however, exploration is indicated. Diagnostic work-up and operative indications are otherwise similar to those in patients with blunt injury.

RECTAL INJURIES.—With the exception of violent blunt abdominal injuries, rectal injuries are usually due to penetrating injuries such as seen in sexually abused children or due to perineal trauma such as sled or picket fence injuries. Thorough examination of the rectum, including proctoscopy under sedation or anesthesia, and evaluation of possible intra-abdominal signs are indicated. If intra-abdominal signs occur, operative intervention with either repair of the perforation or colostomy, or both, will have to be performed. In patients with rectal injuries below the peritoneal reflection, symptoms may develop slowly since the infection may lead to extraperitoneal infection in the perirectal or ischeorectal area. Thorough proctoscopic examination is thereby indicated in all children with suspected penetrating rectal injury.

3. GENITOURINARY INJURY

RENAL INJURY.—Renal injury can be caused by a wide variety of trauma, ranging from a minor blow to the flank or the abdomen, especially when preexisting renal pathology is present (Fig. 3), to major multisystem injury. In over 90% of all patients with renal injury microscopic hematuria is present. Hematuria, however, may be absent in patients with major renal injury such as arterial occlusion or ureteral avulsion. Abdominal findings may vary from localized flank tenderness, upper quadrant tenderness to diffuse abdominal tenderness and ileus. Symptomatology and treatment will depend on the extent of the kidney injury. Renal injuries range from contusion to intrarenal extravasation, extrarenal extravasation, kidney fracture, renal avulsion or renal arterial or venous thrombosis.[31, 32] In all patients with suspected renal injury or patients with hematuria an intravenous pyelogram is indicated. In patients with nonvisualization of a kidney a renal scan or renal arteriography is indicated to rule out renal avulsion, arterial thrombosis or unilateral renal agenesis.[33] The presence of intrarenal or even mild to moderate extrarenal urinary extravasation alone does not constitute an indication for operative intervention. The kidney's ability to recover from injuries and the lack or uncommon occurrence of postoperative complications such as perinephric abscess or renal hypertension justifies the conservative approach used in most institutions. Close follow-up examination is necessary with repeat intravenous pyelograms, scans or angiography if defects persist, however.[34]

Renal contusions and/or minimal extravasation.—After the diagnosis of mild renal injury has been established, the patient

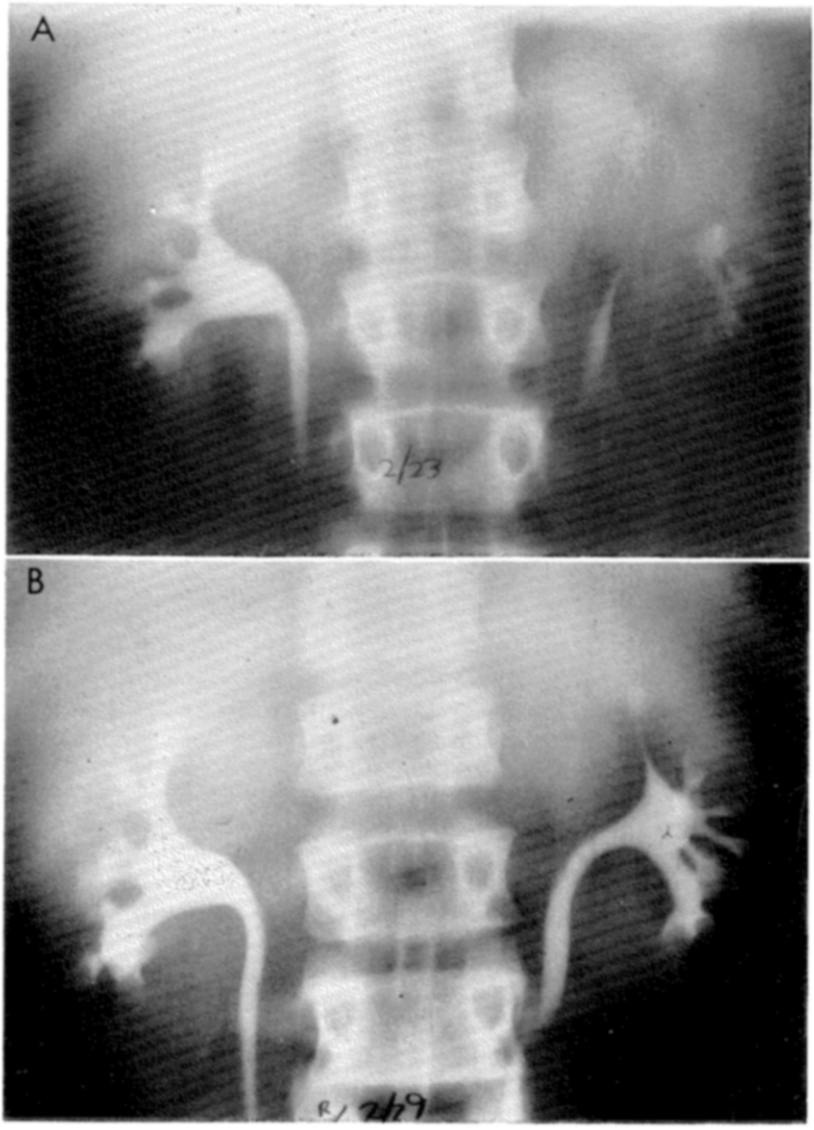


Fig. 3.—A, 12-year-old girl admitted with gross hematuria following blunt abdominal injury. The intravenous pyelogram reveals a left renal contusion without extravasation. **B,** after 6 days of nonoperative treatment the intravenous pyelogram shows a normal appearance of the contused kidney.

is placed on bed rest with intravenous fluid therapy as long as an ileus persists. Urinary output is monitored continuously and several daily samples of urine are kept at the bedside to observe the increase or decrease of hematuria. Repeat intravenous pyelograms are obtained according to the patient's progress or the injury determined on admission (see Fig. 3). In patients with contusion, bed rest is indicated from two to three weeks. In patients with intrarenal or mild extrarenal extravasation the patient is placed on bed rest for several weeks after the hematuria has subsided and the intravenous pyelogram has returned to normal. In patients with extrarenal extravasation who develop a febrile course or persistent gastrointestinal ileus, operative intervention has to be reconsidered.

Major renal injury.—The presence of a shattered kidney, especially with an expanding retroperitoneal hematoma, is an indication for operative intervention. Renal arterial or urethral avulsion warrants immediate operative intervention. In patients with renal avulsion massive hemorrhage is usually present with either impending or actual shock. Prompt treatment of the hypotension with crystalloid solutions and transfusion is required prior to the operative intervention. A discrepancy between minor injury and disproportioned physical or x-ray findings suggests preexisting lesions. The most likely preexisting pathology in children consists of horseshoe kidneys, hydronephrosis or Wilm's tumor. Interpretation of x-rays in patients with preexisting renal anomalies or tumor may be difficult, as seen in Fig. 4.[35, 36] It should be emphasized that even in the presence of obvious major renal injury, nephrectomy is contraindicated unless an intravenous pyelogram has shown the presence of a contralateral normal kidney.

In patients with unilateral renal agenesis major injury may require unusual approaches, such as "bench surgery" with extracorporeal perfusion of the injured kidney, permitting repair and reimplantation.

BLADDER INJURIES.—Both intraperitoneal and extraperitoneal bladder rupture in children usually follow blunt injuries of the abdomen and pelvis. Rupture of the bladder leads to tenderness of the lower abdomen. The ability to urinate is usually, but not always, impaired. In patients with intraperitoneal rupture of the bladder there is evidence of free intraperitoneal fluid (uroperitoneum), and signs of peritonitis. Hematuria is usually present and the intravenous pyelogram may show extravasation of urine through the ruptured bladder. A retrograde cystogram is more reliable and should be performed if the intravenous pyelogram fails to show extravasation in a suspected bladder rupture. The

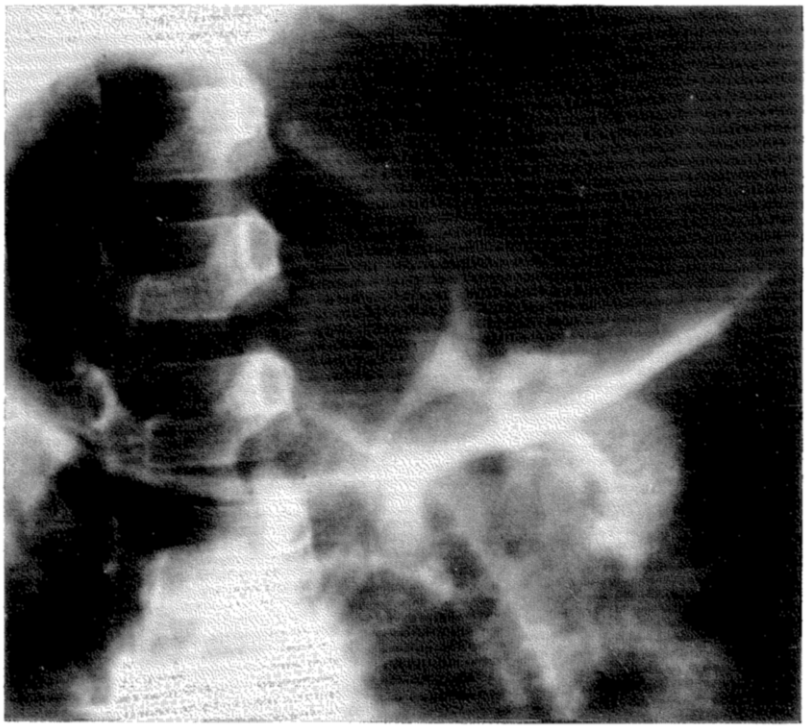


Fig. 4.—Admission intravenous pyelogram of a 2-year-old boy who developed signs of acute peritonitis after a fall from a footstool. Only the lower renal calyces are visible. At operation an intraperitoneal rupture of a Wilm's tumor in the left kidney was found and a nephrectomy performed.

treatment of intraperitoneal or extraperitoneal bladder injury is operative.

URETHRA.—Transection of the urethra is usually associated with violent abdominal injury and/or pelvic fractures. On physical examination the only finding may consist of a drop of blood in the urethra. Hematuria is not present in view of the inability to void. On rectal examination perivesicular and peripubic swelling may be present. Prompt urologic work-up with immediate operative intervention is the treatment of choice. It should be stressed again that the presence of a drop of blood in the meatus may be the only clinical sign of a urethral transection.

TESTICULAR TRAUMA.—Injuries to the scrotum or testis can lead to a hematoma of either of the two structures. In patients with acute testicular hematoma, the hematoma should be released by splitting the tunica albuginea to prevent testicular

atrophy. In children with testicular swelling, without obvious scrotal injury, operative intervention may be warranted to rule out testicular torsion, especially when the history of trauma appears unreliable. The differential diagnosis of testicular swelling and trauma includes torsion of the testis, epididymitis, orchitis, torsion of the appendix testis, preexisting testicular lesions such as tumors, or angioneurotic edema of the scrotum.

VAGINAL INJURY.—Vaginal injuries in young girls may be accidental, self-induced or due to rape. In girls with accidental injury of the vagina, such as straddle injuries due to bicycle or sled, the injury frequently involves the perineum, labia and/or the rectum. In contrast, rape injuries are usually limited to the vaginal introitus, vagina or rectum per se.

Vaginal examination should be performed with the patient under sedation, especially in children who might have been raped. The examination should include rectal examination, inspection of the perineum, vaginal introitus and vaginoscopy. If rape is suspected, the presence of sperm and semen should be ascertained and pertinent authorities informed. In girls with vaginal foreign bodies, usually manifested by discharge with or without pain, x-ray examination for metallic foreign bodies may be helpful. Rectal examination may detect foreign bodies; vaginoscopy, usually under light anesthesia, should also be performed. In children with repeat sexual abuse, regardless of age, obvious vaginal injury may be absent and the vagina can have the appearance of a patulous adult vagina. Secondary ascending infections can occur. In both the young rape victim and the child with self-induced foreign bodies, the history is best obtained by a female member of the team. For obvious reasons the child is unlikely to communicate in confidence with a male member of the team. It should be emphasized that in our experience rape in 75% of all children is usually committed by family members. An adequate or truthful history is therefore difficult to obtain and all children who might have been raped should be handled as battered children with involvement by social worker, court and psychiatrist.

5. CENTRAL NERVOUS SYSTEM INJURY

While it goes beyond the purpose of this monograph to describe central nervous system trauma in detail, it should be stressed that even major CNS damage will rarely lead to shock. A child admitted with obvious central nervous system damage and signs of shock should be suspected of having either intra-abdominal or intrathoracic injuries. In all children with CNS

injury and hypotension abdominal paracentesis and/or lavage is therefore paramount to rule out intra-abdominal bleeding. Examination of the chest by auscultation and x-ray usually suffices to rule out major intrathoracic injury.

The diagnosis of cerebral injury in a child can be difficult, since the development of neurological signs may be more insidious than in adults.[3] Following head trauma a child may display the neurological signs of an intracranial hematoma but recover spontaneously. Neurological signs, such as bilateral presence of Babinski's sign, inequality of pupils and hemiparesis may be present. These may disappear and the child recover without any sequelae. Focal cerebral edema rather than intracranial hematoma may be responsible for the clinical presentation. If neurological signs such as stupor persist, sonogram or angiography should be performed. On the other hand large intracranial hematomas may occur with only minimal clinical signs. A change in behavior, rather than obvious neurologic signs, may be the only indication of their existence. The tendency of a child to fall asleep or react sluggishly to stimulation may precede stupor.

Epidural hematomas can slowly lead to cerebral decompensation, and continuous prolonged observation in children with head injuries with even minor symptomatology is therefore indicated. Especially in infancy, subdural hematomas usually lead to rapid deterioration with bulging fontanelles, retinal hemorrhage or edema followed by stupor and decerebration. Prompt operative removal of the intracranial blood clot is necessary.

As in all children with trauma, the signs and symptoms on admission may be misleading or deceptive; major injury can present with minimal signs, minor injury with major signs or symptoms. Continuous observation and monitoring of neurologic signs are therefore of importance.[37]

Since respiratory function is not uncommonly depressed in children with major central nervous damage, intubation, ventilatory assistance or tracheostomy with continuous monitoring of blood gases is often necessary. Nasogastric intubation to avert the danger of aspiration should be immediately performed in all unconscious or stuporous patients.

6. Extremity Fractures

Extremity fractures in children differ from adults in two aspects: the child's ability to remold even marked deformities and the reduced or accelerated growth due to fractures involving the epiphyses.

DIAGNOSIS OF FRACTURES.—Soft tissue injury with swelling and hemorrhage associated with a fracture produces pain and tenderness at the fracture site. Movement of the fracture site increases pain. Hemorrhage from the fracture site can range from minimal manifestations to major local signs and hypovolemia. In most extremity fractures, but not all, loss of function is apparent. In obvious fractures with gross deformities neither crepitus nor a false point of motion should be elicited intentionally, since it may aggravate local damage or lead to nerve and vessel injury. Axial compression or percussion of the long axis of the fractured bone may produce pain at the fracture site. The placement of the stethoscope at one side of the fracture with percussion of the other side may suggest a fracture due to a diminished pitch in intensity. In all extremity fractures, associated injuries to either vessels, nerves or tendons should be checked and noted before treatment is started. In young children with suspected fractures, x-rays of the contralateral side should be taken since radiologic evaluation can be difficult. In children in whom a fracture is suspected to be the result of abuse, a total skeletal review should be obtained. The presence of various fracture sites at different stages of healing usually confirms the suspicion of a battered child syndrome.

History, as in pediatric trauma in general, may be unreliable, unavailable or misleading. An attempt should be made, however, to identify the cause of the injury. Direct trauma, such as car bumper injuries, will lead to fractures at the site of injury, whereas an indirect force will usually produce a fracture at a more distant site. Discrepancy of history and fracture, such as minor trauma/major fracture, can be found not only in battered children, but also in children with preexisting bone lesions leading to pathologic fractures.

MANAGEMENT OF FRACTURES.—The immediate management should consist of initial treatment of associated injuries, such as hemorrhage and lacerations, followed by splinting of the injured extremity with inclusion of the proximal and distal joint.[3] Definitive treatment depends on the site and the extent of the fracture. The basic rule in children dictates that most fractures can be treated by closed reduction and only a relatively small number of patients will require operative reduction. In patients with open fractures the wound should be dressed; no attempt should be made to reduce open fractures in the emergency room. After a cast has been applied it is imperative that the parents receive instructions to look for vascular compromise. Maintenance of peripheral perfusion, temperature of the distal exposed

extremity, sensation and mobility should be checked at frequent intervals.

One of the most common errors in the treatment of fractures in children is ignoring the child's pain. In spite of splinting, pain usually persists since splinting should not and does not constitute reduction and therefore permits at least minor motion of the fracture site while the child is being examined and x-rayed. Unless the associated injuries include shock or central nervous system injuries, children should be sedated adequately after the clinical diagnosis of an extremity fracture has been made.

IX. ASPIRATION OF FOREIGN BODIES

Aspiration of foreign bodies can occur at any age but it is most commonly seen in children between 1 and 3 years. A history of aspiration can occasionally be obtained, followed by respiratory distress, sudden choking, brassy cough or persistent respiratory infection. In patients with pharyngeal or laryngeal foreign bodies, inability to swallow may be associated. The majority of foreign bodies retained within the pharynx have a shape which can lead to perforation of the pharyngeal wall: toothpicks, chicken bones, fish bones and occasionally metallic foreign bodies. In most children with tracheobronchial aspiration the foreign bodies are nonradiopaque since they usually consist of vegetable matter such as seeds or peanuts. If small foreign bodies are lodged in one of the smaller bronchi, pulmonary infection with abscess formation may result. If either major or main stem bronchus is blocked hyperaeration rather than collapse usually occurs.

DIAGNOSTIC WORK-UP.—On physical examination there may be evidence of cyanosis and moderate to severe respiratory distress depending on the site and location of the aspirated foreign body. In some instances a significant period of time may have passed between aspiration and examination, and physical findings may be completely normal. Auscultation of the chest may reveal stridor. Breath sounds can be diminished if pulmonary atelectasis or pneumonic changes have occurred. In patients with occlusion of a main stem bronchus and a ball valve mechanism, overaeration of the lung can produce hyperresonance. On x-ray examination overaeration is found more often than atelectasis. In patients in whom the aspiration occurred a considerable time prior to examination, pneumonia or pulmonary abscess formation may be found. Since the majority of aspirated foreign bodies are vegetable matter and not metallic, foreign bodies are rarely

identified on x-ray. Large radiopaque foreign bodies, such as can lids or coins, are usually located in an anteroposterior direction in the trachea in contrast to esophageal foreign bodies, which are usually located in a lateral position.

Since the hyperaeration may be minimal and difficult to detect on the upright film, bilateral chest films with the right and left side down alternately may suggest the presence of a nonopaque foreign body if the dependent lung fails to show the usual increased radiopaque appearance present after the patient is placed on one side for more than five minutes due to the increased blood flow or blood volume of the dependent lung. In patients in whom the diagnosis of an aspirated foreign body is strongly suspected but x-rays are negative, pulmonary perfusion scans can further support the diagnosis. In patients with overaeration due to aspirated foreign bodies the pulmonary perfusion is markedly reduced due to increased peripheral resistance. It should be kept in mind, however, that even after successful and complete removal of foreign bodies normal pulmonary perfusion may not recur for up to one week.

TREATMENT OF ASPIRATED FOREIGN BODIES.—In spite of the temptation to remove visible pharyngeal bodies by hand, a removal should not be attempted unless adequate instrumentation (laryngoscope, forceps and light) is available to avoid the risk of pushing the foreign body into the larynx or perforating the pharynx. In most cases the pharyngeal body can be removed with sedation and without the use of anesthesia. In small children an attempt should be made to turn the child upside down with vigorous percussion of chest and trunk, which may dislodge the foreign body.

In patients with laryngeal, tracheal or bronchial aspiration the foreign body should be removed under anesthesia in the operating room. Since most children with acute symptoms following aspiration of foreign bodies show considerable anxiety, preoperative sedation should be used which usually improves mild to moderate respiratory distress rather than compounding it.

X. INGESTION OF FOREIGN BODIES

A review of ingested foreign bodies seen in a children's emergency room could leave the innocent observer to believe that nothing but a ferocious predator could have eaten the vast array of gadgets which appear much too large to have been swallowed by a child. One should remember that even unyielding objects such as fountain pens can be swallowed by small children if they can be inserted into the oral cavity. It is difficult to explain,

however, why a 1-year-old, who is unable to swallow a capsule or pill, can contentedly devour a small choo-choo train.

Foreign bodies which have passed from the esophagus into the stomach, with the exception of unwieldy long or sharp pointed objects, usually pass through the remainder of the gastrointestinal tract without difficulties unless preexisting lesions such as duodenal webs exist. Perforation of the gastrointestinal tract is rare and if it occurs, for instance at the ileocecal junction, the result is usually the formation of an abscess rather than the rapid onset of free peritonitis.

The area where foreign bodies are most likely to be retained in the gastrointestinal tract are esophagus (aortic arch or cardia), stomach, and ileocecal valve.

SIGNS AND SYMPTOMS.—Ingested and retained foreign bodies, even in the esophagus, are remarkably asymptomatic and only an occasional child will complain about chest pain or inability to swallow. In patients with preexisting lesions such as duodenal webs, the accumulation of many foreign bodies may finally lead to partial intestinal obstruction or obstructive symptoms.

ESOPHAGEAL FOREIGN BODIES.—Most ingested round objects retained in the upper esophagus, such as coins, can be removed with a gently inflated Foley catheter under fluoroscopy. If this attempt fails, esophagoscopy is indicated. The accidental translocation of a foreign body into the stomach during esophagoscopy does not constitute a major complication. Coins, marbles, and similar objects will invariably pass through the remainder of the intestinal tract. If the foreign body is nonradiopaque a barium swallow must be obtained to locate the obstructing foreign body.

RETAINED GASTROINTESTINAL FOREIGN BODIES.—In patients with ingested round foreign bodies, with the exception of large objects such as fountain pens or pencils, admission is usually not necessary. Parents can be instructed to watch for the excretion of the foreign body or repeat x-rays can be taken after one to two weeks. Gastric foreign bodies have been known to stay in the stomach up to 10 days and still spontaneously move down the intestinal tract. Operative intervention is therefore not indicated unless either perforation occurs, retention lasts more than two weeks, or the foreign body is of such shape that further progression is unlikely. Small foreign bodies occasionally end up in the appendix where the incidental finding of a foreign body is generally accepted as indication for appendectomy. In children with ingested pointed foreign bodies, such as needles and pins, a high residue diet such as celery or asparagus may form a pro-

tective bulk which will help to evacuate the foreign body. Continuous observation of children with foreign bodies capable of perforation is indicated.

XI. LYE INGESTION

The oral intake of even minor amounts of caustic material, lye or acid, can lead to severe burns of lips, oral cavity, esophagus and stomach, occasionally including the airways. Since acid is rarely available in the average household, the majority of caustic burns seen in childhood are caused by lye. While acid burns occasionally involve the stomach, lye burns are usually restricted to the oral cavity and esophagus. The presence of oral lye burns does not necessarily indicate simultaneous esophageal involvement while even severe esophageal burns can be present without evidence of oral burns. Lye burns of the esophagus may involve mucosa, the entire muscular wall and occasionally can lead to perforation. Initial symptoms may be minor, yet late changes leading to obstruction can occur in the absence of acute symptoms. In a child suspected to have swallowed lye, oral cavity and pharynx should be immediately inspected. In the presence of oral lye burns, rinsing with water is acceptable. No antidote is available, however; the effects of the burn are immediate and an attempt of treatment with neutralizing solution or emetics will only compound the problem. Since the airways may be involved, patency of the airways should be checked and in an occasional patient prompt intubation or tracheostomy, or both, may have to be performed.

The physical findings of a severe lye burn may include dehydration, vascular collapse, acute dehydration and oropharyngeal burns. In patients seen days or weeks after the ingestion of lye, symptoms may be solely related to esophageal stenosis leading to dysphagia. Esophagoscopy should be performed within 24 hours following the ingestion of lye to confirm the diagnosis, to estimate the extent of the damage and to permit the selection of the appropriate treatment. Patients should receive intravenous fluid without oral intake, and antibiotic coverage is started as soon as the burn is suspected and the patient is prepared for esophagoscopy. The introduction of a nasogastric tube after an acute burn without esophagoscopy is contraindicated. If the diagnosis of an esophageal burn has been established or strongly suspected the child is placed on prednisolone, 2 mg/kg body weight/24 hr in divided doses. If the presence of a burn has been confirmed both antibiotic and steroid treatment are continued for 3–4 weeks. Repeat esophagoscopy after 10–14 days

will determine whether esophageal dilatations are necessary. In children with severe burns leading to long segments of stenosis not responding to dilatation, esophageal substitution has to be considered.

It should be stressed that the history of lye intake can often not be obtained and the history may be intentionally kept from the physician.

XII. THE BATTERED CHILD SYNDROME

According to recent statistics by the American Humane Association and the National Center on Child Abuse and Neglect, it is estimated that approximately 1 million battered children should be reported annually. Each year, 20,000 children are estimated to die from circumstances associated with abuse or neglect. In 1973, a total of 110,000 children were born in New York and in the following year 2,300 infants under the age of 1 year were reported as battered children. While the physical abuse of children by adults crosses all sociological lines, in our experience it occurs most commonly in the young infant or preschool child in sociologically deprived groups. The clues to the presence of a "battered child syndrome" consist of:

1. History supplied by one parent, friends, family or social workers.
2. Discrepancy between history of trauma and sustained injuries.
3. History of abused siblings.
4. Unusual reasons for the hospital visit, neglect to state the history of trauma, and parental attitude.
5. General poor condition (but even the best-fed, well-dressed baby may be a victim of child abuse).
6. The presence of various injuries in different stages of healing.
7. Evidence of linear scars resulting from whipping injuries, punctate burn scars from cigarette burns, bruises involving different anatomic areas and in different stages of healing.
8. Lesions concentrated over trunk or buttock.
9. Multiple fractures at different stages of healing.
10. Subperiostial calcifications.
11. Evidence of old fractures without history of treatment.
12. The child's behavior, often frightened, "whimpering" and withdrawn.[4]

While a child's avoidance of parents in the emergency room may be an indication of a battered child syndrome, even a severely abused child may reach for the guilty parent.

Management

Since the trauma experienced by a battered child may range from continuous minor injuries to a severe single life-threatening injury, the management will obviously depend on the injuries sustained. In general, the following steps are indicated in all children suspected of being abused:

1. X-rays of all bones, including chest, to rule out previous extremity fractures, rib fractures, clavicular fractures or skull fractures.
2. Thorough examination, as in all children in the emergency room, with the child totally undressed and completely inspected.
3. Examination of rectum and vagina to rule out sexual abuse.

It should be stressed that boys also are objects of sexual abuse, a fact often ignored. In all children, even when the basis of suspicion may be minor, the physician has to report the suspicions. According to most state laws the physician is legally liable only if he fails to report a suspected child abuse case, and not liable even if he reports a case which either is not or cannot be proven to be child abuse.

It is obvious that the physician's role is that of a protector of the child; he is neither judge nor jury, and it is not his role to accuse the parents, no matter how strong the suspicions.

XIII. BURN INJURIES

Following vehicular accidents, burns are the major cause of traumatic death in childhood. Burns can be divided according to this etiology into thermal, chemical, electrical and radioactive burns. Two thirds of all burn admissions in children are secondary to thermal burns with hot liquids. Often the absence of symptoms such as pain in the child with 3d degree burns complicates the initial assessment of the burned child, leading to a gross underestimation at the time of the initial evaluation. This can be contrasted with the overestimation of minor burns due to their painful nature.

Management of Burns

Respiratory problems.—As in all major trauma the establishment of an open airway is of primary importance although even with massive burns direct involvement of the respiratory tract is rare with the exception of steam explosions. The reflex mechanism closing the glottis usually protects the lower respiratory tract. The oropharynx, however, may suffer directly and endotracheal intubation may be required. The more com-

mon damage to the lower respiratory tract arising from smoke inhalation does not usually become apparent for several hours. Tracheostomy, even in patients with facial burns, should be avoided and only used after the child's condition has been completely assessed and initial treatment started. Since early edema may subside within one or two days nasotracheal intubation will often suffice, alleviating the tracheostomy. The airway obstruction, which may be caused by either secretions, bronchospasm or edema, should be treated with suction, intravenous steroids and humidified oxygen. Gastric dilatation is usually present in major burns, and a nasogastric tube should be inserted to avoid aspiration. Respiratory distress due to the constriction of the circumferentially burned upper trunk may require escharotomy to allow expansion of the chest.

ELECTRICAL BURNS.—Electrical burns usually occur in young infants, either due to biting a poorly insulated electrical cord, exposure to uninsulated electrical wire or insertion of metal objects into electric outlets. While the electrical burn is usually well localized and may look deceptively small the depth of the burn is usually extensive and often involves underlying bone. The most common burn, secondary to chewing of electrical wires, involves the lip. There is a difference of opinion whether immediate excision and primary repair or local treatment followed by operative treatment after initial healing has been accomplished is preferable. In either case the repair is usually extensive and complicated. While minor electrical burns of extremities may be amenable to outpatient treatment alone, the difficulty in assessing the extent of the injury at the time of the first evaluation justifies the admission of all electrical burns.

THERMAL BURNS.—The severity of the injury depends on duration and extent of the contact. The classification is based on the depth of the burn and the extent.

1st degree burn: superficial burn with erythema and edema.

2d degree burn: blister formation with involvement of the entire dermis.

3d degree burn: full thickness burn of skin and deeper structures with skin changes ranging from a pale, dry, leathery look to a charred appearance.

Hot liquids, scalds and flash burns usually cause 1st and 2d degree thermal burns. Flame and contact burns are usually responsible for full-thickness 3d degree burns.

INITIAL ASSESSMENT.—The history of a burn may give an indication as to the severity to be expected. The burned child should be completely examined with an accurate appraisal of the

TABLE 2.—RELATIVE PROPORTIONS OF THE BODY SURFACE ACCORDING TO AGE

BODY PART	INFANT	AGES 1–4	AGES 5–9	AGES 10–14	ADULT
Head	19%	17%	13%	11%	7%
Neck (1 × 2)	2%	2%	2%	2%	2%
Upper Extremities (10 × 2)	20%	20%	20%	20%	20%
Lower Extremities	27%	29%	33%	35%	39%
	(13.5 × 2)	(14.5 × 2)	(16.5 × 2)	(17.5 × 2)	(18.5 × 2)
Anterior trunk	13%	13%	13%	13%	13%
Posterior trunk and buttocks	18%	18%	18%	18%	18%
Perineum	1%	1%	1%	1%	1%
	100%	100%	100%	100%	100%

From Song, I., and Bromberg, B. E.: Relative Proportions of the Body Surface According to Age, in Shaftan, G. W., and Gardner, B.[3] Reproduced by permission.

depth and the extent of the burn. While the rule of "9's" is applicable in teenagers and adults, the assessment of the surface area in younger children depends on the age of the child. Table 2 allows an estimate of the surface area involved, forming the initial basis for fluid therapy.

In all major burns a nasogastric tube is inserted. Intravenous fluids are started after a secure airway has been established. Sedation in major 3d degree burns, especially with respiratory involvement, is not indicated. The patient's weight is immediately determined, and an indwelling urinary catheter is inserted to monitor urinary output. Hematocrit value, blood type and cross match and serum electrolyte values are obtained. Central venous pressure monitoring is essential. Hemoglobinuria usually requires the addition of either mannitol or furosemide (Lasix) to avoid tubular damage. Blood transfusions are only given with hematocrit levels below 20 vol%.

FLUID REPLACEMENT IN MAJOR BURNS (MODIFIED BROOKE'S FORMULA).—The following are required during the first 24 hours: Ringer's lactate (1.5 ml/kg body weight × % burn); colloid (0.5 ml/kg body weight × % burn); maintenance with ¼ isotonic saline (2000 ml/m²/24 hr). Half the total volume is administered during the first 8 hours; the second half of the calculated fluid is administered during the remaining 16 hours.

During the subsequent 24 hours the total electrolyte and colloid replacement is reduced to 50%; maintenance fluid is continued at the same level. Regardless of the extent of the burn, no more than 50% of total body surface is calculated for the fluid administration.

Since there is a difference of opinion whether administration of colloid in the first 24 hours is advisable, several modifications of Brooke's formula exist: colloid is not infused during the first 24 hours and Ringer's lactate is increased to 2 ml/kg body weight × % burn. Colloid is then administered on the 2d day.

Prophylactic antibiotic therapy is used in all major burns. Cultures of burn wounds are taken on admission. Tetanus toxoid is administered in patients with previous immunization; hyperimmune globulin (human) is given if there is no reliable record of previous tetanus immunization.

INITIAL WOUND CARE.—Regardless of the type of care, open or closed, strict aseptic technique must be maintained.

Occlusive dressing.—Minor burns, or burns of hands and feet, are usually treated with occlusive dressings. Nonadherent water-permeable mesh is placed on the burn wound with a choice of various topical chemotherapeutic agents, including Furacin,

Sulfamylon, silver nitrate solutions, gentamycin or silver sulfadiazine. In burns of the hand, the fingers are placed in a position of function, separated by gauze with splinting of the entire hand.

Exposed (open) therapy.—The open technique is most commonly used in burns involving face, neck, perineum, and burns involving a large surface area. Open therapy requires hospitalization and is not applicable for ambulatory treatment.

All children with either 3d degree burns or more than 10% involvement of the body surface (regardless of the depth of burn) and significant burns of hands, face, feet or perineum should be admitted to the hospital.

From the onset of treatment, psychiatric support should be made available to all children with major burns.[3, 4]

XIV. OFFICE TRAUMA

The most common soft tissue injuries in children are abrasions, contusions, lacerations and crush injuries. As in all injuries the history is an essential part of the initial work-up. Delay between injury and office visit may change the treatment to be employed. Exact information of previous immunizations is essential to determine whether tetanus toxoid or antitoxin should be used. Allergy to antibiotics or local anesthetics should be known. Previous medical history may reveal that the "contusion or bruise" is not an isolated injury but part of a bleeding disorder, and the treatment of simple lacerations in patients with bleeding disorders obviously varies from that in the healthy child. Apparent superficial injuries, such as tire marks, may suggest associated major injury.

Contusions

Contusions without associated major trauma, such as underlying bone or joint injury, rarely require treatment other than rest, immobilization and occasionally hydrotherapy to facilitate absorption. In patients with contusion, bruises or swelling around joint areas, thorough examination for either bone or ligament injury is indicated, especially in young infants. Special x-rays, such as stress x-rays, may have to be taken to confirm the diagnosis of ligamentous injury.

It should be stressed that the "sprained ankle" can represent a much more serious injury than a "simple fracture." In contusion with swelling over extremities an underlying fracture should be ruled out as well as a preexisting lesion which may not have been apparent prior to the injury.

Abrasions

Superficial skin abrasions, involving not more than 10% of the surface area, can be treated on an ambulatory basis. Meticulous cleaning with saline and bacterial agents such as pHisoHex or Betadine should be followed by either closed or open treatment as in 1st degree burns. Antibiotic coverage is rarely indicated, but tetanus immunization is given in all skin wounds. Children with abrasions of more than 10% of the body surface should receive their initial treatment as inpatients.

Lacerations

The treatment of laceration depends on location, associated injuries (vascular, tendon, nerve), extent, contamination (animal bites or introduction of foreign matter) and interval between injury and examination.

The following lacerations are best treated in the emergency room or operating room:

1. Lacerations requiring cosmetic repair, such as facial lacerations.
2. Skin lacerations crossing joint creases even if there is no associated nerve or tendon injury; special techniques such as Z-plasties or flaps may be required.
3. All lacerations associated with suspected nerve, vascular or tendon injury. The initial evaluation of associated nerve or tendon injury may be extremely difficult, especially in a small child. Occasionally the lack of sensation or motion, indicating nerve or tendon involvement, may not be apparent until after laceration has been closed. The child should then be promptly referred for definitive treatment to an appropriate institution, since primary repair may even be possible at that time.
4. Lacerations older than 24 hours.
5. Lacerations caused by human or animal bites.
6. Extensive laceration which may require debridement or skin coverage, or both.

The repair of simple lacerations.—The wound is carefully inspected and cleaned meticulously with saline pHisoHex or Betadine solution. The depth of the wound is explored to insure that foreign bodies are not retained.

In patients with known injuries due to glass cuts, x-rays should be obtained routinely to rule out the presence of glass splinters. Even glass not containing lead is usually apparent on x-ray. Depending on the type of injury the foreign body may be located at a considerable distance from the entrance wound.

Other foreign bodies, such as nonradiopaque wooden splinters, may be difficult to find, and even if there is no evidence of foreign body the parents should be warned that the presence of a foreign body cannot be completely ruled out.

After the wound has been completely irrigated and cleaned, associated tendon, nerve or vascular injury ruled out, the subcutaneous defect is closed with absorbable sutures, preferably no. 3–0 or 4–0 catgut. The skin is then closed with small appropriate nonabsorbable sutures, preferably 5–0 or 6–0 nylon, with the exception of areas of particular stress, such as the sole of the foot, where 4–0 nylon should be used. In potentially contaminated wounds antibiotic coverage should be instituted.

Facial and neck sutures are removed within 4 days after the injury and Steri-Strips can then be applied to the skin to prevent disruption due to tension. In areas of increased tension, such as extremities, hands or feet, sutures may have to remain for 1 or 2 weeks depending on the stress exerted on the wound. Small and superficial lacerations can be closed with Steri-Strips alone if there is no subcutaneous "dead space" which permits the accumulation of fluid and therefore potential contamination. Local anesthesia for the closure of laceration is accomplished with 1% lidocaine (Xylocaine) infiltration without epinephrine.

In most children adequate sedation (pentobarbital [Nembutal] 1 mg/kg body weight and/or meperidine [Demerol] 1 mg/kg body weight up to 50 kg) will not only calm down the frightened child but facilitate both the cleansing and repair of the wound. The fact that a laceration can be repaired in a completely mummified child, held down by 3 adults, does not negate the use of sedation in children with injury.

Crush injuries

The most common crush injury occurring in childhood is the crush injury of the fingertip caught in either car doors or doors at home. Even deceptively minor looking crush injuries of the fingertip with only subungual hematomas may require prompt treatment. A subungual hematoma not only can be exceedingly painful, it can interfere with the viability of the fingertip. The prompt release of the subungual hematoma, accomplished by either incision or the use of a hot paper clip inserted through the nail, not only relieves the pain but may save the fingertip. In view of the often associated fracture of the distal fingertip and the danger of partial or complete loss, it is advisable to refer all crush injuries to an appropriate institution. In a patient with amputation of the fingertip, the amputated tip,

wrapped in sterile saline sponges, should be sent with the child. Even though replantation is not often successful, an attempt is usually worthwhile since even unsuccessful replantation does not interfere with the final treatment.

Animal Bites

Puncture wounds due to animal bites, regardless of the species involved, should not be closed but treated open after cleansing and careful irrigation with saline, pHisoHex or Betadine solutions. Only extensive lacerations, especially in the face, should be primarily repaired after careful debridement.[39] Animal bites treated in the office should be carefully inspected for infection at frequent intervals with cultures to determine the appropriate antibiotic therapy.

Tetanus

Although the World Health Organization in 1975 estimated that approximately 1 million deaths occurred as a result of tetanus, tetanus transmission due to animal bites or scratches is infrequent and only 2 or 3 such cases following insect bites, dog bites or other animal injuries are reported in the United States each year. Although the total incidence of transmission of tetanus via animal injuries or human bites is therefore exceedingly small, the potential fatality occurring with tetanus mandates that all injuries leading to a break of skin, including bites, be treated for tetanus. Each patient with a wound should receive tetanus toxoid intramuscularly at the time of injury, either as an initial immunizing dose or as a booster for previous immunization, unless he has received a booster and has completed his initial immunization series within the past five years. In patients where prior records of immunization are not available, immunization unknown or not given, passive immunization with tetanus immune globulin (human) should be given simultaneously. The anaphylactic reactions often present in the past are rarely encountered with tetanus immune globulin (human) (TIG [H]). The prophylactic dose of TIG (H) consists of 75 units for children under 5 years, 125 units for children from 5 to 10 years and 250 units for children over the age of 10 years.[40]

The failure to provide immunization against tetanus is best described by Wesley Furste[41] quoting Ovid: "Too late I grasp my shield after my wounds." Even minor wounds have led to tetanus and death.

Rabies

Rabies is transmitted by the virus contained in the saliva of a clinically rabid animal. Transmission through droplet and fomite transmission has been reported, however. The average incubation period ranges from 20 to 150 days with an average of 57 days. After the prodromal state the clinical course averages 7 to 8 days. There may be a relationship between the amount of local tissue destruction during inoculation and the clinical course. At the present time in the United States rabies is attributed predominantly to wild animals, in particular the skunk, fox, bat and coyote. Skunk bites are considered to be the most dangerous. Unprovoked attacks by skunk, fox and other wild animals should be considered as potential rabies transmission and both serum and vaccine used for treatment. The domestic dog has become an uncommon source of rabies. In known pets, such as cats and dogs, treatment is not indicated if the animal can be observed. The recommended dose for passive immunization using hyperimmune serum is 1,000 units/40 kg body weight. Approximately 5 ml is injected locally around the edges of the bite or the wound. The vaccine should be used according to the manufacturer's instructions. As in all infected wounds, a thorough cleansing with soap can reduce the chance of a rabies infection significantly, without obviating vaccination or serum injections. If the biting animal remains clinically asymptomatic for 10 days it is unlikely to carry rabies, although animals are known to be capable of carrying rabies without clinical manifestations.[3]

Snakebites

Most poisonous snakebites in the United States are due to pit vipers. The injection of the venom produces severe pain at the site of the bite, followed by erythema and edema spreading in a radial fashion. The symptoms are related to the amount of venom injected into the site of the bite and consist of blurring of vision, drowsiness, salivation and sweating. Paresthesia, slurring of speech, nausea, vomiting and respiratory difficulties can occur. If no symptoms occur within approximately 30 minutes it is unlikely that venom was injected.

Pit viper bites are managed in the following way. A tourniquet is applied above the area of edema and erythema. A cruciate incision is placed between the fang marks up to the depth of the bite and local suction is used. Ice is supplied to the site of the bite and extremity and cooling maintained for 24–48 hours. The tourniquet is intermittently removed and replaced above the spreading area of erythema.

Hydrocortisone is given intravenously (100 mg every 4 hr for 48 hr). Antivenin is injected around the bite or the proximal muscles and given as intravenous drip in saline over a 30-minute period. Depending on the type of bite and venom, repeat intravenous injections may be necessary at 30-minute intervals. A subcutaneous skin test with a 1:50 solution testing the patient for allergy to the antivenin should be obtained prior to its use. Systemic support consists of intravenous crystalloid solutions, antibiotics and steroids. Bleeding and clotting profile should be followed closely.

Insect Bites

The usual reaction to insect bites in nonallergic patients consists of the formation of a wheal around the sting site. A toxic reaction can occur with multiple stings or immediate hypersensitive reaction with an onset minutes after the sting. Bronchial spasm, tachycardia, hypotension and urticarial reaction can follow and may lead to death. A delayed hypersensitive reaction can occur 1 or 2 weeks after the sting and may consist of fever, lymphadenopathy or polyarthritis.

Local treatment consists of removing the involved sting by scraping, followed by cleansing, ice packs, rest, elevation and the administration of antihistamines. In patients with toxic reaction supportive care with intravenous fluids, antihistamines, sedation, calcium gluconate and intravenous hydrocortisone may be useful. Isuprel, epinephrine or aminophylline can be used in severe hypersensitive reactions with bronchospasm.

Black Widow Spider

The black widow, found throughout the United States, is identifiable by a red hour-glass figure on its ventral aspect. The bite is extremely painful. The local pain is followed by rigidity of the abdominal wall. Although the pain is self-limiting, its intensity often requires treatment. Local treatment with ice packs may alleviate some of the pain; intravenous calcium gluconate, muscle relaxants, sedatives and antivenin can be used as supportive treatment.

Scorpion Stings

Two types of venom are found in scorpion bites, one leading to local symptoms such as burning, swelling and pain; the other, due to a neurotoxin, may lead to death. The neurotoxin does not cause local swelling or discoloration but paresthesia followed by

hyperesthesia and hypoesthesia. The patient may show general signs such as drowsiness, sluggish speech and convulsive episodes with laryngospasm and respiratory and circulatory depression. The climax of the symptoms usually appears within 3–4 hours but may last as long as 2 days.

If a patient is bitten by a scorpion and there is little or no local reaction the danger of a neurotoxin injection should be considered. Treatment consists of tourniquet application, local hypothermia with ice accompanied by the use of barbiturates, calcium gluconate and a specific antivenin. Only 2 of approximately 30 types of scorpion in the United States carry the neurotoxin.[3]

XV. COMMON PEDIATRIC EMERGENCY PROCEDURES*

Nasogastric Decompression

Nasogastric decompression is indicated in all children with major trauma, including CNS injury, major burns and thoracic or abdominal trauma.

*The section on common pediatric emergency procedures was originally published in Shaftan, G. W. and Gardner, B.[3] Reprinted by permission.

Technique:

1. Efficient nasogastric decompression depends on the internal diameter of the nasogastric tube, its patency and length. Nasogastric feeding tubes, with small diameter and considerable length, create an increased peripheral resistance if used as drainage tubes and are not designed for nasogastric decompression.
2. In infants and young children, the largest catheter that easily passes through the ala and choana should be placed into the stomach.
3. After the catheter has been introduced, injection of a small amount of air with auscultation over the stomach and aspiration of gastric material will confirm its correct position.
4. Catheters should be taped in place, avoiding:

a) Pressure on the ala with possible resulting necrosis of the cartilage.

b) Occluding the nostrils by the anchoring tape to permit the infant to continue nasal breathing.

5. Gravity drainage is sufficient in most infants for adequate decompression, but even if intermittent suction is used, frequent injections of either small amounts of air or saline are indicated to either verify the patency of the tube or to restore its patency.

6. A nonfunctioning nasogastric tube is more deleterious than no tube at all.

7. In children over the age of 1 year sump drains can be used with continuous suction. Although the continuous inflow of air through the sump drain makes a clogging of the tube more unlikely, frequent manual irrigations and aspirations are still indicated to assure patency.

Warning:

1. Don't use a small feeding tube for gastric decompression.
2. Don't occlude both nostrils or apply pressure to the ala while anchoring the catheter.
3. Don't assume that "intermittent" or "continuous" suction provides suction without manual check.
4. Don't clamp the tube. The irrigation of a nonfunctioning nasogastric tube may lead to air swallowing and more gastric distention than if no tube is used.
5. Don't consider that even a functioning nasogastric tube is a guarantee preventing vomiting and aspiration.

Venous Cutdown

In contrast to adults, where lower extremity venous cutdown may lead to thrombophlebitis and embolism, the lower saphenous vein is the preferred site for an intravenous cutdown in infants and children. If traumatic injury or occlusion of major intra-abdominal vascular structures is anticipated in patients with suspected major intra-abdominal injury the saphenous vein should not be used, but either jugular or brachiocephalic veins.

Technique:

1. A venous cutdown should be performed under complete sterile conditions with the physician gowned, gloved and masked.
2. After adequate skin sterilization and draping, an incision measuring approximately 3 mm is made 1 cm above the anterior third of the medial malleolus into the subcutaneous tissue.
3. The incision is gently spread in a vertical fashion and with the use of a blunt nerve hook the saphenous vein can easily be delivered into the field.
4. The distal end is ligated with a 4–0 or 5–0 silk tie; another tie is loosely placed around the proximal portion and the vein is incised between them. An intravenous catheter with a blunted tip, approximately twice the size of the collapsed vein, is then gently inserted but no higher than midcalf. Attempting to pass the catheter past the popliteal fossa will either result in perfora-

tion of the saphenous vein or in obstruction of the catheter when the leg is bent.

5. The catheter is secured in place with the proximal tie and the wound is closed with one single atraumatic nylon suture.

6. The wound is covered with a small dressing soaked with a bactericidal solution, such as Betadine, and the catheter is securely taped in place.

7. The adhesive tape encircling the catheter extends past the incision and is securely taped, but not in a circular fashion, to the calf. This eliminates restraints like footboards, which are not only uncomfortable for the child, but may mask infiltration.

8. In patients undergoing operative procedures, the junction of catheter and intravenous tube should be securely taped so that separation does not occur unobserved during the operative procedure.

9. The catheter is removed as soon as signs of infiltration, tenderness, pain or reddening occur.

Warning:

1. Don't use encircling tapes.
2. Don't use stiff or pointed catheters.
3. Don't use hypertonic infusions, especially with pumps, in peripheral veins.
4. Don't perform a cutdown procedure under unsterile conditions, unless it is a lifesaving emergency.
5. Don't use lower extremity cutdowns if major intra-abdominal trauma is indicated.
6. Don't leave a cutdown catheter in place with signs of local infiltration, infection or sepsis possibly related to a contaminated catheter.

JUGULAR VENOUS CUTDOWN.—A venous cutdown of either the internal or external jugular veins may be preferable in children for:

1. Continuous measurement of central venous pressure.
2. Anticipated intravenous hyperalimentation.
3. An intravenous line when accessible peripheral veins are absent (previously used or collapsed in shock).
4. Patients with intra-abdominal vena cava compression, abdominal injury or anticipated operative caval occlusion.

Selection of veins: both external and internal jugular veins can be used for the insertion of intravenous cutdown catheters. Although an occlusion of all four veins can result in temporary facial cyanosis and venous congestion, collateral veins will usually prevent serious complication. While external jugular veins

are usually easily identifiable in older, particularly skinny children, the identification of the external jugular vein may be difficult in children in shock or in obese children, especially under one year of age.

Catheterization of the left jugular vein, especially the external jugular vein, may be difficult since the catheter may not advance into the superior vena cava but may go into peripheral veins. It is easier to catheterize the right jugular veins, especially the internal jugular vein, in an emergency.

Venous cutdown technique:

1. Maintenance of sterility as described above, in particular if intravenous hyperalimentation is anticipated.

2. External jugular vein:

a) The easiest point to identify and catheterize the external jugular veins is at the junction of the lower and middle third of the anterior border of the sternocleidomastoid muscle.

b) The distance from this point to the approximate entry into the atrium should be measured, and a catheter should be marked accordingly and inserted into the jugular vein.

c) Regardless of which jugular vein is used, the proper location of the catheter should be checked by:

1) Fluctuation of the central venous pressure during inspiration and expiration.

2) X-rays to determine the exact location of the tip of the catheter.

3. Internal jugular vein:

a) Although the internal jugular vein can be ligated proximal to the insertion of the catheter, a small circumferential purse suture of 6–0 or 7–0 silk is preferred. This allows a patency of the jugular vein and prevents the damping of a central venous pressure which can occur after ligation of the vein around the catheter.

b) If a long-term position of the catheter is anticipated, as in patients with hyperalimentation, the ipsilateral postauricular site should be prepared for the entrance of the catheter. An area above and behind the ear should be shaved and thoroughly prepared. A small incision is carried into the subcutaneous tissue, and a groove director is advanced subcutaneously to the neck incision, immediately over the jugular vein catheterization. The catheter is brought through the postauricular opening and then inserted into the jugular vein as described before. The catheter is sutured to the scalp to prevent movement. Antibacterial and antifungal ointment is placed around the opening and the incision is occluded by a water-tight dressing.

Warning:

1. Intravenous Pressure. If the catheter is introduced into peripheral veins or into the intra-abdominal vena cava, erroneous intravenous pressure readings can be obtained, especially if intra-abdominal pressure is increased. Proper identification of the tip of the catheter by (1) radiologic identification and (2) evidence of negative and positive pressure within the thoracic cavity is essential.
2. Perforation. The use of stiff catheters, especially if used in the left jugular vein, can lead to perforation with a resultant "glucose thorax" with escape of the administered fluid into the intrapleural or retropleural space.
3. Arrhythmias. The dissection of the jugular vein, especially of the internal jugular vein, may lead to cardiac arrhythmias in premature infants. Careful dissection and administration of atropine may be necessary in these patients.
4. Hyperalimentation. Hyperalimentation should not be attempted unless all ancillary services and trained personnel are available (proper solutions, sterile preparation, adequate facilities to follow metabolic changes and laminar flow for preparation of fluids).

BRACHIOCEPHALIC CUTDOWN.—Preparation for brachiocephalic cutdown is as discussed under venous cutdown, above.

Warning: if an antecubital cutdown is used, the brachial artery can easily be mistaken for a vein. For this reason a needle aspiration should be performed to properly identify the brachial artery and vein. If the brachial artery is transected by mistake, restoration of arterial flow is indicated since peripheral gangrene can occur in children with ligation of the brachial artery.

FEMORAL CUTDOWN.—A femoral vein cutdown is rarely indicated in children. Although thrombosis of the femoral vein after cutdown is tolerated by most children, the insertion of the catheter through the saphenous vein approximately 0.5 cm distal to the junction of femoral vein is preferable to a direct femoral vein catheterization.

ENDOTRACHEAL INTUBATION

Even though endotracheal intubation may be life saving in many instances, improper use may be more detrimental to the patient than mouth-to-mouth or mask respiration by personnel unfamiliar with intubation.

Emergency endotracheal intubation is indicated only:

1. If airway and assisted mask ventilation fail.
2. If there is glottic or supraglottic obstruction.

3. If appropriate endotracheal tubes and laryngoscopes are available.

In the majority of acute respiratory emergencies, the insertion of an airway, mask or mouth-to-mouth assisted ventilation is preferable to an attempt at intubation, until endotracheal intubation can be attempted by personnel familiar with the procedure. Repeated attempts at unsuccessful intubation not only can lead to severe local trauma, preventing further successful intubation, but can lose valuable time with increase in hypoxia and further deterioration of the patient. If a satisfactory air exchange can be obtained through orally assisted ventilation, as confirmed by auscultation, clinical observation of chest expansion and maintenance of a normal heart rate, intubation can be postponed until circumstances are appropriate. The addition of a nasogastric tube to prevent gastric overdistention, vomiting, aspiration and interference with diaphragmatic motion is indicated in all patients undergoing prolonged mask or mouth-to-mouth respirations.

Technique: endotracheal intubation for the inexperienced physician is best accomplished in the following way:

1. Prepare various sizes of endotracheal tubes likely to fit into the glottic space without trauma (for infants, sizes 8–12).
2. Measure and prepare an internal stylet if the endotracheal tube is flexible and soft.
3. Select an appropriate laryngoscope blade.
4. Clear the oropharynx of secretions prior to the insertion of the laryngoscope.
5. Have an assistant maintain hyperflexion of the head and slight pressure on the larynx if necessary.
6. Insert a nasal catheter attached to 100% oxygen.
7. Introduce the laryngoscope blade gently without pressure on pharynx or palate toward the base of the tongue, lift up the base of the tongue without touching the epiglottis and have your assistant put slight pressure on the larynx. This will bring epiglottis and vocal cords into view.
8. Evaluate the existing pathology, and if intubation is possible select the appropriate endotracheal tube and insert it between the vocal cords for a distance of 3–4 cm.
9. Use mouth inflation of the endotracheal tube with simultaneous auscultation and examination of the chest and stomach.
10. If the intubation attempt was unsuccessful, remove tube and laryngoscope and hyperventilate with mask or mouth-to-mouth and repeat the procedure after the condition of the patient has been stabilized.
11. Although an experienced endoscopist can lift up the tip of the epiglottis and insert the tube without difficulties, manipu-

lation of the epiglottis may lead to laryngospasm and make intubation impossible for the inexperienced. The use of the base of the tongue as fulcrum is therefore safer for the inexperienced endoscopist.

12. If the patient has been intubated successfully, confirm that both lungs are properly ventilated. Avoid deep intubation since the endotracheal tube may extend into the right main stem bronchus, occluding the left main stem bronchus.

13. Tracheostomy without intubation is rarely indicated. It is reserved for the patient in whom existing pathology or trauma prohibits both assisted mask or mouth-to-mouth ventilation and intubation.

Warning:

1. Don't attempt intubation when mask or mouth-to-mouth ventilation may be successful.
2. Don't waste valuable time by repeat intubations without attempting to ventilate the patient by mask or mouth-to-mouth.
3. Don't laryngoscope the patient without having cleared his secretions prior to laryngoscopy.
4. Don't attempt intubation unless your equipment is appropriate.

Postintubation:

1. Endotracheal tubes can be kept in place for several days if there is no associated trauma during introduction.
2. In patients with observed or anticipated trauma, or if prolonged respiratory support is indicated, tracheostomy is preferable to avoid the superimposed trauma created by the indwelling tube.
3. If prolonged assisted ventilation by respirators is expected, nasotracheal intubation is preferable to orotracheal intubation, since it will decrease the trauma on the vocal cords imposed by the continuous motion of the endotracheal tube during the positive-pressure phase of the respirator.
4. After the orotracheal or nasotracheal tube has been secured and the patient has stabilized, confirm the exact position of the tracheal tube by x-ray.
5. Prior to the introduction of the endotracheal tube, under elective circumstances, the length of the largest catheter capable of passing through the lumen of the endotracheal tube should be marked. This catheter is not used for aspiration, but as a guide to the personnel responsible for endotracheal suctioning. By comparing the guide catheter and the catheter used for suctioning, a beginning obstruction at the end of the endotracheal

tube interfering with the passage of the endotracheal suction catheter can easily be identified.

Tracheostomy

A tracheostomy in an infant or a child is neither a minor procedure nor, with rare exceptions, should it be performed on the ward or in the emergency room.

If possible, the tracheostomy should be done under general anesthesia in the operating room following endotracheal intubation. Complications following tracheostomies are frequently related to tracheostomies performed with faulty technique or improper site. The internal diameter of the trachea in children, especially in infants, is relatively narrow at the level of the first and second ring and begins to widen at the third and fourth ring just prior to the intrathoracic entrance. Therefore, the location least likely to create a postoperative stenosis is at the fourth tracheal ring.

Technique:

1. Endotracheal intubation with general anesthesia and controlled ventilation.
2. Hyperextension of the neck.
3. A transverse neck incision over the midline, approximately 1–2 cm cephalad to the manubrium.
4. Transection of the platysma, identification and separation of the strap muscles.
5. The areolar tissue anterior to the trachea is dissected bluntly and retracted until the tracheal rings can be visualized.
6. The fourth tracheal ring is identified.
7. A vertical incision is made into the fourth ring, and a nonabsorbable suture is placed on each side of the incision encircling the transected cartilaginous ring.
8. Gentle traction on these sutures will elevate the trachea into the wound, and an appropriate tracheostomy tube, preferably a Silastic tube, is selected in accordance with the internal diameter of the trachea.
9. If the incision appears inadequate, the proximal or distal ring can be incised to enlarge the opening.
10. After removal of the endotracheal tube, the tracheostomy tube should be inserted without undue pressure on the trachea.
11. If a metal tube is used, the length of the tube has to be measured to avoid a placement into one of the main stem bronchi. If the metal tracheostomy tube appears too long, the tube should

only partially be inserted with a stent between the skin and the tube until a proper tube can be obtained.

12. After the tracheostomy tube has been inserted, dental rolls are tied to the end of each traction suture and left in place (Haller procedure). If the tracheostomy tube should inadvertently dislodge, the personnel in the recovery room or the ward can simply lift the trachea into the wound by a pull on the traction suture and reinsert the tracheostomy tube.

13. A closure of the skin around the tracheostomy tube is unnecessary.

Warning:

1. Don't perform a tracheostomy without an endotracheal tube unless intubation is impossible.
2. Don't try to force a tracheostomy into an inadequate tracheal incision.
3. Don't use a metal tracheostomy tube if the curvature or size is inappropriate.

Tracheostomy extubation:

1. After the respiratory emergency leading to the tracheostomy has subsided, extubation should be performed gradually.
2. In children, gradual change to small tracheostomy tubes will permit extubation over the period of several days.
3. The partial or complete "blocking" of tracheostomy tubes, in particular in infants, is contraindicated since the plugged indwelling tracheostomy tube leads to considerable airway obstruction.
4. Removal of a tracheostomy tube in an infant can be facilitated by the immediate insertion of a small plastic catheter which can be used for temporary ventilation if the removal of the tracheostomy tube leads to respiratory distress.

Abdominal Paracentesis

Indications for abdominal paracentesis in children are:

1. Evaluation of intraperitoneal trauma in the unconscious patient with multiple trauma.
2. Differentiation between abdominal wall and intraperitoneal trauma following blunt injury.
3. Decision not to operate on a patient with penetrating abdominal trauma.
4. To establish the diagnosis of primary peritonitis.

Technique:

1. Paracentesis should only be performed in the right or left

lower quadrant—or in midline 1–2 cm below the umbilicus. The introduction of a paracentesis needle in the upper quadrants may result in damage to either liver, gallbladder or spleen.

2. The supine patient is slightly rotated with a padding behind his back, so that the lower quadrant to be aspirated is in a slightly inferior position.

3. Various types of needles can be used for the aspiration or lavage; 18-gauge spinal needles with an indwelling stylet or needles with an outer Teflon sheath are both suitable.

4. In the noncomatose patient, a small intradermal injection of procaine is followed by a small incision with a pointed blade to facilitate the slow introduction of the paracentesis needle.

5. Loss of resistance indicates that the needle has perforated the peritoneum. Either the stylet or the needle within the Teflon catheter is withdrawn, and the latter is slightly advanced.

6. A syringe is attached and slowly aspirated. The presence of blood which fails to clot is indicative of defibrinated intra-abdominal blood due to trauma. In patients with suspected primary peritonitis, the presence of purulent material confirms the proper location of the needle. The material is aspirated for Gram's stain and bacteriological culture.

7. In patients with suspected intraperitoneal trauma, where neither peritoneal fluid nor blood can be obtained, 100–250 ml of saline is slowly infused through the needle or catheter, followed by reaspiration. The return of sanguineous fluid indicates that intra-abdominal trauma with bleeding has occurred.

8. Peritoneal lavage is a much more sensitive test than paracentesis, so that even minute amounts of intraperitoneal bleeding, not necessarily requiring operative intervention, may yield a positive lavage. One milliliter of blood dispersed in 500 ml of saline will produce a bright red color. The finding of a positive lavage in the absence of a positive paracentesis is a matter of interpretation, and in the absence of peritoneal signs the decision to perform exploratory celiotomy is an individual one.

Warning:

1. Don't perform paracentesis in either upper quadrant.

2. Don't interpret the aspiration of fecal material as evidence of peritonitis. If the suspicion exists that the paracentesis needle inadvertently entered a loop of intestine, a repeat paracentesis and/or lavage is indicated. The perforation of intestine with a paracentesis needle rarely leads to persistent leak or complication.

3. Don't regard a negative paracentesis as a negative diagnostic study.

Tube Thoracostomy

Tube thoracostomy is indicated in instances of pneumothorax, tension pneumothorax, pleural effusion and empyema, or following thoracic operations.

Effective drainage of intrapleural fluid is best accomplished through a dependent portion of the chest, and the most accessible dependent portion of the chest in a patient lying in bed is a low midaxillary position which does not interfere with the patient's resting position. Evacuation of air, with or without tension, can be accomplished through any intrapleural site, but in contrast to adults, where the anterior second or third intercostal space is frequently used, the introduction of a thoracostomy tube in infants and young children is difficult in this area due to the proximity of major vascular structures. Evacuation of both fluid and air in infants and children is therefore best accomplished through a midaxillary thoracostomy tube in the sixth or seventh interspace.

Technique:

1. The child is placed in a lateral position lying down, with the involved side elevated.
2. Procaine is injected over the site of entrance, and a small incision, approximately the size of the tube to be introduced, is carried through the skin into the subcutaneous space.
3. In infants and young children, a curved hemostat is slowly advanced between the intercostal muscles until the pleura is reached.
4. The pleura is perforated with the tip of the hemostat in a position parallel to the thoracic wall, to avoid injury to the underlying lung.
5. The exchange of air or the escape of fluid indicates an open communication between the intrapleural space and the skin.
6. The hemostat is intermittently opened and advanced, thereby enlarging the entrance into the intrapleural space.
7. A thoracostomy tube, approximately the size of the intercostal space, with two or three side holes, is then advanced into the chest and secured with two nonabsorbable skin sutures tightly closing the skin around the tube to prevent an air leak.
8. Depending on the underlying pathology, the tube is then attached to either a simple water seal drainage or negative suction.
9. An airtight dressing, preferably Furacin or Vaseline dressing, is applied and covered by tape, additionally anchoring the thoracostomy tube.

Postthoracostomy management:

1. When the thoracostomy tube is attached to simple water seal drainage, its patency can be checked by observation of the continuous fluctuation of the water level during inspiration and expiration.
2. Lubrication of the tube with mineral oil will facilitate the "milking" required at frequent and regular intervals to preserve patency of the tubing.
3. In patients on negative suction, the fluctuation may not be apparent and patency is therefore more difficult to evaluate. Intermittent disconnection, unless an air leak exists, is therefore required to allow the nursing personnel to monitor the tube's patency.
4. If a chest tube has become occluded and further drainage is indicated, irrigation of the chest tube is contraindicated since it may allow retrograde contamination. A nonfunctioning chest tube should be removed and replaced by a new tube.

Warning:

1. Don't insert a chest tube under unsterile conditions.
2. Don't use a chest tube larger than the intercostal space; it will be compressed and become nonfunctional.
3. Don't clamp chest tubes when the patient is transported to the operating room or other facilities, if an active air leak exists.
4. Don't irrigate chest tubes to restore patency.

Thoracocentesis

Thoracocentesis is indicated in patients with pneumothorax, tension pneumothorax or empyema or for diagnostic aspiration of a pleural effusion.

Technique:

1. The patient should be in an upright sitting position or slightly tilted toward the involved side.
2. A small intradermal wheal with procaine precedes the introduction of the larger bore needle.
3. Instead of entering chest at a right angle, a slanted angle will allow the entrance of the needle through the pleura parallel to the thoracic wall, which probably is less likely to injure the lung, especially in nonsedated apprehensive children or crying infants. The bevel of the needle should face the thoracic wall, with the shorter side toward the lung.
4. The syringe is attached to the needle prior to the introduction of the needle, and the movement of the piston is tested

prior to aspiration. If the intent of the thoracocentesis is aspiration and evacuation of pleural effusion, a three-way stopcock is placed between the syringe and the needle to allow the change of syringes without introduction of air.

5. In patients with suspected tension pneumothorax, the upright position and tangential introduction of the needle are unnecessary. Since the patient's respiratory and cardiac status may be compromised, aspiration is best done in a supine position.

6. After the diagnosis of tension pneumothorax has been made, the piston is removed from the syringe to allow the continuous escape of air until a thoracostomy tube can be introduced.

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