Chapter 5
Birth Trauma

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Abstract It is important to differentiate injuries that can occur in the newborn and infant population from intentional injury because fractures resulting from abuse primarily occur in the infant and toddler age group. Worlock and colleagues showed that 80% of fractures caused by abuse were in children less than 18 months old. On the other hand, 85% of fractures in children older than 5 were due to nonintentional trauma (BMJ 337:a1518, 2008). While these percentages are measures of different types of injuries sustained in different age groups, they emphasize the need in differentiating intentional injury from nonintentional injury in the infant and toddler age group.

5.1 Introduction

Injury can occur during a difficult delivery with or without the involvement of instrumentation. Significant birth injury has been declining, and is more of a problem in underdeveloped countries but still accounts for between 6 and 8 injuries per 1000 live births. There are several risk factors for birth injury. These include infants larger than 4500 g, prematurity, forceps delivery, vacuum extraction, abnormal fetal presentation, prolonged labor, and precipitous delivery [1, 2].

5.2 Trauma Involving the Soft Tissues of the Newborn Head

The mechanics of the birth process is a blend of potentially traumatizing compressions, contractions, torques, and traction. When the process is complicated by abnormal fetal size, maturity, or presentation, this may lead to increased incidence and severity of damage to the soft tissues of the head and even a skull fracture [3]. These are not typically seen with intentional injury of the newborn since they occur at delivery.

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5.2.1 Cephalohematoma

Cephalohematoma is a subperiosteal collection of blood caused by rupture of vessels beneath the periosteum [1]. It occurs in approximately 2.5% of normal newborn deliveries and is typically associated with forceps and breech deliveries [2]. Vacuum extraction often produces these types of hematomas, particularly when the cup has to be reapplied after an unexpected release. Skull fractures are found in 5% of children that have been delivered by vacuum extraction [4].

Cephalohematoma do not cross suture lines and most commonly occur on the parietal and occipital bones. Subperiosteal bleeding may be slow and may not be apparent immediately after birth, but may occur within the first few days of life. Skull fractures may be present in up to 5% of these nonabusive hematomas. They are the linear, nondepressed variety and usually go undiagnosed unless problems arise while the infant is in the newborn nursery [2].

5.2.2 Subgaleal Hematoma

A subgaleal hemorrhage occurs between the galea aponeurosis of the scalp and the periosteum. Ninety percent of these hematomas are caused by the use of vacuum extraction during delivery of the newborn, but a forceps delivery can cause it too.

Subgaleal hemorrhages are associated with head trauma (such as intracranial hemorrhages) or skull fractures 40% of the time [1]. These hemorrhages present with a boggy mass that develops over the scalp most commonly in the occipital area of the skull. The mass can cross suture lines, in contrast to the cephalohematoma. It develops insidiously over 12–72 h after delivery. In severe cases, shock may develop in the infant [1]. These traumas are not primarily indicative of intentional injury.

5.3 Cranial Injuries of the Newborn

Cranial injuries that can occur as a result of birth trauma include both linear and depressed skull fractures. Various studies have shown that in children under 3 years of age, skull fractures are the most common fracture type in both abused and nonabused children. The most common site of the fracture is the parietal area of the skull in both intentional and nonintentional injuries [3].

5.3.1 Linear Skull Fractures

Linear skull fractures are associated with compression of the skull from the application of forceps or from the skull pushing against the maternal symphysis or ischial spines [1].

5.3.2 Depressed Skull Fractures

Depressed skull fractures usually occur secondary to compression associated with a forceps delivery, but have been described as occurring in utero. These are typically the "ping-pong ball" type due to the inward buckling of the neonatal calvarium [2]. These rounded deformations occur due to the malleability and elasticity of the immature neonatal skull [4].

A complete newborn history of delivery and nursery stay is critical in determining when the fracture may have occurred. When this is not available, confusion can result.

5.4 Postcranial Fractures

5.4.1 Clavicular Fractures

Birth trauma has to be considered as a possible etiology when a fracture is diagnosed in an infant a few weeks old. Clavicular fractures are the most common fracture seen with birth trauma [2]. The reported incidence ranges from 0.3 to 2.9% of newborns. The fracture is not diagnosed at discharge in up to 40% of these injuries. Shoulder dystocia, large for gestational age, and prolonged second stage of labor are risk factors associated with clavicle fracture. Most of these fractures occur in normal newborns during an uncomplicated delivery, the reason why so many go undiagnosed in the hospital [2].

There are complete and incomplete clavicular fractures associated with birth trauma. Many do not cause the newborn any discomfort, especially if the fracture is the incomplete variety. The most common presentation is decreased movement on the affected side. Physical examination may reveal crepitus, a palpable bony prominence, or discoloration over the injury. The fracture is usually found in the mid-shaft region of the clavicle because it is due to compression secondary to a shoulder dystocia. Clavicular fractures can be associated with brachial plexus injuries when traction on the shoulder or arm is needed to deliver the newborn [2]. Fractures of the clavicle occur more often with vaginal deliveries than with Cesarean sections. It is possible to differentiate a clavicle fracture due to birth trauma from clavicle fractures from other causes by dating the fracture with a radiograph. If a callous formation is not seen within 11–14 days after birth, the fracture did not occur during the delivery [4].

5.4.2 Rib Fractures

Rib fractures due to birth trauma are rare. Most rib fractures in infants are thought to be due to abuse unless proven otherwise. Rib fractures are the third most common

type of injury seen in abused children of all ages. They are rarely associated with external evidence of trauma.

During abuse, most fractures result from compression in the anterior–posterior plane of the chest due to shaking [5]. The fracture that results from anterior–posterior compression may result in stress over the ventral cortex and a fracture on the posterior rib where the rib tubercle articulates with the transverse process. Direct trauma of sufficient force that can be seen during abuse may produce a fracture at the site of the injury.

Various studies have yielded conflicting information on the location of the fractures that can occur due to intentional or nonintentional trauma. According to these studies, fractures on the rib could be either anterior or lateral if abuse was present. Posterior rib fractures were more significantly associated with abuse, as well as multiple rib fractures. Rib fractures in abused children tend to be found in children less than 1 year old. In birth trauma, rib fractures are found posteriorly near the costovertebral junction and are rare unless associated with diseases that produce bone fragility [2, 5].

The mechanical forces associated with cardiopulmonary resuscitation do not result in rib fractures in the newborn unless there are complicating conditions such as severe prematurity or conditions associated with bone fragility such as rickets and osteogenesis imperfecta [5, 6].

Accidental rib fractures are unusual in infants but may occur with massive trauma. In contrast to non-accidental rib fractures, they tend to be associated with older infants and to occur more laterally on the rib shaft [6].

Differentiation between non-accidental trauma and accidental trauma is largely dependent on gathering information from the birth record as well as how the injury occurred. Bone scans are more sensitive than radiography in diagnosing a rib fracture [6].

5.4.3 Fractures of the Extremities

Fractures of long bones such as the humerus and femur are uncommon in newborns and infants. The incidences of these particular types of fractures are only 0.13 and 0.05 per 1000 live births [2].

Fractures of long bones are usually easy to diagnose. They typically present with decreased movement of the affected extremity, swelling at the site, pain when the extremity is manipulated, and crepitus. The obstetrician may have heard a snap at the time of delivery [2]. Occasionally, the fracture is not diagnosed during the newborn hospitalization, and this may make determination of abuse more difficult.

Diagnosis of fractures of long bone is usually made with conventional radiography. This is not true with epiphyseal fractures because the epiphyses are non-ossified at birth. Ultrasonography can establish the diagnosis. Radiographs will show callus formation in 7–10 days, and this may help with defining the time of the injury as well [2].

5.4.3.1 Humeral Fractures

Humeral fractures are the most commonly fractured long bone resulting from birth trauma. These fractures are usually located in the diaphysis of the bone, and are associated with breech presentation, Cesarean delivery, and low birth weight [2, 7].

During a vaginal delivery, humeral fractures can be due to hyperextension or rotation of the arm during passage through the birth canal. These fractures are usually transverse. Large infants are at increased risk for this, as well as infants during a breech presentation (regardless of the size of the infant) [4].

Proximal humeral epiphyseal injury is rare in newborns and may not be diagnosed until several days of age. This injury can occur during the birth process or with child abuse. These fractures present in the same manner with decreased movement of the arm and irritability of the infant when the arm is moved [7].

Spiral fractures that are identified in the humerus are closely associated with intentional trauma and are one of the most common fractures seen in children younger than 15 months of age. Supracondylar fractures are more commonly seen in nonintentional injuries [3].

5.4.3.2 Fractures of the Femur

Femoral fractures due to birth trauma are rare in uncomplicated vaginal deliveries. Spiral fractures of the proximal femur have been reported during breech deliveries, twin deliveries, forceps births, premature births, and Cesarean sections [4]. However, one study found that spiral fractures of the femur was the most common abusive injury seen in children under 15 months of age [3]. Fractures are less common in Cesarean deliveries [8].

Breech deliveries may result in an epiphyseal fracture instead of the more common transverse diaphyseal location due to traction on the extremity. The epiphysis is the specialized area of bone that is linked to the diaphysis by the metaphysis. It is the part of the bone that allows for growth and is therefore more fragile.

Femoral fractures can be seen in association with neuromuscular diseases that prevent or limit movement of the extremity by the fetus while in utero. The bone involved is weakened due to the inactivity, making fractures more likely to occur during any type of delivery [7].

5.5 Causes of Bone Fragility

Congenital and/or metabolic diseases can be responsible for producing bone fragility. The two most frequently recognized disease processes that result in fractures in the newborn period are osteogenesis imperfecta (OI) and metabolic bone disease of prematurity [9]. Both of these diseases present with osteopenia that is seen on a radiograph of the involved bone. Osteopenia is defined as insufficiency of bone mass that results from a reduced production of bone, or an increased breakdown of

bone, or both. This increases the susceptibility of fracture of the involved bones. The above-mentioned diseases are caused by a decreased production of bone.

The differentiation between child abuse and non-accidental trauma relies on clinical history and examination supplemented by radiological studies such as plain films and ultrasonography. Dating of fractures by an experienced pediatric radiologist as well as the pattern of the fractures can suggest the causes and mechanisms of certain injuries.

Premature infants tend to present with diaphyseal fractures of long bones and ribs not associated with intentional injury. Metaphyseal fractures can be pathognomonic for intentional trauma when seen in children younger than 2 years of age that have normal bone structure, but are rare in both OI and metabolic bone disease of prematurity. Metaphyseal fractures can be very subtle and often are not associated with tissue swelling or bruising. They can be difficult to see on conventional radiography. They are often called corner or bucket handle fractures, and are the result of twisting or shearing forces.

The occurrence of multiple fractures in children increases the suspicion of child abuse, but can be seen in infants and children with OI. In the case of OI, bone deformities are usually present [9].

5.5.1 Osteogenesis Imperfecta

OI is one of the most common skeletal dysplasias. In the United States, it is estimated to occur in 1 out of 20,000 live births. This may be an inaccurate estimation since the milder types I and IV may be underdiagnosed. It is a congenital defect in the formation of connective tissue in the skeleton and may manifest with findings such as blue sclera, triangular facies, macrocephaly, hearing loss, defective dentition, barrel chest, scoliosis, limb deformities, fractures, joint laxity, and growth retardation.

The defect is present in all the tissues in which type I collagen is an important constituent. These tissues include bone, ligaments, teeth, and sclera. The basic defect is either in the amount of collagen or a reduction in the quality of type I collagen. In 90% of cases of OI, the defect is caused by a mutation in the type I collagen genes COLIA1 and COLIA2, which encode type I collagen -1 and -2 protein chains, respectively.

There are four types of OI. Types I and IV may result in fractures that could be confused with child abuse. Types II and III are so severe that they are not likely to be considered a cause of abuse, so they will be discussed briefly.

Type I OI is an inherited autosomal dominant disease. Ten percent of newborns with OI type I may present with fractures. They do not typically have long bone deformities unless fractures have occurred. The sclera may be blue or white. Teeth may be abnormal, but this is not helpful in the newborn period to distinguish OI from abuse. Fractures can occur anytime, but happen frequently in the newborn period, as previously mentioned. Bowing of the lower limbs can occur. Radiographs reveal osteopenia and normal callus formation at the site of the fracture.

Type II OI is a lethal syndrome. The result is a stillborn infant.

Type III OI presents with severe bone fragility and multiple fractures leading to progressive bone deformities. It has an autosomal recessive inheritance pattern.

Type IV is not as well defined as the other types. Patients may have normal height, and the sclera may not be discolored. Dentition may be normal as well. Like type I, fractures begin in infancy and can occur in utero. Type IV does not have impaired hearing, which is characteristic of type I. Bowing of the lower limbs may be the only manifestation of the syndrome if it is type IV [9–11].

Types I and IV can be mistaken for child abuse. The fractures associated with OI are usually seen in the diaphyseal region of the long bones. However, up to 15% of the fractures may be in the metaphyseal area of the bone [7].

Differentiation will require a detailed family history and a thorough clinical examination, as well as radiography. Due to the defect in the type I collagen protein, the overall bone mass is reduced within the skeletal envelope. Bone biopsies may need to be performed to aid in diagnosing OI. The biopsies reveal a thinner and more porous cortex. Tubular bones are more narrow, leading to an increased risk of fracture when compared to normal bones. Type I OI will show milder abnormalities and the abnormalities in type IV will be more severe.

A molecular diagnosis of the bone disease may be necessary. There are three ways to diagnose this in the laboratory. Biochemical analysis of collagen species and mutational analysis of RNA require skin fibroblasts from a skin biopsy. This may be unacceptable in an infant. The third way is with mutational DNA and is less traumatic [9] (Table 5.1).

Table 5.1 Summary of the types of osteogenesis imperfecta [12]

Type	Characteristics	Genetics	Types of bony involvement
I	Sclera – white or blue, abnormal dentition, impaired hearing	Autosomal dominant	Fractures in newborn, bowing of lower limbs, osteopenia with normal callus formation at fracture site
II	Lethal syndrome	Autosomal dominant	–
III	Severe bone fragility	Autosomal recessive caused by parental mosaicism	Fractures associated with progressive bony deformities
IV	Not as well defined	Autosomal dominant	Fractures in infancy or in utero, bowing of lower limbs; fractures and deformities can be severe

5.5.2 Metabolic Bone Disease of Prematurity

Metabolic bone disease of prematurity (also known as osteopenia of prematurity and preterm rickets) is seen in infants born before 28 weeks of gestation. The fractures

that occur because of this disease are in infants (with a corrected gestational age) after 10 weeks of life and no later than 6 months.

Rib fractures are the most common fractures diagnosed in preterm infants, but this may be because preterm infants tend to have a lot of chest radiographs done to evaluate lung maturity and to follow their progress while on the ventilator.

Fractures in the diaphysis of long bones can also occur. The incidence of all types of fractures associated with this disease is not known because the fractures may not be identified because infants are not ambulating and are often critically ill because of their prematurity [9].

Other risk factors for this disease are cholestatic jaundice, bronchopulmonary dysplasia, prolonged intravenous nutrition, and diurectic treatment with furosemide (greater than 2 weeks) that is used to treat bronchopulmonary dysplasia. These risk factors are responsible for decreasing bone mass and compromising the integrity of the bones. Intravenous nutrition is unable to provide the necessary ingredients needed to supply the mineral substrates for bone formation and mineralization.

Metabolic bone disease of prematurity is a self-limiting condition. As the preterm infant begins to eat a calcium-fortified formula and move around more, the bones strengthen and become less fragile. Usually by the age of 2 years, the preterm infant's bone mass and strength have caught up with children born at term gestation [9, 12].

The newborn history and hospital course should be all that is needed to differentiate between child abuse and preterm rickets.

5.6 Uncommon Diseases That May Produce Fractures in Infants and Toddlers

There are several other rare diseases of bone in infants and children that can cause fractures and may be confused with child abuse. However, these are not commonly seen and have other distinguishing characteristics besides fractures.

5.6.1 Menkes' Syndrome

Menkes' syndrome or kinky hair syndrome is associated with inadequate absorption of copper. Metaphyseal fractures and periosteal reactions of bone can be seen in Menkes' syndrome as well as intentional trauma of infants and children.

A periosteal reaction is the formation of new bone in response to injury or other stimuli to the bone. Chronic irritation of the bone can be seen in certain medical conditions such as hypertrophic osteopathy or in response to a healing fracture, chronic stress injury, subperiosteal hematoma, osteomyelitis, or cancer. Periosteal reactions take about 3 weeks to develop. Wormian bones in the skull and reduced serum levels of copper and ceruloplasmin will confirm this diagnosis [7, 12].

5.6.2 Cole–Carpenter Syndrome

Cole–Carpenter syndrome presents with ocular proptosis, hydrocephalus, and osteopenia. This is an extremely rare syndrome, and fractures can be a component of this disease [9, 12].

5.6.3 Bruck Syndrome

Infants with Bruck syndrome are born with joint contractures and bone fragility. This is an extremely rare syndrome, and fractures can be a component of this disease [9, 12].

5.6.4 Idiopathic Juvenile Osteoporosis

Congenital idiopathic juvenile osteoporosis (IJO) has a heterozygotic defect in the gene *LRP5*. Infants with IJO can present with vertebral crush fractures and metaphyseal fractures of long bones. Vertebral crush fractures are caused by osteoporosis and may occur with very minimal force during twisting or even standing [9].

5.6.5 Osteoporosis Pseudoglioma

Osteoporosis pseudoglioma syndrome results from homozygotic genetic mutations. It is very rare, and the infants have a progressively deforming bone disease similar in nature to OI type III. The deformities of the bones are so severe that it is unlikely to be confused with child abuse [9].

5.6.6 McCune–Albright Syndrome

McCune–Albright syndrome is a condition that causes fibrous dysplasia of the skeletal system that weakens the structure of the bone, patchy cutaneous pigmentation, and certain types of endocrine dysfunction. The endocrine dysfunction may result in precocious puberty (the most common), hyperthyroidism, and Cushing syndrome. The bony lesions can result in pathologic fractures [9, 12].

5.6.7 Osteopetrosis

Osteopetrosis is characterized by increased density of bone. Inheritance is usually autosomal recessive, but the inheritance pattern may be autosomal dominant in

some people. Fractures are not usually seen in this disease. Hyperostosis is seen radiographically [9, 12].

5.6.8 Caffey's Disease

Caffey's disease is also called infantile cortical hyperostosis. It is seen in children younger than 6 months of age. Cortical thickening is usually seen in the mandible, clavicle, and ulna. It is more commonly confused with osteomyelitis because of a similar periosteal reaction in the involved bone [7, 9, 12].

5.6.9 Infantile Severe Hypophosphatasia

In infantile severe hypophosphatasia, biochemical studies will aid in diagnosis. Infants will have very low serum alkaline phosphatase activity, and there will be elevated urinary levels of phosphoethanolamine. Sometimes the diagnosis can be made in utero. The skull may lack calcification of the frontal, parietal, and occipital bones. Infants with severe cases die in infancy, but those with milder types can present with fractures during this time period [9, 12].

5.6.10 Familial Hypophosphatasia

Familial hypophosphatasia (also known as vitamin D–resistant rickets) was first described in 1937 by Albright, Butler, and Bloomberg. It is usually transmitted as an x-linked dominant trait where males are more severely affected. Children are normal at birth and grow normally until about 6 months of age. At that time, growth retardation develops, phosphate levels fall, and alkaline phosphatase activity becomes elevated. Serum calcium levels remain normal.

Fractures can result because the structural integrity of the bone has been altered. Several typical findings of rickets are seen on radiographs such as cupping of the metaphyseal ends of long bones including the proximal and distal tibia, femur, radius, and ulna. In contrast to vitamin D–deficient rickets, the head and chest are minimally involved. Other radiological findings associated with vitamin D–deficient rickets are fraying of the metaphysis, widening of the physis, and "Looser's zones" (sharply defined, symmetric, transverse stress fractures of long bones) [12].

5.6.11 Scurvy

Scurvy usually presents after 6 months of age and is due to vitamin C deficiency. There may be presence of subperiosteal hemorrhage, thin cortices, and osteopenia. Metaphyseal fractures can occur, but bone mineralization has been impaired, differentiating scurvy from child abuse [7].

5.6.12 Vitamin A Intoxication

Vitamin A intoxication rarely produces fractures. There may be widening of the cranial sutures and a thick undulating periosteal reaction of long bones. Vitamin A levels can confirm the diagnosis [7].

5.6.13 Congenital Insensitivity to Pain

Congenital insensitivity to pain has an unspecified inheritance pattern. It is seen in males more often than in females and presents in early infancy. Children are completely normal except for pain and temperature insensitivity. Children with this condition do not perspire and develop high fever when exposed to warm environmental temperatures. They can present with multiple fractures and epiphyseal separations in various stages of healing. Clinical history and a detailed neurosensory examination will determine the diagnosis [12] (Table 5.2).

Table 5.2 Disorders that may mimic child abuse

Disease/pathology	Typical age affected	Bones involved and type of fracture	Authors
Osteogeneis imperfecta	Newborn, infant, and toddler	Skull linear, diaphyseal long bone, rarely metaphyseal fractures	[10, 11]
Metabolic bone disease of prematurity	Premature infant > 10 weeks and < 6 months	Diaphyseal long bone and ribs	[9, 12]
Menkes' syndrome	Infant and children	Metaphyseal fractures and periosteal reactions	[7, 12]
Cole–Carpenter syndrome	Infant and children	Long bone fractures	[9, 12]
Bruck syndrome	Infant and children	Long bone fractures	[9, 12]
Idiopathic juvenile osteoporosis	Infants	Vertebral crush fractures and metaphyseal fractures of long bone	[9, 12]
Osteoporosis pseudoglioma	Infants	Multiple fractures and bone deformities	[9, 12]
McCune–Albright syndrome	Infants and children	Pathologic fractures of long bone	[9, 12]
Osteoporosis	Children	Fractures not usually seen	[9, 12]
Caffey's disease	Infants < 6 months	Fractures not usually seen	[9, 12]
Infantile severe hypophosphatasia	Infants	Skull and fractures of long bone	[9, 12]
Familial hypophosphatasia	Infants > 6 months and children	Long bone fractures	[12]
Vitamin A intoxication	Infants and children	Periosteal reaction of bone without fractures	[7]
Congenital insensitivity to pain	Infants and children	Multiple fractures and epiphyseal separations	[12]

5.7 Conclusion

Differentiating nonintentional trauma from intentional trauma is always difficult especially in the infant and young child. There are many injuries that can occur around the time of delivery and many conditions that can cause fragile bones in this age group that increase the risk of sustaining a fracture. Unless there are multiple fractures and other evidence of trauma in a setting compatible with an accident, care must be taken to discover the cause, timing, and mechanisms involved that produced the injury. A complete and comprehensive history and physical examination paying close attention to signs of trauma must be performed. Various laboratory testing and radiological procedures can further delineate who or what is responsible for the injuries sustained.

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