The Pancreas in Child Abuse

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ABSTRACT

The pancreas can be a critical indicator of inflicted injury in young children. Due to its retroperitoneal location and the amount of incursion of the abdomen required to cause injury, the pancreas is unlikely to be significantly injured in minor trauma incidents. Typical blunt force injury mechanisms for the pancreas include motor vehicle collisions, inflicted injury from blows or kicks, and bicycle handlebar injuries with deep incursion of the abdomen. The death of a toddler is described in which a pancreatic injury was a critical indicator of abusive injury rather than the claimed accidental fall or cardiopulmonary resuscitation-related trauma. Review of the medical literature regarding the epidemiology, etiology, and pathology of childhood pancreatic injuries is discussed. Pancreatic injury is a marker of severe blunt force trauma and should rouse a suspicion of nonaccidental trauma in young children. In the absence of a severe, high velocity or deep abdominal incursion traumatic mechanism, such as motor vehicle collision or bicycle handlebar injury, pancreatic laceration specifically is a marker of inflicted injury in children under the age of five. *Acad Forensic Pathol.* 2018 8(2): 219-238

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CASE STUDY

A 2-year 8-month-old girl with no significant medical history was reportedly found unresponsive at the bottom of six concrete steps in the garage of her caretaker's residence. She was transported by ambulance to the nearest local hospital where death was pronounced shortly after arrival following unsuccessful resuscitative efforts.

Autopsy revealed multiple contusions of the face, scalp, chest, abdomen, back, arms, and legs. Contusions of the chest and abdomen are shown in **Image 1**. Internally, there were multiple liver lacerations (**Image 2**) involving the left lobe, caudate lobe, and right lobe, with 225 mL hemoperitoneum (**Image 3**). The right adrenal gland (**Image 4**) was transected and there was extensive right periadrenal and retroperitoneal hemorrhage. The head/neck of the pancreas had a contusion and a 1 cm superficial laceration (**Image 5**). Extensive hemorrhage was in the mediastinal connective tissue (seen in the right side of the mediastinum in **Image 6**) with extension of the hemorrhage into the hilar pleura of both lungs and along the carotid sheaths (**Image 7**) in the neck. The heart had a 0.5 cm transmural laceration of the right auricle and a laceration of the endocardial surface of the right atrium with 100 mL hemopericardium (seen within the intact pericardial sac in **Image 6**). The anterolateral aspect of the left third rib had a non-displaced fracture (**Image 8A**) with hemorrhage in the adjacent intercostal musculature and in the overlying serratus anterior muscle (**Image 8B**). There were no skull fractures or intracranial injuries. No natural diseases or congenital abnormalities were identified at autopsy. Toxicology testing was negative for drugs and alcohols.

Histologic examination of the right adrenal gland, pancreas, and thymus revealed extravasated erythrocytes with no significant neutrophilic or other inflammatory cell infiltrate, indicating acute perimortem injury (**Images 9 to 11**). No fibrosis, fibroblastic proliferation, or hemosiderin-laden macrophages were observed to suggest chronic or repetitive injury.

Several weeks after the toddler's death, the caretaker admitted to placing the decedent's body at the bottom

of the garage stairs in an attempt to stage the scene to appear consistent with a fall. He also admitted to striking her in the chest/abdomen multiple times with two closed fists. He subsequently pled guilty to the District Attorney's charges and was sentenced to life in prison. During the sentencing hearing, the forensic pathologist was called to testify. The direct examination focused on the extent of injuries and the pathologist's diagnosis of inflicted injury, while the cross-examination raised the issue of cardiopulmonary resuscitation- (CPR) related injuries.

DISCUSSION

Pancreatic injuries are seen fairly uncommonly in pediatric autopsies. Since the pancreas has a retroperitoneal location, it is often spared during more minor abdominal trauma events (1). Injuries of the gland are rare, accounting for less than 2% of all abdominal injuries in children (2). However, pancreatic injuries may be underestimated, particularly in more minor trauma episodes not resulting in death due to the clinical difficulty of diagnosis and/or the presence of other distracting intraabdominal injuries. Pancreatic injuries include peripancreatic hemorrhage/hematoma, pancreatic contusion, pancreatic laceration, pancreatic transection (i.e., full thickness laceration), and associated ductal injuries. These injuries are most commonly due to blunt force trauma in children, while penetrating trauma (such as gunshot or stab injury) is seen more frequently in adults. Due to the close anatomic proximity, injuries of the liver, spleen, stomach, small bowel (especially duodenum), and adrenal glands may accompany pancreatic injury.

The unique anatomical features of children make them more susceptible to blunt abdominal injuries. A less muscular and thinner anterior abdominal wall and less intraabdominal adipose tissue provide less cushioning and resistance to a blow to the abdomen, compared to adults. In a direct, deep impact of the pediatric abdomen, the pancreas is compressed between the force on the abdominal wall and the unyielding spinal column, resulting in laceration, transection, and/or hemorrhage (**Figure 1**) (1, 3). Aside from an inflicted blow to the abdomen, other etiologies of such direct, deep impacts

Image 1A: Contusions of the anterior chest and abdomen.

with significant pancreatic injury are most commonly motor vehicle collisions and bicycle handlebar injuries (1, 4-6). A retrospective study by Jacombs et al. of all children under 16 years of age with pancreatic trauma admitted to a major children's hospital in New South Wales demonstrated that the majority of blunt force pancreatic injuries were due to motor vehicle collisions, with the majority of injuries being contusions or lacerations without duct injury or tissue loss

(7). Transection of the pancreas was reported in 20% of the 65 cases of pancreatic injuries, and the transection cases included both survivors and nonsurvivors (7). Nonaccidental injury (i.e., inflicted trauma) was the etiology in ten of the 65 cases (15%), with six survivors and four deceased. Other individually rarer etiologies included falls and accidents associated with bicycles, horses, skateboards, and go-karts (7). Bicycle handlebar-related accidents tend to produce

Image 1B: Contusions of the lateral left chest and abdomen.

isolated but severe pancreatic injury (6). The discrete, focused impact of a handlebar end is not dissimilar to an inflicted blow. In other less focused blunt force impacts, the force is dispersed over a broader body surface area, compared with the concentrated force of an assailant's fist or foot in abusive injury (8). A high incidence of hollow-organ injuries (i.e., stomach, small bowel, and duodenal perforations) has been reported in pediatric nonaccidental trauma cases, for similar reasons, with 50% of the abdominally injured patients having hollow viscus injuries in one study, as compared to less than 10% of adults with blunt abdominal trauma (8). This difference is likely attributable both to the concentrated application of force in abusive injury and the anatomical vulnerability of children, as previously discussed.

Falls are the most common explanation provided by caregivers for blunt abdominal injuries in an attempt to conceal the true nature of inflicted injuries (9). A 2016 study reviewed blunt abdominal trauma cases in children admitted to two level one trauma centers, comparing the patterns of injuries seen in nonaccidental trauma to those seen after a fall-related incident (9). Nonaccidental trauma was the most common cause of blunt abdominal trauma for patients under five years old (9). In the study group of patients younger than five years, the mortality rate for nonaccidental blunt abdominal trauma was 17.46%, while there were no deaths in children who sustained abdominal injuries in falls (9). Nonaccidental trauma also produced more severe injuries in general, with higher injury severity scores. In this same study group of patients under age five, the incidence of pancreatic injuries was

Image 1C: Contusions of the lateral right chest and abdomen.

significantly higher in nonaccidental trauma (25.4% of cases, $n = 16$) compared with falls (5.7% of cases, $n = 2$), with an associated risk ratio of 4.44 (9). The magnitude of this risk ratio weighs pancreatic blunt injury heavily toward nonaccidental etiology; however, a limitation of the study is that it did not stratify different types of pancreatic injury to distinguish the more severe and likely more specific pancreatic laceration from other less-severe injuries such as pancreatic contusion. The authors indicate the presence of pancreatic injury (or hollow viscus injury) should provoke clinical suspicion of nonaccidental trauma (9).

Cardiopulmonary resuscitation is often performed on children who have sustained blunt abdominal trauma, in particular those who die from their injuries. Cardiopulmonary resuscitation is also a common mechanism

postulated as an explanation for inflicted abdominal injuries. The potential exists for injuries to occur during CPR and it is important to recognize and classify these injuries appropriately. A retrospective study of all children under the age of 14 who died in Melbourne, Australia from 1994 to 1996 was undertaken to determine the incidence, type, and pattern of injury related to resuscitation attempts in children who die (10). Children who had recognized trauma prior to resuscitation were excluded from the study. Injuries detected in the resuscitated group included: superficial cutaneous bruises/abrasions, airway injury, lip injury, pulmonary contusion, splenic hematoma, and dental injury. Most injuries in the resuscitated group were minor in nature and no intraabdominal injuries were reported (10). Similarly, Price et al. reported no intraabdominal injuries in 324 natural pediatric deaths,

Image 2A: Lacerations of the posterior surface of the liver.

all of which received CPR (11). In 1984, Waldman et al. reported an 8-year-old girl who underwent CPR with interposed abdominal compressions (IAC-CPR) and ultimately died of a ruptured cerebellar arteriovenous malformation (12). At autopsy she was found to have a 2.5 cm liver laceration; intraluminal blood in the stomach, duodenum, and proximal jejunum; hemorrhage in the parenchyma of the pancreas; and 150 mL hemoperitoneum. Alternative techniques to standard CPR, including IAC-CPR, generally require additional training, personnel, and equipment. To date, no adjunct has been shown to be universally superior to standard manual CPR for prehospital basic life support (13). Overall, the likelihood of CPR-related abdominal injuries in children is very low and pancreatic laceration has never been reported in association with CPR to our knowledge. However, if intraabdominal injuries are identified at the time of au-

topsy, questions regarding alternative CPR techniques may be warranted.

Inflicted abdominal blunt injuries, in general, have significantly higher mortality than do accidental injuries, with reported mortality rates up to 50% (14-18). Delay in seeking medical treatment (due to an attempt to conceal the abuse) undoubtedly contributes to this higher mortality rate (18). Factors that may contribute to the mortality rate in pancreatic injuries specifically include associated complications (such as pancreatitis, peritonitis, bile leak, etc.), delay in presentation, nonspecific presentation leading to delayed diagnosis, and the difficulty of diagnosis.

In the clinical setting, pancreatic injury is rare and difficult to diagnose, being subtle and often overlooked when there is multi-organ trauma involving liver,

Image 2B: Lacerations of the anterior surface of the liver.

spleen, and/or kidney (19). Diagnosis may be delayed, as radiologic imaging findings are of post-traumatic pancreatitis, with edema and blood infiltration manifesting as pancreatic enlargement and peripancreatic fluid, which may take hours to develop (19). Computed tomography (CT) scanning is the preferred clinical modality for assessing pancreatic injury. The CT scan may appear normal in the first 12 hours following pancreatic trauma (19). The portions of a lacerated or transected pancreas may remain in close apposition and be difficult to detect on CT. When they occur, lacerations or transections tend to occur at the junction of the body and tail due to shearing injuries and compression against the spine (19). However, this may also depend on the direction of the force or blow. Ductal injuries may also be difficult to detect

on CT scanning, and raise the risk of complications (19). Endoscopic retrograde cholangiopancreatography (ERCP) is increasingly being used to evaluate for ductal injuries, allowing for non-operative treatment if no ductal injury is identified, or more prompt operative treatment if a ductal injury is present. Endoscopic retrograde cholangiopancreatography is also clinically useful in managing the late complications of pancreatic injury by drainage of pseudocysts or fistulas (19). Of note, however, is the risk of ERCP-associated acute pancreatitis (20). A systematic review and meta-analysis of complications of ERCP in pediatric patients reported a complication rate of 6%, with post-ERCP pancreatitis representing the bulk of complications, and bleeding and infections associated with ERCP being less common (21). However,

Image 3: Reflection of the rectus abdominis with hemoperitoneum visible through the intact peritoneal lining.

these patients represent a variety of disease states and ERCP intervention types, and the inclusion of chronic pancreaticobiliary disease cases likely increases the pooled complication rate. It is important for the forensic pathologist evaluating the pancreas following ERCP to consider whether an iatrogenic component plays a role in pathologic findings such as pancreatitis or perforation; the clinical history is critical to obtain in previously hospitalized patients. Magnetic resonance cholangiopancreatography (MRCP) provides a non-invasive alternative for evaluation of injury to the ductal components of the pancreas (19), but may provide less precise anatomical delineation.

Regarding laboratory testing and diagnosis of pancreatic injuries, amylase sensitivity and specificity are low (6), but serial levels in the clinical setting may aid in diagnosis (7). In the study by Jacombs et al. previously described, the amylase level was elevated in about half of those tested at the time of presentation with such an injury, increasing to 63% after admission with serial testing (7). A Clinical Report from the American Academy of Pediatrics on the evaluation of suspected child abuse recommends that clinical screening laboratory tests include liver and pancreatic enzyme concentrations in all children presenting with serious trauma, even if they are not exhibiting acute

Image 4: Transection and periadrenal hemorrhage of right adrenal gland (on left) and unremarkable left adrenal gland (on right).

abdominal symptoms, as abdominal trauma may be masked or overlooked in the setting of other injuries (22). Postmortem testing for lipase and/or amylase is subject to issues of false elevation due to postmortem pancreatic autolysis, hemolyzed serum specimens (which clinical laboratories may reject), and difficult interpretation due to lack of specificity (particularly for amylase). Another article in this issue, by Brown and Prahlow, addresses the utility of postmortem pancreatic enzyme testing (23).

At autopsy, recognition of pancreatic trauma in the infant or child is relatively straightforward, though caution should be taken regarding the postmortem interval and autolytic postmortem changes that can produce a dark discoloration mimicking hemorrhage. If a laceration is present, its size should be measured and documented, along with its location (i.e., head, body, or tail of pancreas), whether full-thickness (i.e., transection), and whether major ductal structures appear to be involved. Photographs of all injuries should be taken *in situ*, *ex situ*, and following sectioning. Histologic examination of sites of peripancreatic hemorrhage, pancreatic contusion, or pancreatic laceration can aid in demonstrating true hemorrhage, acute in-

flammation of vital reaction, or evidence of acute injury superimposed on older injury. Acute pancreatitis may accompany blunt injury of the pancreas if there is a survival period following the trauma incident. Histologic elements of tissue repair, including fibroblast proliferation, fibrosis and scar formation, increased vascularity, and hemosiderin-laden macrophages are reported as histologic evidence of older trauma (24). Iron and trichrome stains may be utilized to highlight hemosiderin deposition and fibrosis, respectively (24), though all of these findings should generally be visible on hematoxylin and eosin stained slides. In a report of a series of four cases of repetitive blunt abdominal trauma, Dye et al. described toddlers aged one to two years with acute abdominal trauma as the cause of death, with histologic findings supporting prior episode(s) of trauma. Three of the four cases demonstrated evidence of older pancreatic injury (with acute pancreatic injury superimposed); histologic findings of older injury (e.g., fibrosis, reactive fibroblast proliferation, and/or hemosiderin-laden macrophages in the pancreas) were unexplained by any natural disease process and were also absent in age-matched atraumatic controls (24).

Image 5: Pancreas with contusion and laceration of the surface of the head/neck.

Image 6: Hemopericardium visible through the intact pericardial sac and extensive hemorrhage within the mediastinal connective tissue to the right of the pericardial sac.

Image 7: Hemorrhage tracking along carotid sheaths of the neck.

Other signs of older trauma to the pancreas could include fistula formation or pseudocyst. Pseudocysts developed in just under one-third of pediatric pancreatic blunt force trauma survivors in the study by Jacobs et al. in New South Wales, and were the most common complication following pancreatic injury (7). Other complications of pancreatic trauma include pancreatitis and intraabdominal abscess (19). Chronic

pancreatitis may develop following pancreatic trauma, including inflicted trauma. In a case series of 49 childhood pancreatitis cases, one third of cases caused by trauma were due to child abuse (25). The differential diagnosis for etiologies of relapsing acute or chronic pancreatitis in childhood includes congenital anomalies (pancreas divisum, choledochal cysts), diabetes (with associated hypertriglyceridemia), cystic

Image 8A: Non-displaced fracture of the anterolateral left third rib.

Image 8B: Hemorrhage of the left serratus anterior muscle.

fibrosis, hereditary pancreatitis, drugs, infection (such as mumps), and inflicted trauma (26).

CONCLUSION

Pancreatic injury is a marker of severe blunt trauma in children and should raise suspicion of nonaccidental trauma. In the absence of a history that is compatible with direct, deep incursion of the abdomen and/or high velocity impact (such as motor vehicle collision,

handlebar injury, etc.), inflicted injury is likely. Pancreatic laceration has not been reported in association with CPR in young children, to our knowledge, and falls are far less likely to produce serious pancreatic injuries in young children compared to nonaccidental trauma. Histologic examination of pancreatic injury is useful in suspected child abuse cases, as it may document acute as well as older injury to establish the often repetitive nature of abusive injury.

Image 9A: Histology of the right adrenal gland in **Image 4** showed disruption of the cortical parenchyma and fibrous capsule, and extravasated erythrocytes within the adjacent fibroadipose tissue (H&E, x20).

Image 9B: Histology of the periadrenal fibroadipose tissue in **Image 9A** at higher power showed extravasated erythrocytes with no significant neutrophilic or other inflammatory cell infiltrate (H&E, x100).

Image 10: Histology of the head/neck of the pancreas in **Image 5** showed extravasated erythrocytes within the peripancreatic connective tissue with no significant neutrophilic or other inflammatory cell infiltrate (H&E, x100).

Image 11: Histology of the thymus showed extravasated erythrocytes within the interstitial connective tissue with no significant neutrophilic or other inflammatory cell infiltrate (H&E, x100).

Figure 1: With a direct blow, the pancreas is compressed between the force applied to the abdominal wall and the underlying spinal column. Created under contract by professional medical illustrator Diana Kryski.

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