Forensic Pathology

of

Child Death

Autopsy Results & Diagnoses

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Forensic Pathology of Child Death

Autopsy Results & Diagnoses

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Foreword

At least 2000 children die each year from some form of child maltreatment. With this book, Drs. Case and Kermgard provide a rich and well-organized approach to better understanding what has happened to these children and how to know. While some cases are obvious, there are too many in which the abuse happened in secret, and the pathologist is in a vital position to unravel the truth.

Key clusters of injuries help to define abuse in the absence of admission by the perpetrator. In the legal arena, lawyers, judges, and juries want to know what the evidence is and how they can be sure. By systematically showing injuries at all levels and types, it becomes clear how abusive trauma occurs and what happens to the child when it does.

Like accidental trauma, fatalities most commonly occur to the head. Chapter 4 goes in depth to help readers better understand the ways in which caregivers hurt children and how this manifests grossly and microscopically. Because abusive head trauma is probably the most contested abuse diagnosis in court, this chapter provides an unparalleled view of what is currently known.

As usual with STM Learning books, this text provides detailed pictures that are rarely seen elsewhere. For students and teachers, having such high-quality photographs brings to light what words alone cannot appreciate.

One of the major advantages of this text is the case studies, which vividly illustrate key points in the pathological evaluation of suspected child abuse. They help to cement concepts about trauma around the narrative of what has happened to the child. When children cannot testify for themselves, it is through the dedication of these professionals that honor can be brought for each child by determining the truth.

Forensic Pathology of Child Death will be a key resource for those seeking to understand the details of abusive trauma and how to make such important diagnoses.

Randell Alexander, MD, PhD
Professor and Chief
Division of Child Protection and Forensic Pediatrics
University of Florida
Jacksonville, Florida

Our Mission

To become the world leader in publishing and information services on child abuse, maltreatment, diseases, and domestic violence. We seek to heighten awareness of these issues and provide relevant information to professionals and consumers.

Preface

My vision for this atlas was to illustrate many of the cases of child deaths that I have autopsied or otherwise encountered over a very long career as a forensic pathologist, neuropathologist, and medical examiner. I began doing medical examiner cases in February 1975 in St. Louis County, Missouri, a suburban metropolitan area with a population of approximately 1 000 000. I did not see a child abuse fatality in St. Louis County until 1981, but then the number of abusive fatalities gradually increased over the following years. In 1977, I began working as a medical examiner in the St. Louis City Medical Examiner's Office, which had just transitioned from a coroner's office to a medical examiner's system. St. Louis City is an urban inner city that had a population of 486 000 in 1977. The population has since declined to 310 000 in 2019. As soon as I began doing medical examiner cases in the City of St. Louis, I was struck by the large number of fatal child abuse cases we encountered in our work.

I am both a forensic pathologist and a neuropathologist. My experience with child abuse fatalities has been greatly influenced by my neuropathology background. Most of the child abuse fatalities we see in the medical examiner's office are head injuries. When I started in the City of St. Louis Medical Examiner's Office, I was truly overwhelmed by the number of cases I was seeing of dead children who primarily had head injuries but also had other abusive injuries. As a neuropathologist, my interest was piqued by these interesting head injuries. I pondered over what I saw in these cases that have such similarity in their pathology. One similarity I found was that of the abusive head injury fatalities, no one presented conscious. All these children with head injuries were dead at the scene or unconscious. That led me to study the literature on traumatic unconsciousness, which I believe has assisted in understanding much of what is demonstrated in child abuse head injury.

In 2014, Elizabeth Kermgard was a medical student at St. Louis University where I was a professor of pathology. Elizabeth wanted to work on a project in the medical examiner's office with me and had most of the summer to dedicate to that project. She is now a pediatric resident and is the coauthor of this atlas. Elizabeth abstracted much of the data on the cases included in this atlas, a task I was not in a position to do for lack of time. The cases in this atlas include child deaths from 1999 to 2017 in the St. Louis metropolitan area (St. Louis County and the adjacent counties of St. Charles, Jefferson, and Franklin with a total population of 1.75 million) and the City of St. Louis from 1986 to 1994. Access to the case data from St. Louis City was generously provided by Dr. Michael Graham, Chief Medical Examiner of St. Louis City, but time constraints prevented procuring a great depth of investigational data or photographs for those cases. I did believe it was worthwhile to include these cases for the sake of illustrating the wide variety of the types of deaths and their injuries. The reader should understand that each death has a great amount of information from police reports and medical records.

One of my objectives in sharing these cases with the reader was to demonstrate what the medical examiner finds when an autopsy is done by well-trained forensic pathologists. The intent was to document every mark on the child's body. Every case in this atlas was performed by a forensic pathologist that I had a role in training and to whom I stressed that a child's autopsy should include documentation of each and every mark on the body. As the reader will see, this is important because the homicide cases frequently have a remarkably large number of marks of injury on their bodies. This is considerably different than what we see in the children dying from accidental mechanisms, and although only some natural deaths are included in this atlas, large numbers of injuries are not found incidentally on the bodies of children dying from natural causes.

In this atlas, some cases have no autopsy indicated. If an individual has been hospitalized, their injuries have been documented, and if the death is believed to be accidental

after investigational review by the medical examiner, it is common practice for the body to be released without an autopsy and signed out as to cause and manner of death by a medical record review.

The cases illustrated in this atlas have brief histories provided. There was extensive circumstantial and historical information that could not be relayed in the atlas but was known to the medical examiner when considering the cause and manner of death. The majority of the cases in this atlas are homicidal deaths, and reaching that conclusion requires having all available history, including medical history from birth to the incident, all social history, and all investigative data from the medical examiner and police. All these pieces of information must be correlated with the autopsy findings. While the case studies show only a brief history with the autopsy findings and then conclusions as to the cause and manner of death, that is only for the sake of brevity in creating this atlas. It does not reflect the actual process used in reaching the conclusions as to cause and manner of death.

Since 1991, the state of Missouri has had a child fatality review system that is county-based and includes members of the medical examiner's office, child and social services, juvenile court, prosecution, police agencies, public health, and a variety of other agencies who might have knowledge of a particular case. On a monthly basis, each child's death is reviewed so that each member can share information and provide an opportunity to access further investigational information. That might include further police interviews pertaining to a particular autopsy finding, such a positive toxicology finding. It also could include additional medical records or information that a child's teacher might possess or reviewing a teenager's phone messages right up to the time of their death. All this information is critical to each panel member being able to fulfill their function when investigating the child's death. The decision to include the child's age, gender, and race from the original police reports was made to benefit readers seeking to conduct studies of their own and is not intended to be a statement about the role of those factors in the child's treatment or death.

This atlas is written for the health professionals who need an understanding of what happens to children who have suffered from abusive trauma. It will also be informative to social services, law enforcement, and the legal profession. This atlas has many photographs that are often very graphic. It is not intended to shock but to inform. This is what happens to children at the hands of others.

The children in this book are gone, but they are not forgotten. Their stories and autopsies will hopefully help us better understand what happened to them.

Mary Case, MD

Elizabeth Kermgard, MD

Reviews

For the forensic pathologist, the investigations of sudden, unexpected death in children are some of the most demanding. These deaths are even more challenging when they involve neuropathological injury. This book, whose lead author is both a forensic pathologist and neuropathologist, is organized by body region (eg, neck, chest, abdomen), which offers a practical approach for the forensic pathologist. Chapter 4 examines in detail the neuropathology of pediatric head trauma. Detailed discussions of injuries and mechanisms of injury are intermixed with referenced studies that put our understanding of these injuries in proper context and elevate this work beyond the typical descriptive forensic pathology text. It is an academic, well-referenced work that also includes over 700 color images and numerous case studies. Not only will forensic pathologists and fellows find this valuable but given the well-written, concise discussions and descriptions, the nonmedical pediatric death investigator will also find it understandable and useful.

James R. Gill, MD
Chief Medical Examiner
State of Connecticut
Office of the Chief Medical Examiner

Forensic Pathology of Child Death *is a comprehensive guide to the evaluation of the pediatric death in the context of forensic pathology. It covers just about every kind of injury, whether traumatic or accidental, one is likely to see in a medicolegal setting. Fatal, inflicted child abuse is fairly rare but is something every forensic pathologist is going to encounter in their career. A book like this will be especially helpful to those practitioners who don't work in a large metropolitan area or in association with a children's hospital, where many of these cases originate, and will help in deciding whether they should refer the case to someone with more experience. This is especially true in those cases with subtle injuries. The case histories are a guide to the proper documentation of findings, which is as important as the diagnosis. The author's recognition as an expert in pediatric trauma ensures this will be a much-used reference.*

Carl J. Schmidt, MD, MPH
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Forensic Pathology of Child Death *is the definitive reference for evaluating childhood deaths. It will be useful for forensic pathologists, pediatricians, law enforcement officers, and prosecutors. The book has been written by Dr. Mary Case, an internationally recognized expert on forensic pathology and child abuse. This text is liberally augmented with actual case studies and photographs. The book exhaustively covers all aspects of child death with an intensive emphasis on abusive head trauma. This book should be available to all professionals faced with making important decisions in the face of family tragedies.*

Carole Jenny, MD, MBA
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Forensic Pathology of Child Death *represents the career contributions of Dr. Mary Case, an internationally recognized expert in the field of pediatrics and neuropathology, over her 4 decades of investigating thousands of child deaths in St. Louis, Missouri. This text discusses the role of the forensic pathologist and common traumatic injuries, including a chapter on subtle lethal abusive injuries. Chapter 4 is dedicated to the investigation of pediatric head trauma. In addition to photographs highlighting investigations and injuries, this book contains extensive demographic information on the author's casework. This text provides exceptional and detailed case studies that illustrate the major causes of death in children and infants. The case studies present actual scenarios to illustrate difficulties encountered in child death investigations. This text will be an especially valuable resource for students of forensic pathology, law enforcement, social workers, child death investigators, and physicians treating children.*

Jeffrey Jentzen, MD, PhD
Forensic Pathologist
Professor of Pathology
University of Michigan

With excellent photographs and detailed case examples, this text offers a clear and streamlined exploration of both the investigative process and the forensic science that contribute to the analysis of child fatalities. Dr. Case provides an outstanding discussion of injury mechanisms in the context of pediatric neuroanatomy that will be valuable to all professionals who participate in child fatality review teams. The well-referenced chapters and balanced evaluation of the medical literature create an excellent reference for anyone who participates in the assessment of child deaths.

Marcella Donaruma, MD, FAAP
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Given the scope of material and detailed treatment of the content, it is remarkable that Dr. Mary Case has produced such a practical and approachable text. The work is a testament to her clinical and training expertise. A comprehensive and user-friendly guide, filled with pictures, case studies, and helpful references to practice standards, this text is suitable for a variety of medical and nonmedical professionals. Complex forensic pathology is presented in a well-organized and useful volume. This will become a go-to resource for those who work in the field of child maltreatment.

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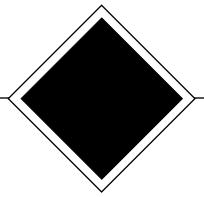
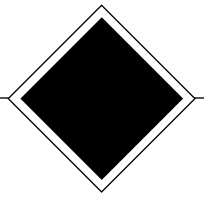


Contents in Brief



Contents in Detail

Forensic Pathology of Child Death

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Chapter 1

Role of the Medical Examiner in Fatal Cases of Child Maltreatment

Introduction

Forensic pathology is a medical specialty developed to function within the role of the medical examiner. The medical examiner is part of the medicolegal death investigation system, which is created by a state statute. The forensic pathologist works within the office of the medical examiner. Forensic pathologists perform autopsies and carry out record reviews to determine cause and manner of death of individuals whose death may have some impact on the well-being of others. The types of deaths that fall into the jurisdiction of the medical examiner vary by state statute but generally are deaths that occur suddenly or unexpectedly; by possibly unnatural causes; from accidents, homicides, or suicides; that may be related to dangers in the workplace or a public place; that occur outside of hospitals or the care of a physician; or that fall into certain categories of interest, such as children, individuals in custody of the law or in the care of others, or at home unattended by a physician or other care provider.

In the United States, all states currently have specific medical examiner or coroner laws for the investigation of deaths of children. In Missouri, for example, the statute requires that the death of any child younger than age 18 years be investigated by the medical examiner or coroner. Child death laws generally require that a death investigation be carried out by the medical or coroner system unless a child in a particular age group dies from a known natural disease. These laws also specify that certain categories of children must have autopsies and may further indicate which physicians will conduct those autopsies. In most medical examiner systems, these children are autopsied by forensic pathologists.

The forensic approach to an autopsy is significantly different from a hospital autopsy. Hospital autopsies are performed to determine why the patient has died and to evaluate the treatment modalities and the accuracy of diagnostic procedures. Forensic autopsies are performed on a select group of individuals when there is concern for a possible unnatural death or harm to society. State statutes usually allow medical examiners to autopsy those who fall into their jurisdiction without family permission or consent.

Death Investigation

The following duties fall to the medicolegal system[1]:

— To determine the cause and manner of death

— To identify the deceased, if unknown

— To determine the time of death

— To collect evidence including toxicology specimens as well as materials for DNA analysis, hair, fibers, or other types of material

— To document injuries or lack of injuries

— To determine how the injuries occurred

— To document any natural disease present

— To determine or exclude other contributory or causative factors to the death

— To provide expert testimony if the case goes to trial

The ***cause of death*** is the disease or injury that creates the physiologic disturbance that leads to death. For example, a gunshot wound to the chest is a cause of death. The ***manner of death*** describes how the cause of death occurred. Manners of death include natural, accident, suicide, homicide, and undetermined. A gunshot wound could be an accident, a suicide, or a homicide depending on the circumstances surrounding the injury. An investigation of the death would reveal the circumstances and might include accessory information from the death scene investigation, reports from police or other law enforcement agencies, and medical records. Sometimes, even after all information from the autopsy, toxicology report, histologic examination, and accessory investigation is gathered, the pathologist is still unable to ascertain a manner of death. The manner is then considered to be undetermined. When reviewing the manner of death of bodies autopsied by the St. Louis County Office of the Medical Examiner in 2018, 37% were natural, 7% were homicide, 9% were suicide, 35% were accidental, and 12% were undetermined.[2]

Many people, including nonforensic physicians, confuse cause of death with mechanism of death. It is not unusual to see death certificates signed by such physicians listing the cause of death as "cardiac arrest" or "cardiopulmonary arrest." However, interruptions of vital functioning of the cardiac or cardiopulmonary systems are not causes of death. ***Mechanisms of death*** refer to the actual pathophysiologic derangements that result in death. Mechanisms include exsanguination, renal failure, respiratory failure, and cardiac arrest. A gunshot wound of the chest might cause death through the mechanism of exsanguination.

Determining the mechanism or mechanisms of death can be very helpful in child maltreatment cases. A case of a liver laceration in a young child is a good example. Liver lacerations cause a loss of blood. Large liver lacerations can rapidly cause exsanguination. Comparable injuries are seen in vehicular accidents, where even adults may die within 15 to 30 minutes from a large liver laceration. This information is helpful in knowing how the clinical presentation of an injured child would look. Methods for studying these mechanisms come from collections of case histories with known similar injuries and observing the appearance and progression of these cases.

Review of Information

The death investigation begins when a death is reported to the medicolegal death investigator. Every medical examiner system has protocols for hospitals, police departments, funeral homes, hospice agencies, nursing homes, and other professionals who might interact with a dead body. The medicolegal death investigators' duties include taking telephone reports of deaths, responding to certain death scenes and carrying out death scene investigations, ordering medical records and police reports, and arranging the transportation of bodies coming into the medical examiner office. The depth of the investigation depends on the complexity of the case and may include a detailed scene investigation. This might entail recreation of how the body was found and how it was initially positioned and could include visiting more than 1 scene if a body has been moved. The death investigators work closely with the forensic pathologists. This medicolegal investigation is separate from the police investigation, which also generates information needed by the forensic pathologist to fully evaluate a case. Police evidence technicians are present at many forensic autopsies to obtain evidence and document injuries and findings.

To properly evaluate the death of a child, a number of records need to be reviewed. These include the child's medical records, beginning from birth and extending to time of death. All medical records, including birth records, pediatrician visits, emer-

gency medical service records, emergency department records, and hospital records, should be available before the case is finalized, although they will not be available before the autopsy. Growth charts, which may have been generated by the pediatrician or obtained from hospital records, are helpful in cases when there is suspected nutritional neglect. Information about the family and child from family service agencies, child protective services, and the juvenile court system needs to be available to the pathologist. Police department records also need to be reviewed. Sometimes unique records such as insurance examinations may be helpful in finding out missing details of a child's life. In some cases, school records may have information related to a child's death. The child fatality review process is one of the most efficient methods of accessing all the information needed by the forensic pathologist before decisions are made about the cause and manner of a child's death. This review activity allows each agency with information about a child to share their knowledge with all others involved in the death investigation. The child death review process varies from state to state but generally involves a panel of individuals including the medical examiner, prosecuting attorney, family services, police, juvenile court, pediatricians, and any others who might have information about a particular death.

A detailed history, including the child's developmental, medical, and social history, should be gathered by the medicolegal death investigator. Significant family medical and social history should also be collected, including family size, structure, ages, and any recent changes or sources of stress such as criminal background, drug use, divorce, or death.

The investigative information also includes statements made by the parents or caretakers, siblings, or others who have knowledge of the circumstances surrounding the death of a child. It is also pertinent to acknowledge the reactions of the individuals who were caring for the child when the lethal event occurred (eg, do the individuals appear appropriate in their emotional state, is there any evidence of intoxication or mental disturbance).

Scene Investigation

The ***scene*** refers to the location where the incident surrounding the death or injury occurred. The purpose of the scene investigation is to assess the scene, the circumstances, and the body if it is still in place, or, if the body has been transported for care, the site where the child was found. Information of interest at the scene investigation is detailed in **Table 1-1**.

Details of the scene listed in **Table 1-1** should be documented by photography and written descriptions so the information can be reviewed by the pathologist before the autopsy. In specific types of deaths, recreation dolls and scenarios may be used. This is particularly true in the case of an infant found dead or unresponsive in bed, because this may ultimately be found to be sudden infant death syndrome (SIDS), sudden unexpected infant death (SUID), or a sleep-related death.

Scene recreation involves having the individual who found the child demonstrate the position in which the child was found or how the child was injured using a scene recreation doll. Most people are not sufficiently verbal or detail oriented to accurately describe these circumstances. Using the scene recreation doll allows the investigator to photographically document a complex scene (**Figure 1-1**). Many asphyxial deaths are best understood by studying scene recreations. Children can fall into positions that interfere with breathing or chest excursion (**Figure 1-2**). Sometimes children fall into areas that entrap them, such as the case of an 18-month-old toddler who fell headfirst off the bed and into a deep box filled with clothing. The scene might have findings that are directly related to injuries on a child, such as an indented wall where a child's head was impacted (**Figure 1-3**). In cases where there is a history of injury resulting from a fall, scene investigation helps establish the height the child fell from and the contact surface details. Investigations of cases with scalding injuries require very detailed scene recreations to determine whether the injuries found could in fact be sustained by the described scenario.

Table 1-1. Information of Interest at the Scene of the Crime

Site or Objects of Investigation	Information of Interest
Home or incident site	— Geographic location — Urban — Suburban — Rural — How the home compares with other homes in the same area — Dwelling appearance — State of repair — Cleanliness — Furnishings — Dangerous conditions — Infestations — Temperature — Weather — Clothing — Available food — Siblings — Behavior of everyone — Drug paraphernalia — Electric and plumbing
Bedding/ sleeping surface	— Toys, objects near body — Presence of purges, exudates — Type of bedding, sheets, blankets, pillows — Others present in bed/sleeping surface
Physical evidence	— Stains — Blood — Medications — Formula — Bottles
Body	— Terminal position — Initial position if different from terminal position — Moved or altered position — Pattern of lividity — Presence of rigor — Body temperature — Odor — Hygiene

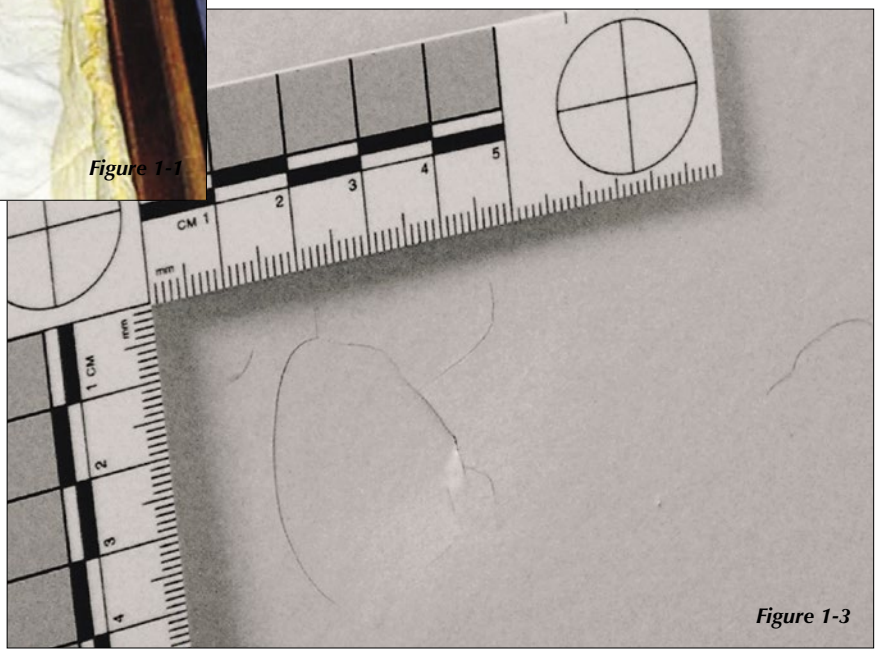

Figure 1-1. *Scene recreation doll used to recreate unsafe sleeping circumstances.*

Figure 1-2. *Scene recreation doll illustrating a 10-month-old boy who fell out of bed and became caught between the dresser and crib, causing asphyxia.*

Figure 1-3. *Hole indented in the wall where a 5-year-old girl's head was slammed.*

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Chapter 2

Forensic Autopsy

The purpose of the forensic autopsy is to fulfill the needs of the medical examiner system, as noted in Chapter 1.[1] Although the autopsy will note and document all findings in the body, there may be less interest in the strictly medical issues of the deceased, and these issues may not be as fully addressed as they would in a hospital autopsy. The forensic pathologist or medical examiner uses a number of autopsy procedures that are necessary for the full investigation of their cases but may be unfamiliar or may even seem strange to hospital pathologists. Such procedures include removal of bones for documentation of injury and aging of injury; removal of digits, fingers, or hands for identification; extensive dissection of soft tissue; skeletonization of the face or body for examination of wounds; removal of eyes and inner ears; retention of the body after autopsy for later reexamination; and removal of the entire rib cage or spine. Special dissections may be used to investigate certain areas of injury, such as the posterior neck dissection to examine the vertebral arteries, vertebral bones and ligaments, and the surrounding soft tissues; dissection of the palms of the hands or soles of the feet to examine for deep injury; and dissection of the genitalia for demonstration of injury. Many of these procedures will be discussed later in this chapter.

Before the autopsy, radiographs are taken in appropriate cases. In most medical examiner offices, all children younger than age 3 years and older children in select cases will have radiographs taken. Images should be taken of all areas of the body using as many views as necessary to see the child's entire anatomy. In most cases, the following views are suggested:

— Anterior/posterior skull and lateral skull

— Anterior/posterior torso to include chest, abdomen, and pelvis with adequate penetration to view posterior ribs

— Anterior/posterior views of upper and lower extremities

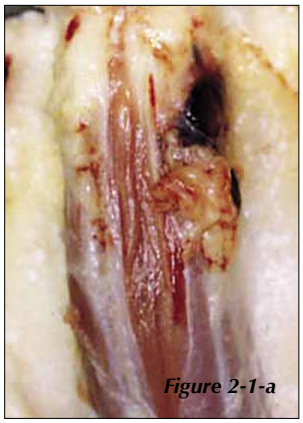
— Anterior/posterior joints

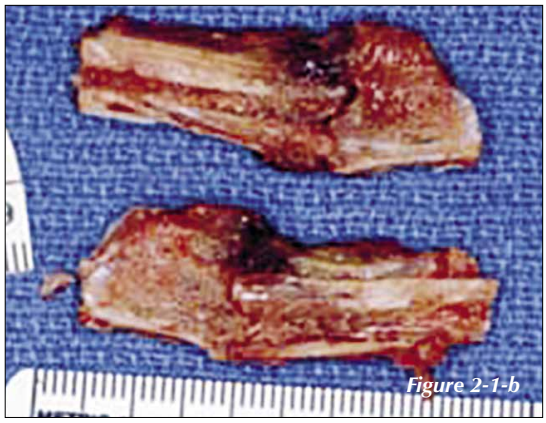
— Lateral view of entire spine

When any bony injury is found or is questionable, the soft tissue surrounding the injured bone is dissected to look for hemorrhage around the bone and to take samples of the tissue for microscopic examination. Microscopic slides from the soft tissue are used to determine the age of the injury by measuring the state of progression of the inflammatory response to the injury (**Figure 2-1-a** and **b**). The injured bone is also dissected free and removed. Photographs of the external and cut surfaces of the bone document the fracture. Microscopic sections of the bony injury may also be used to determine the age of injury. A relatively new technique used in cases of obvious abusive injury is to expose all the long bones during the autopsy by dissecting away the soft tissue even if no injury is visible on the radiographs. Further imaging can then be taken of the exposed bone, and subtle bony injury can sometimes be detected. Hemorrhaging in the periosteum may also be found by this technique, which may point to underlying bony injury and allow further inspection of the adjacent bone.

Figure 2-1-a. *Fracture of radius with surrounding soft tissue hemorrhage.*

Figure 2-1-b. *Radius removed and incised to submit for microscope sections for aging of fracture.*





External Examination

The forensic autopsy begins with a detailed examination of the body in the condition in which it arrived to the morgue. The clothing on the body is examined and documented. In certain cases, there may be evidence on the clothing that is important to the investigation and can be retrieved. The clothing is removed and may be given to the evidence officer. Measurements of height, weight, and—in young children—the dimensions of the head, chest, and abdomen are noted. The forensic pathologist then proceeds systematically through a detailed external examination of the body.

The external examination in a forensic autopsy is of paramount importance, and it may take several hours to complete the descriptive and photographic documentation. Each anatomic part of the body—face, scalp, neck, chest, abdomen, back, genitalia, buttocks, and extremities—is examined and described regarding the presence of identifying marks, scars, fresh injury, healing injury, and healed injuries. Injuries are individually characterized as an abrasion, contusion, laceration, cut, incised wound, burn, or penetrating injury such as a gunshot wound or stab. Each injury is described by size, color, and shape. Sections of tissues from the injuries are taken for microscopic examination to determine the age of the injury (**Figure 2-2**). If patterned injuries are noted, these are documented photographically and the type of pattern suggested is described (eg, loop mark). In the case of a possible bite mark, before the area is cleaned, a swab is taken using sterile saline on a cotton swab to lift possible DNA from the skin surface. Possible bite marks are examined by a forensic odontologist. The degree and distribution of livor and rigor are described and photographed, and sometimes such postmortem changes can be helpful in discerning that historical information—such as the position of the body or time of death—is not consistent with these changes.

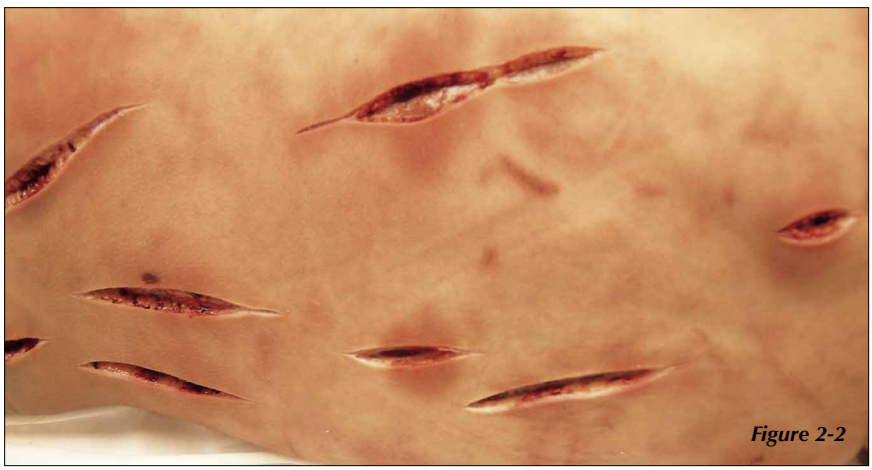


Figure 2-2. *Many contusions on back incised for photography and to take sections to submit for microscopic examination for aging of contusions.*

Chapter 3

Fatal Child Maltreatment

The author has worked in a large metropolitan medical examiner's system in Missouri for 44 years and has had the unique experience of serving as a forensic pathologist and personally performing approximately 11 000 autopsies, as well as working as a neuropathologist and providing brain examinations on many thousands of other forensic autopsies for colleagues. Between 1975 and 1985 in the metropolitan area, which includes the City of St. Louis, there were 160 child deaths (excluding gunshot wounds, house fires, vehicular accidents, sleeping-related deaths, and drownings outside of the home) of particular interest. Of these deaths, 70 (44%) were child abuse homicides, 63 (39%) were accidents, and 27 (17%) were undetermined in manner. **Appendix 3-1** lists the injuries found in these children.

Between 1986 and 1999 in St. Louis County, a suburban area with a population of 1 000 000, there were 72 child deaths (excluding gunshot wounds, house fires, vehicular accidents, sleeping-related deaths, and drownings outside of the home) of particular interest, including 32 homicides (44%), 21 accidents (29%), and 19 with an undetermined manner of death (26%). Differences in the number of deaths between these 2 periods are primarily because the latter period does not include data from the City of St. Louis, which has 2 large children's hospitals. Many child victims of abuse die in these hospitals, and their cases are handled by the city medical examiner regardless of their point of origin. **Appendix 3-2** lists the injuries found in these children.

In both periods, the cases with an undetermined manner of death were similar in most aspects to the homicide cases, but because they lacked certain details, these were certified as undetermined. It is likely that most were, in fact, homicides. The cases in this atlas also include child deaths from 1999 to 2017 in the St. Louis metropolitan area (St. Louis County and the adjacent counties of St. Charles, Jefferson, and Franklin, with a total population of 1.75 million) and the City of St. Louis from 1986 to 1994. There is not a separate appendix for these cases, but they are included in the atlas with case histories and many with photographs.

Injuries Not the Cause of Death

For the 70 homicide cases from 1975 to 1985 discussed earlier, **Appendix 3-3** lists the injuries noted in the children who died from inflicted injury. **Appendix 3-4** lists each nonlethal injury noted in the 63 children who died from accidents between 1975 and 1985. The vast difference in the number of marks on the bodies of children who died from homicide versus children who died from an accident is striking. Similar findings were also noted in the next period studied.

Appendix 3-1. Injuries Found in 160 Child Deaths in the City of St. Louis, 1975-1985

Appendix 3-1. Injuries Found in 160 Child Deaths in the City of St. Louis, 1975-1985

Homicide: 70 (44%). Of these children, 82% were younger than 3 years and 45% were younger than 1 year.

Head injury: 28 (40%); 90% had subdural hemorrhage

- — Subdural hemorrhage with fracture: 11
- — Subdural hemorrhage without fracture: 14
- — Brain contusions: 7
- — Contusion-tears: 2
- — Cervical spine contusions: 1
- — Likely shaking: 4 (subdural hematoma [SDH]/subarachnoid hemorrhage [SAH], no impact)

Abdomen: 14 (20%)

- — Liver lacerations: 9
- — Mesentery lacerations: 2
- — Laceration of stomach: 1
- — Laceration of duodenum: 2

Chest: 1

- — Lacerations of heart: 1

Asphyxia: 12 (17%)

- — Suffocation: 7
- — Ligature strangulation: 1
- — Manual strangulation: 2
- — Forced food into airway: 1
- — Plastic bag: 1

Blunt soft tissue trauma: 2

Drowning: 1

Scalding: 3

Neglect: 7 (10%)

Of environmental safety: 3

- — Carbon monoxide (CO) poisoning from fire, left unattended: 2
- — Intoxicated mother overlaid child: 1

Of medical care: 4

- — Pneumonia: 1
- — Complications of strep throat: 1
- — Intoxication with alcohol and aspirin: 1
- — Perforated ulcer from malnutrition: 1

(continued)

Chapter 4

Head Trauma

Introduction

In the United States, it is estimated that 2000 children die each year from abuse and neglect.[1] Inflicted head trauma in infants and young children is a cause of death often seen by the medical examiner because abuse is the most common cause of severe traumatic brain injury, and many of these head injuries are fatal. As many as 80% of lethal cases of child physical abuse are a result of injury to the head.[2] There are many additional fatal abusive causes of death, but when considering the major categories of head, chest, and abdomen, injuries to the head account for a majority. Abusive injury accounts for most cases of head injury in children younger than age 1 year and 10% of all traumatic injuries in children younger than 5 years of age.[3] The younger an abused child is, the more likely it is that the most significant injuries are to the head.[4] Although the majority of children with abusive head injury are younger than 2 years of age, identical injuries can be seen in children up to 4 or 5 years of age.[5-8]

Fully appreciating traumatic head injury in young children requires an understanding that young children and infants have unique differences in the brain, skull, and neck related to the long period of developmental and anatomical maturation that occurs in the human species. In most animal species, these developmental periods are brief, some only a day or two. None are as long as the many years required for maturation in the human species. These differences are most marked at the youngest ages but do extend into middle childhood. This makes young children particularly susceptible to injuries from acceleration-deceleration forces, which may cause shearing injury of the brain and adnexal vascular structures. The skull of the young child is thin and pliable, features that assist the fetus in moving through the birth canal, but are of less help in reducing the force of a blow to the head, allowing force to cause fracture of the skull or to be transmitted through the skull to the brain.

The brain is a large, heavy organ at birth and grows rapidly after birth to reach 75% of its full weight by age 2 years (although the brain is far from mature at this age). The weight of an infant's or toddler's head is, proportionally, much heavier than it will be later in life. An adult's head is about 2% to 3% of the body's weight, while an infant's head may be as much as 20% to 30%. In young childhood, the head may be as much as 10% to 15% of the body's weight.[9] The brain of the young child is very soft in consistency because of the high water content, immaturity in the number of and development of the glial cells, immaturity of the myelination of axons, and the small size of the axons. A thin or absent layer of myelin facilitates axonal damage resulting from strain, as most axonal damage occurs at the node of Ranvier where myelin is discontinuous.[10,11]

Raghupathi and Margulies[12] used a neonatal porcine model to study nonimpact rotational velocities and found that the younger piglet brain had a lower threshold for injury than the adult pig brain. Using the same porcine model at a toddler age, Ibrahim et al [13] found that the neonate piglet was more vulnerable to acceleration-deceleration movements of the head compared to the toddler pig brain. The subarachnoid space that serves as a buffer against the distribution of force into the brain from blows to the head is relatively thin in young children, although it occupies a large surface area.[14]

Subdural Hemorrhage

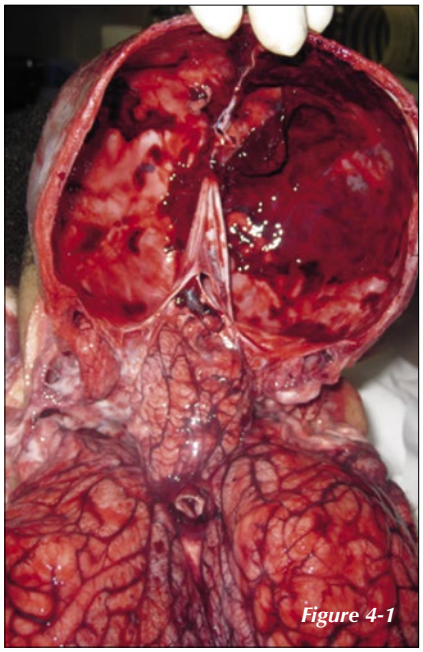
The most common finding at autopsy in a case of abusive head trauma is the presence of subdural blood. Knowledge about the subdural space has changed over the last 30 years, and the current understanding is that there is not a true subdural space.[50,51] The dura is made up of fibroblasts and large amounts of extracellular collagen. The innermost layer of the dura is the dural border cell layer, which is continuous with the arachnoid outer barrier cell layer. Although an anatomic patent subdural space does not exist, such a space may be created if blood enters the dura-arachnoid junction and dissects open the dural border cell layer. The dural border cell layer is the weakest plane and will dissect open if traumatically cleaved. The dura is attached to the inner table of the skull, and the arachnoid is attached to the pia mater on the surface of the brain.

When the skull is lifted away at surgery or autopsy, the dural border cell layer is separated from the arachnoid so that there appears to be a naturally occurring space beneath the dura. The actual space created is intradural within the dural border cell layer. The bridging veins pass through the meninges, the pia, and the arachnoid as they exit the cortical surface of the brain and pass to the venous sinuses in the dura. The walls of the bridging veins are attached to the dural border cell layer and to the arachnoid cells. The attachment to the arachnoid is stronger than the attachment to the dural border cell layer, so that when there is differential motion between the brain-skull interface, the dura moves with the skull and the arachnoid moves with the brain. If the motion is great enough to strain the bridging veins, blood enters the intradural layer of the dural border cells and is seen as "subdural" blood. This discussion will continue to use that terminology, although it is understood that the subdural space is only a potential space.

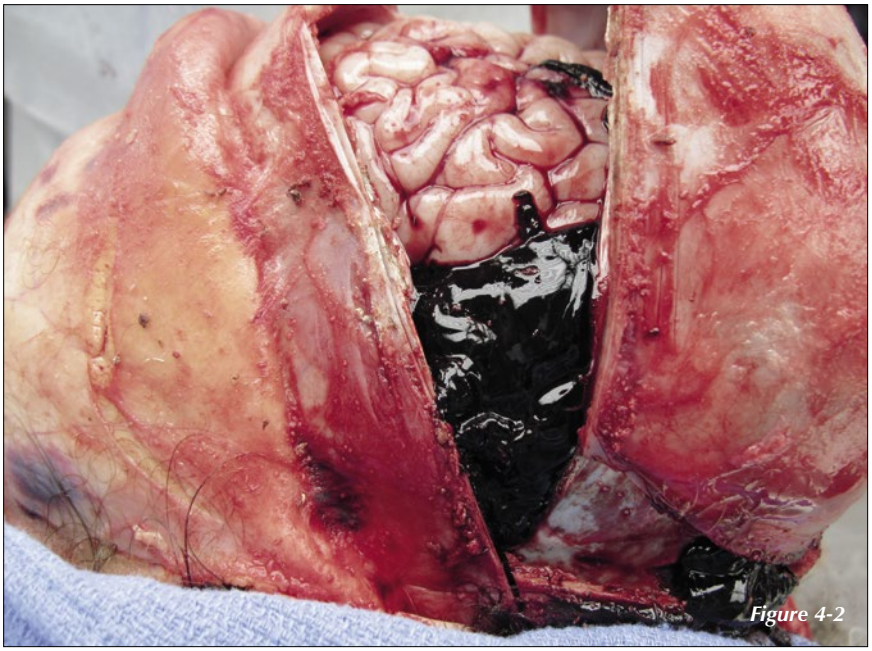
SDH is present in 90% to 95% of cases of fatal inflicted head injury at autopsy and can be imaged in 40% to 55% of living children with such head injuries.[23,52,53] There is a difference in the numbers of cases with SDH at autopsy and in the living on computed tomography (CT) scan because a thin layer of subdural blood that is visible at autopsy may not be visible on CT imaging, while small amounts of interhemispheric blood can be seen on CT but not at autopsy.[54,55] Magnetic resonance imaging (MRI) is better able to detect small amounts of SDH than the CT scan, although many young children with abusive head trauma are too critically ill to undergo MRI.[14] In many cases, the subdural blood is a thin layer over both cerebral convexities (**Figure 4-1**).

Figure 4-1. *Posterior dissection of brain and spinal cord. Child is face down. The skull cap is being retracted to show subdural blood over cerebral convexities but greater on the left.*

Figure 4-2. *The opened skull reveals subdural blood over left cerebral convexity.*



In some cases, the SDH will be unilateral rather than bilateral, but it will be over the cerebral convexity rather than focally in an isolated location (**Figure 4-2**). The subdural bleeding is caused by the inertial brain motion, which separates the cortical surface from the overlying skull and attached dura, resulting in the tearing of bridging veins.[56,57] Inertial motion of the brain begins earliest in the posterior hemispheric fissure so that the earliest subdural blood appears there and then spreads anteriorly and outward.[58] Wells et al[59] looked at intracranial hemorrhage in 293 children younger than age 3 years. They found that interhemispheric SDH was the most common type of subdural bleeding, as it was seen in 49% of the 293 cases, and 73% of the children with interhemispheric SDH had abusive head trauma. They found that accidental head



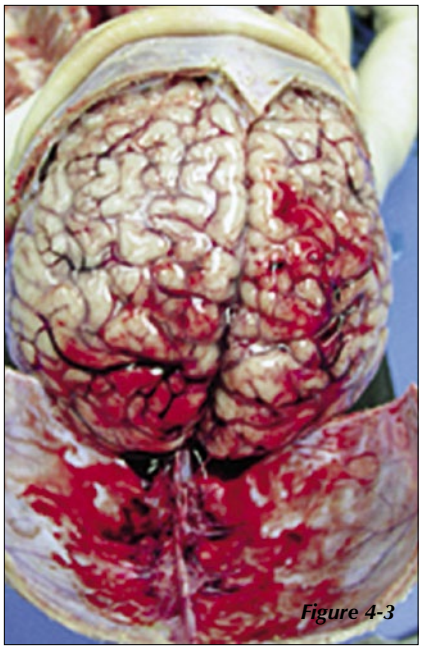


Figure 4-3. *Skull opened to demonstrate minimal subdural blood over cerebral convexities.*

trauma caused just 15% of the interhemispheric subdural bleeding, and all of these injuries were associated with relatively high force—3 falls from heights greater than 2 meters, 12 motor vehicle collisions, 4 infant walker-stair falls, and 2 blows to the head. SDH over the convexities was seen in 47% of cases, and abusive head trauma accounted for 72% of the convexity SDH. Accidental head trauma accounted for 10% of the convexity SDH, and these were from injuries caused by the scenarios noted above.

In cases with an associated skull fracture, the subdural blood is not always immediately adjacent to the fracture. The amount of subdural blood may be minimal, even less than 5 to 10 mL of blood. Because the amount of blood is so minimal, it is important that the pathologist always be the person who opens the calvarium of a child so that any subdural blood can be observed and documented (**Figure 4-3**). During the process of removing the calvarium, the venous sinuses will be disrupted, and that breech will cause blood to be added to any subdural blood already present. Once the brain is removed, there is often subdural blood in the cranial fossae. Many cases of inflicted head trauma will also have subdural blood within the spinal subdural space. The general opinion of forensic pathologists is that the spinal subdural blood has descended by gravity from the intracranial compartment. A divergent view is that of Rorke-Adams,[60] who notes that subdural blood that originates in the supratentorial space cannot gain access to the spinal subdural space. However, in many cases of abusive head trauma, there is subdural blood in the posterior fossa in addition to subdural blood over the convexities. Rorke-Adams[60] also notes that subdural blood in the posterior fossa has easy access to the spinal subdural space.

SDH may occur in association with numerous causes and conditions, including inflicted head trauma, accidental head trauma, medical or surgical manipulation, metabolic diseases, birth trauma, tumors, genetic disorders, autoimmune diseases, clotting disorders, infectious diseases, long-term shunting for hydrocephalus, and other miscellaneous conditions. In cases of possible inflicted head trauma, other sources of subdural bleeding must be considered, and close attention must be given to the history, physical examination, radiological imaging, and laboratory studies before excluding other causes of the bleeding. Subdural blood isolated to the ventral surface of the brain or to a small focal area of the convexity requires very close examination for another source of bleeding, as these locations are in variance to the mechanism of ruptured bridging vein bleeding.[61,62] Contact injury to the head can also produce subdural bleeding. Denton and Mileusnic[44] reported a 9-month-old boy who fell from 30 inches and sustained a right parietal fracture with a thin, adherent clotted 2 cm x 2 cm x 0.1 cm SDH underlying the fracture. This child survived without symptoms for 72 hours and at autopsy had severe brain edema and herniation.

Chronic Subdural Hematoma

Few cases of SDH evolve into chronic subdural hematomas, as most subdural blood will be resorbed over several weeks.[62-66] Experimental models are unable to reproduce a chronic subdural hematoma from acute subdural blood.[67] It has become clear that the majority of chronic subdural hematomas develop from subdural hygromas.[68] A subdural hygroma is caused by a traumatically induced tear of the arachnoid so that cerebrospinal fluid (CSF) can pass into the subdural space as an acute SDH is resolving.[69,70] A major factor promoting the resorption of acute subdural blood is the high levels of tissue thromboplastin in the brain and CSF.[71] Any pathologic process that causes cleavage of the dural border cell zone can induce proliferation of the dural border cells, which will produce a neomembrane. In some cases, as an acute SDH resolves, the cleaved intradural zone may remain as a persistent space. A lowered intracranial pressure, which would exist over areas of cerebral atrophy, when there has been prolonged drainage of CSF or when there has been prolonged use of osmotic agents could promote persistence of an intradural space.[72,73] CSF or remnants of the liquid portion of an acute SDH can then pass into the cleaved space and create the hygroma. Whether there is persistence of the lowered intracranial pressure determines what will happen to a hygroma. If there is return to

later admitted to shaking the infant. In this study, the author found a much higher incidence of tDAI than did the Geddes studies. In the author's study,[102] in some cases of head injury, both VAI and tDAI were present together and could be distinguished. Many infants and children with inflicted head injury have such global hypoxic damage that it may be difficult to recognize the pattern of tDAI when there is extensive VAI, because the tDAI pattern is much less pervasive compared to the VAI pattern.

Brain Swelling

Brain swelling is a common finding in the autopsies of young children who died from inflicted head injury if there is survival for some period of time. If the child dies shortly after the injury, there may be little swelling of the brain. Brain swelling is recognizable by the flattening of the gyral surfaces and narrowing of the sulci, along with the appearance of the brain filling the cranial cavity when the brain is removed. Brain weight is also a good indicator of swelling if the weight is 10% to 15% greater than the expected value. Brain swelling is hypothesized by some investigators to be caused by hypoxia that follows the apnea that commonly accompanies these head injuries. Hypoxia does not fully explain the pathological findings, such as SDH, retinal hemorrhages, and the pattern of atrophy that develops in surviving children (**Figure 4-8**).

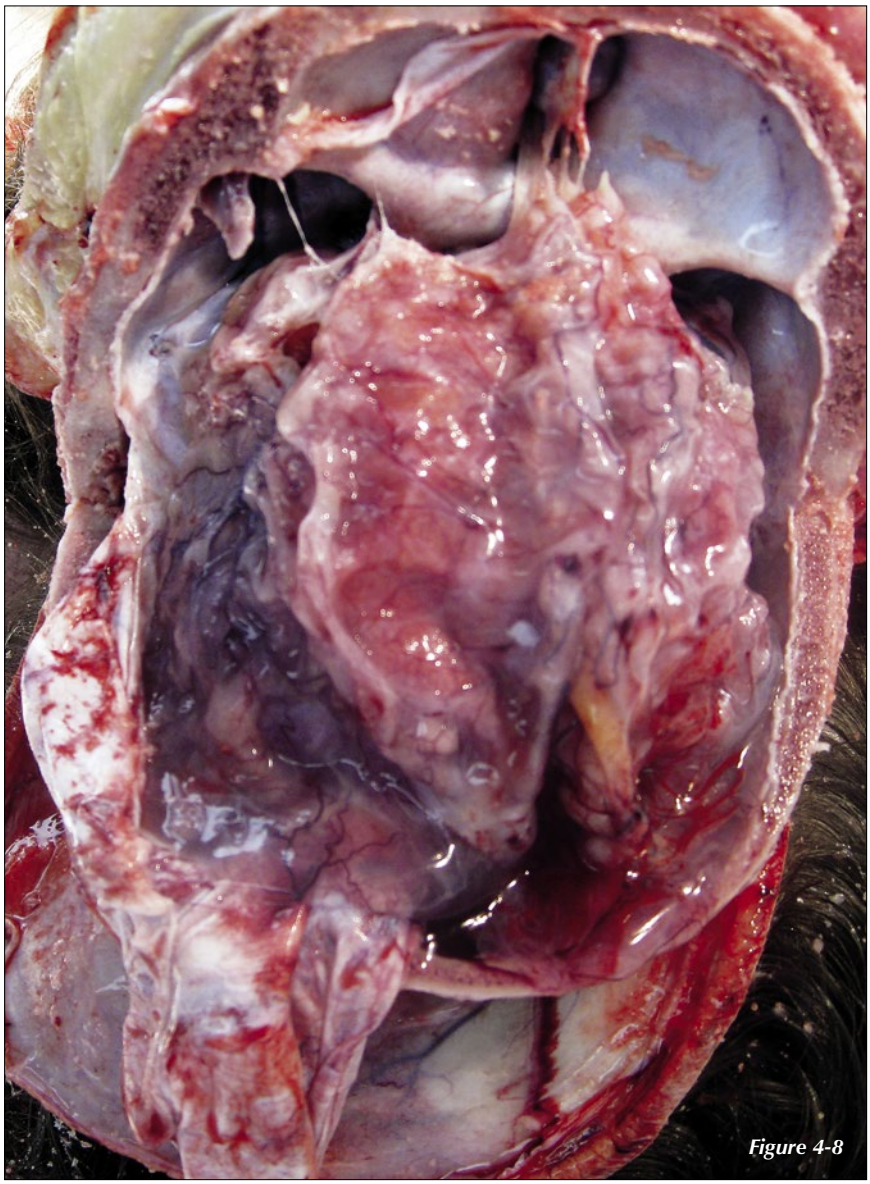


Figure 4-8. *Calvarium opened to show small atrophic brain following 13 years of survival after severe abusive head trauma.*

Head Trauma Case Studies

Case Study 4-1

A 17-month-old Hispanic boy was pronounced dead on arrival (DOA) when presented to the emergency department (ED). The father admitted to shaking the child. The father also said he had shaken the child on other occasions to make the child stop crying, and on this occasion, the child became unresponsive.

Cause of Death: Closed head trauma

Manner of Death: Homicide

Table 4-1. Autopsy Results

Injuries

Type	*Measurement*
Healing contusion on left sternal border	5 mm
Abrasion on right upper eyelid	1 mm
Abrasion on right cheek	2.5 cm
Abrasion on tip of nose	5 mm
Abrasion on left nasal ala	5 mm

Internal Injuries

Acute subdural hemorrhage over right cerebral convexity	70 mL
Contusion tear of right inferior temporal gyrus and corpus callosum	2 to 3 mm
Unilateral retinal hemorrhages and heavy optic nerve sheath hemorrhage in other eye	
Subarachnoid hemorrhage, right and left parasagittal regions	

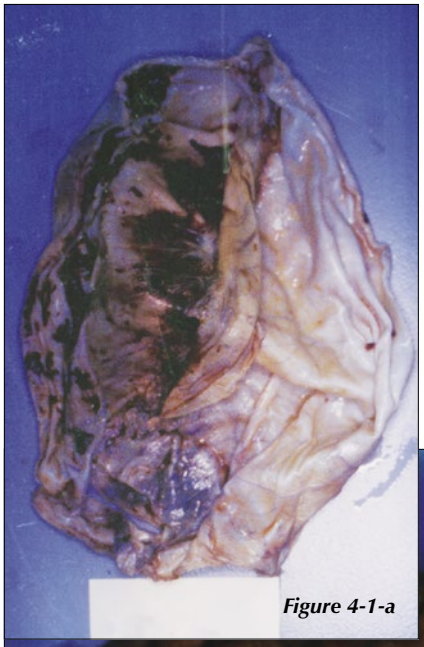


Figure 4-1-a. *Undersurface of dura showing acute subdural hemorrhage over right cerebral convexity.*

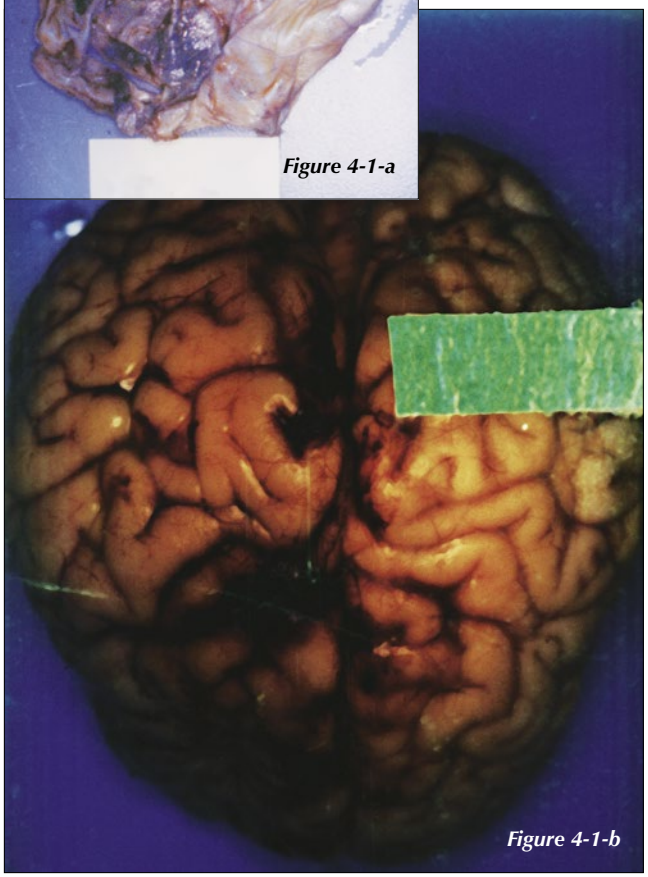


Figure 4-1-b. *Subarachnoid hemorrhage over right and left parasagittal cerebral convexities.*

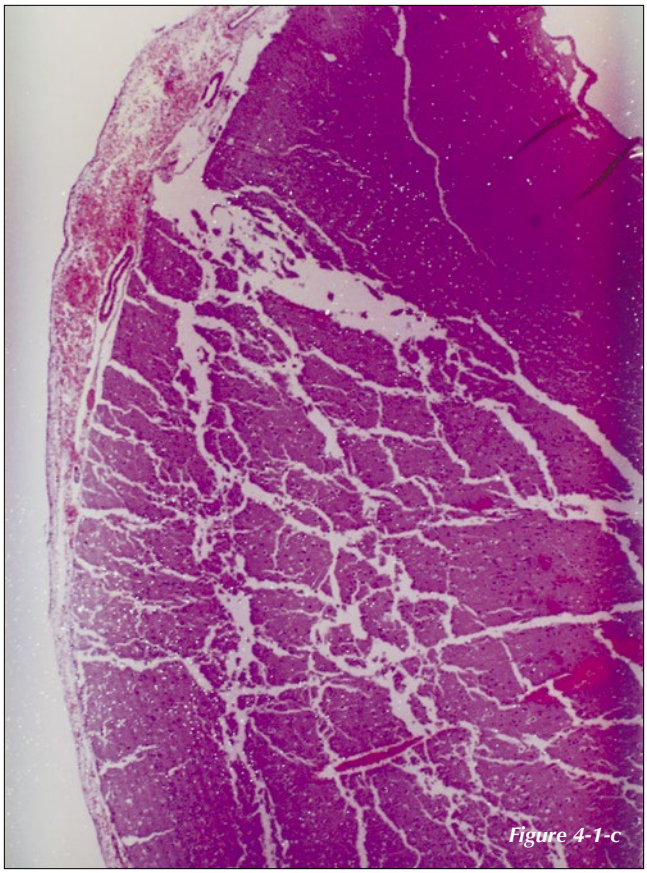


Figure 4-1-c. *Subarachnoid hemorrhage over cerebral convexity on low power.*

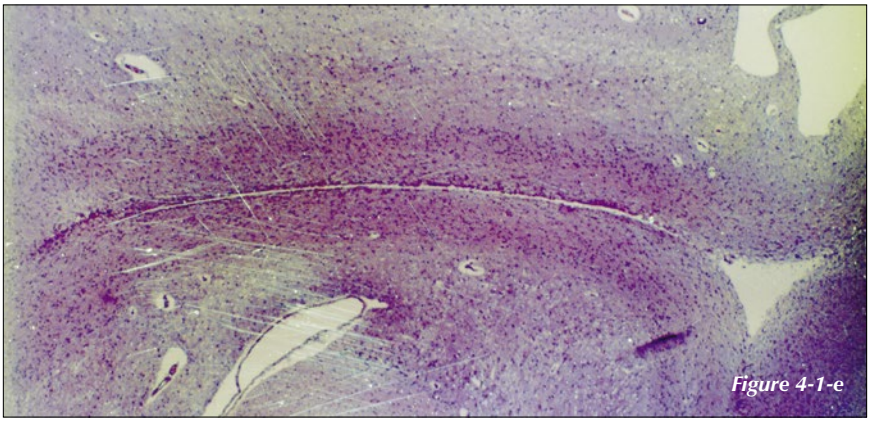
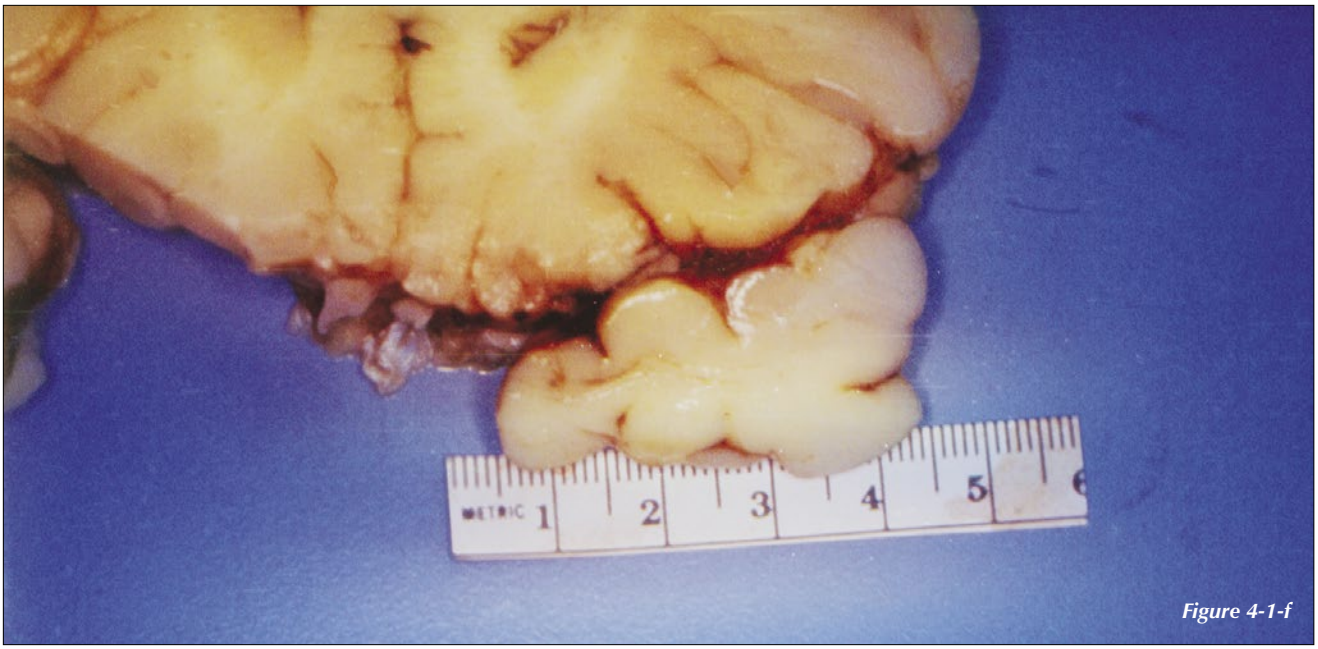


Figure 4-1-d. *Contusion tear of corpus callosum.*

Figure 4-1-e. *Contusion tear of corpus callosum on low power.*

Figure 4-1-f. *Contusion tear of right inferior temporal gyrus.*



Chapter 5

Injuries of the Spine and Spinal Cord

Epidural Hemorrhage of the Cervical Spine

In 1967, Towbin[1] observed epidural hemorrhages in the cervical spine of 5 children who died suddenly and unexpectedly. He suggested these findings might be traumatic and might be related to the cause of death of these children (ie, producing mechanical injury to the spinal cord). Two years later, Harris and Adelson[2] described 19 infants aged younger than 1 year who died suddenly and unexpectedly. Five of these infants died of natural causes from diseases noted at autopsy. Fourteen of the deaths were unexplained by findings at autopsy and were considered to be sudden infant death syndrome (SIDS) deaths. Eighteen of the 19 infants had hemorrhage within the spinal epidural region, which was greatest in the cervical portion, that varied from venous congestion to hemorrhage within the adjacent soft tissues. These authors made 3 conclusions: (1) these epidural hemorrhages were not traumatic; (2) the presence of blood was not damaging to the spinal cord; and (3) hemodynamic forces were probably responsible for this congestive phenomenon.

In 1989, Hadley and colleagues[3] described 13 infants aged 1.5 to 14 months who were diagnosed as shaken infants. Eight of the infants died, and autopsies were done on 6. These autopsies were interesting for the following reasons: 5 of 6 had epidural hemorrhages in the cervical spine, 4 of 6 had subdural hemorrhage (SDH) in the cervical spine, 4 of 6 had contusions of the high cervical cord, and 1 of 6 had none of these findings. The subdural blood in the region of the cervical spine is not an unexpected finding because in infants with abusive head trauma, the SDH in the posterior cranial fossa can descend by gravity into the spinal subdural space. Although Harris and Adelson[2] had studied spinal epidural hemorrhages in infants and concluded these were hemodynamic phenomena, their 1969 study preceded the time when the diagnosis of inflicted head trauma was being generally made. No one had specifically looked at infants with abusive head injury to determine whether those children had hemorrhage in the spinal epidural space.

To elucidate the findings in the spinal area of young children with and without abusive head injury, the author conducted a study from 1989 to 1992 on children younger than age 3 years who died and were autopsied in a large metropolitan medical examiner's office. This study examined the spines in 50 cases of inflicted head trauma and control cases without head injury for the presence of epidural blood. From this study, it was apparent that both groups frequently had spinal epidural hemorrhage and that no relationship could be established between head injury and the spinal epidural hemorrhage (**Figure 5-1**). It is recommended that all autopsies in children younger than age 3 years include a posterior neck dissection and examination of the vertebral bones and spinal cord when there is any possibility of head trauma.[4] While the epidural blood is indicative of trauma, there could be other findings of trauma such as fracture, which can be seen best in a posterior dissection.

Figure 5-1. *Infant who died from SIDS demonstrating extensive epidural blood from the cervical to the thoracic regions of the spine.*

Hadley's 1989 paper[3] described autopsies in 6 infants dying from inflicted head injury and found that 4 of the 6 had contusions of the cervical cord. Hadley did not elaborate on the pathology of these contusions, so it is difficult to know if they were similar to those described by Geddes and colleagues[5,6] in some of their cases—who were found to have focal axonal injury in the cervical region—or if they were truly contusional hemorrhages.

Distraction Injury of the Cervical Spine

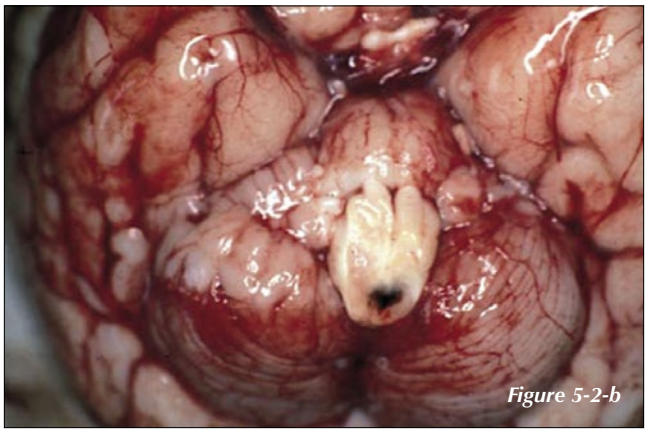
A very rare abusive injury of the cervical cord is a distraction injury.[7] In 1995, Piatt[8] described a 15-month-old child who presented to the emergency department (ED) with quadriplegia after reportedly falling from a couch. This child had linear bruises in front of the right ear and jaw, along with showers of petechial hemorrhages over the left side of the neck, over both ears, the right side of the jaw, and the upper chest. The child had older bruises at the corner of both eyes, on both arms, and on the right thigh. There was an old fracture of the right clavicle. MRI demonstrated fusiform swelling of the midcervical cord that represented hematomyelia. Two months later, MRI demonstrated spinal cord atrophy, and the child's quadriplegia persisted. Parrish[9] reported a case of isolated spinal cord injury in a case of child abuse. This was a 2-month-old infant who was found at autopsy to have a contusion of the upper cervical spinal cord and lower medulla. The eyes were studied and found to have anterior chamber bleeding bilaterally, a dislocated left lens, and vitreous hemorrhage. These injuries were hypothesized to be the result of direct compressional force and that the perpetrator had picked up the child by the head—with the perpetrator's thumbs positioned over the child's eyes—and violently shook the child while grasping the head.

In the years following these reports, the author has seen 3 cases with findings that suggest a distraction mechanism of injury to the cervical cord and lower medulla.[10] Two of the cases were siblings. In the first of these 2 children, the father described that he had grasped the 3-month-old infant by the head and shook her body. That child survived with a central cord syndrome. A second sibling was found dead at age 3 months. Her autopsy demonstrated petechial hemorrhages of the right bulbar conjunctiva and hematomyelia of the upper cervical cord and medulla. It was suspected that the father had performed a similar abusive act as with the first child by grasping the head and shaking the body, causing a distraction injury of the cervical cord and medulla.

The third case was a 25-day-old infant reported to have been found unresponsive in the morning after crying all night. He was dead on arrival at the ED. Autopsy demonstrated contusions of the right mandible, below the left lower lip, and on the right shoulder, left abdomen, posterior left arm, right thigh, and both legs. Several of the contusions on the extremities looked like gripping marks. There were petechial hemorrhages of the right preauricular area, left lateral forehead, and bulbar and palpebral conjunctivae. There was a single small retinal hemorrhage and fracture of the right clavicle with early callus. The autopsy also revealed a separation of the C3-4 intervertebral disc and hematomyelia of the upper cervical cord and lower medulla (**Figure 5-2-a** and **b**). The

Figure 5-2-a. *A 3-month-old infant with distraction injury of the cervicomedullary region. Right leg shows gripping marks from grasping the leg with the fingers.*

Figure 5-2-b. *Brain at autopsy with transverse section of caudal medulla showing a 4 mm area of hematomyelia.*



mechanism of grasping a child by the head and violently shaking the body is suggested by these findings. As the child is grasped by the head, the weight of the unsupported suspended body will distract the upper cervical spinal cord and lower medulla.

There is an artifact that may resemble a cervical cord contusion or distraction injury of the cord. Patients who become brain dead from brain swelling cutting off the cerebral circulation and who are kept alive for several days in that state will begin to show fragmentation of the cerebellar tonsils. As the tonsils disintegrate and drop into the subarachnoid space, the material may descend downward into the cervical spinal cord subarachnoid space, where it may compress and crowd the small vessels and result in ischemia of the cervical cord. Ischemic lesions of the cervical cord appear as hemorrhagic softening of the central cord, which resembles a contusion. Cerebellar detritus can be found within the subarachnoid space of the cervical cord in these cases. Identical lesions have been demonstrated in experimental animal models of brain death.[11]

Injuries of the Spine and Spinal Cord Case Studies

Case Study 5-1

A 3-month-old Caucasian boy arrived in the ED at 7:11 AM in full arrest. His body temperature was 92.3°F. The father said the child had been restless all night and was crying much of the previous day. At 11:00 PM the night before the child died, the father called the pediatrician and said the child was crying from gas. The doctor told the father to go to the ED if he felt there was a serious problem. The father was up with the child all night and would sleep only briefly before the child would start crying again. At 6:00 AM the child settled down and went to sleep. The father laid the child down on his left side on a full-size bed. The father then lay down across from the child and fell asleep. He woke up at 6:30 AM and noticed the child was not breathing. 911 was called.

Department of Family Services had 1 hotline call at 3:45 PM the day before the child's death from a professional person who stated the child was at high risk because the mother had a history of drug abuse. She had 1 child who died of SIDS, and she was not bonding with this child. A scene investigation was carried out. The father stated the child had been crying, and the mother went to another part of the house to get away. The father and child remained in the basement apartment.

Cause of Death: Cervicospinal blunt trauma

Manner of Death: Homicide

Note: This is a distraction injury from grasping the child's head and shaking the body.

Table 5-1. Autopsy Results

External Examination

— Well-nourished infant

— Child was 21 inches and 7 pounds

— Eyes show 2 petechiae on left bulbar conjunctiva, multiple petechiae on the right bulbar and inferior palpebral conjunctivae, and a 5 mm confluent hemorrhage on the right lateral bulbar conjunctiva

Injuries

Type	*Measurement*
Contusion, inferior edge of middle third of right mandible	10 mm
Abrasion along vermilion border, left upper lip laterally	8 mm x 1 mm
Contusion, linear, below left lower lip	10 mm x 1 mm
Somewhat square area of petechiae on right preauricular area	20 mm x 20 mm
Some petechiae on left lateral forehead	
Contusion, anterior right shoulder medial to axillary line	20 mm x 5 mm
Punctuate contusions, lateral left abdomen, consisting of:	30 mm x 10 mm area
— an anterior contusion	3 mm
— a box of contusions	4 to 2 mm
— posteriorly, 2 somewhat parallel linear contusions	4 mm x 1 mm
Contusion, posterior left arm	20 mm x 3 mm
Contusion, posterolateral right proximal thigh	20 mm x 4 mm
Curved contusion, right calf, continuing onto posteromedial right knee with S-shaped configuration	40 mm x 1 mm
Contusion, proximal anterior right thigh	30 mm x 12 mm
3 contusions, proximal anterior right thigh	2 mm (2), 3 mm
Contusion, proximal anteromedial left leg	20 mm x 4 mm
Contusion, left calf	20 mm

(continued)

Injuries of the Spine and Spinal Cord Case Studies

Table 5-1. Autopsy Results *(continued)*

Injuries *(continued)*

Type	*Measurement*
Contusion	40 mm x 8 mm
— consisting of 2 parallel linear marks separated by wide, pale area on posterolateral distal left thigh	5 mm
Approximately 3 to 9 other patchy contusions on left leg and knee	5 mm x 1 mm

All contusions were red-purple; incision into the contusions showed superficial hemorrhage

Fractures

— Diastasis of C3-C4 intervertebral disc

— Fracture of right clavicle with surrounding red/brown hemorrhage (microscopically, this is a healing fracture with superimposed refracture)

Internal Injuries

— Moderate hemorrhage in cervical perivertebral musculature

— Extensive hemorrhage within membrane of C1-C2 posteriorly

— Extensive hemorrhage in anterior prevertebral soft tissues including the distal pharyngeal soft tissues

— Mild hemorrhage in left paravertebral muscles

— Mild hemorrhage, 20 mm x 25 mm area, midoccipital periosteum

Neuropathology

— After fixation, the brain weighed 540 grams

— Cervical cord contusion with hematomyelia from upper cervical cord to lower medulla, 4 mm wide at greatest extent in the cord

Eyes

— Single petechial retinal hemorrhage

Figure 5-3-a. *Left leg of infant showing gripping marks from grasping the leg with the fingers.*

Figure 5-3-a

Figure 5-3-b. *At autopsy, when the brain is removed by sectioning between the cervical spinal cord and the medulla, an area of hematomyelia can be seen in the caudal medulla-cervical cord junction.*

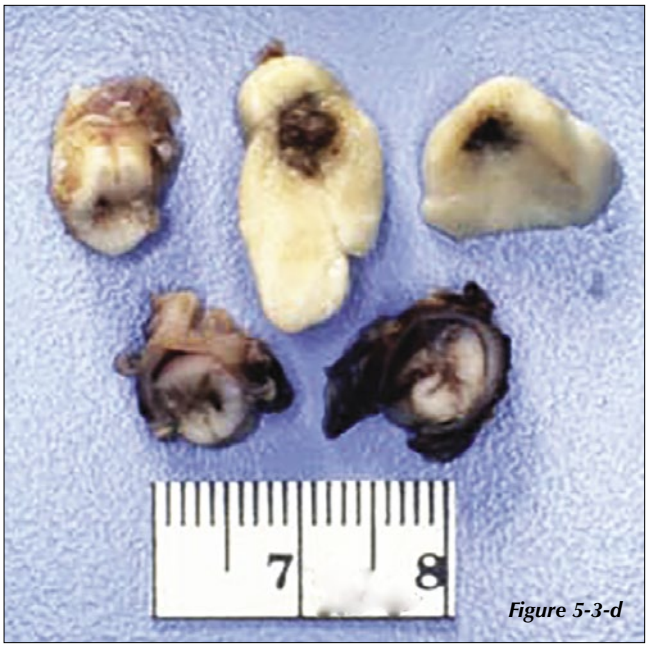


Figure 5-3-c. *After fixation, an area of hematomyelia can be seen in both the medulla and upper cervical cord at their junction.*

Figure 5-3-d. *After fixation, the junction between the medulla and cervical cord is cut into transverse sections showing the area of hematomyelia extending from medulla into the cord.*

Chapter 7

Abdominal Trauma

Significant blunt abdominal trauma is a rare but deadly form of child abuse and is second only to head injury in causing deaths by abuse.[1] Only 1% of children hospitalized for child abuse have abdominal trauma, but 45% to 50% of these abdominal injuries are lethal.[2] In the author's series of fatal child abuse cases, abdominal trauma accounted for 20% of child abuse deaths in the years 1975 to 1985 and 9% in the years 1986 to 1999. During those periods, no accidental fatal abdominal injuries were encountered in these populations (which excluded motor vehicle accidents [MVAs] and gunshot wounds). In the literature, about 12% of child abuse deaths are attributed to abdominal injuries.[3,4] Abusive abdominal trauma has a high mortality rate compared to accidental injuries of the same magnitude.[5] In abusive injuries, the perpetrator knows that the child has been injured but does not wish to arouse suspicion, so they delay seeking medical care until the child is morbid or dead. By contrast, in accidental injuries, medical care is sought immediately.[2]

Inflicted abdominal injuries tend to terminate with severe peritonitis or hemorrhagic shock as a result of the untreated injuries. The anatomy of the young child's abdomen is distinct in that the abdominal wall has little or no muscle for protection against impact, and force can easily penetrate. The rib cage is widely flared, and the ribs are flexible, so fewer organs are covered by this protective layer. Abdominal injuries are caused by direct blunt force from a punch or blow or from indirect forces of deceleration when a child is thrown against a wall or object. In accidental circumstances, solid organs such as the liver, kidney, and spleen tend to be more commonly damaged than hollow organs. In inflicted abdominal trauma, the spleen and kidney are seldom injured, although the liver is frequently injured by both accidental and inflicted trauma.[6,7] Hollow viscus injury is more common in inflicted abdominal trauma than in accidental trauma, and it most commonly occurs in the proximal small bowel. Pancreatic and mesenteric injuries also occur. It is important to note that the abdominal wall may not demonstrate any area of contusion even when there has been significant impact and underlying lethal trauma (**Figure 7-1-a** and **b**). In some cases, however, prominent marks are present (**Figure 7-2-a** and **b**).[8]

Figure 7-1-a. *A 6-year-old girl on autopsy table before autopsy showing that no marks are present on the abdomen. This child was kicked in the abdomen at noon by her aunt and died the following evening.*

Figure 7-1-b. *Abdomen opened to demonstrate extensive peritonitis with purulent exudate over the peritoneal surfaces and turbid brown fluid within the peritoneal cavity.*

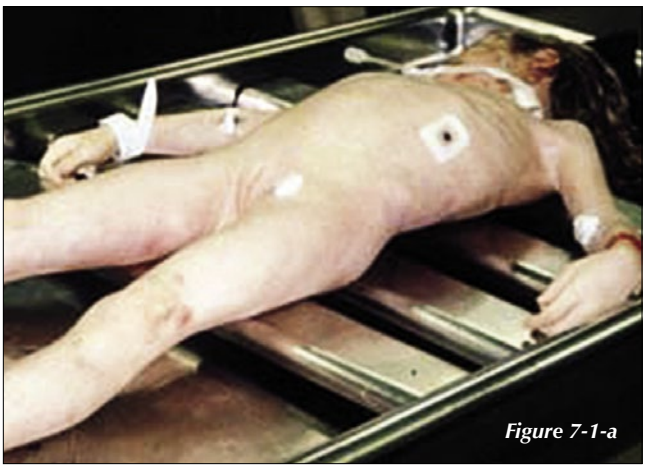


Figure 7-1-a

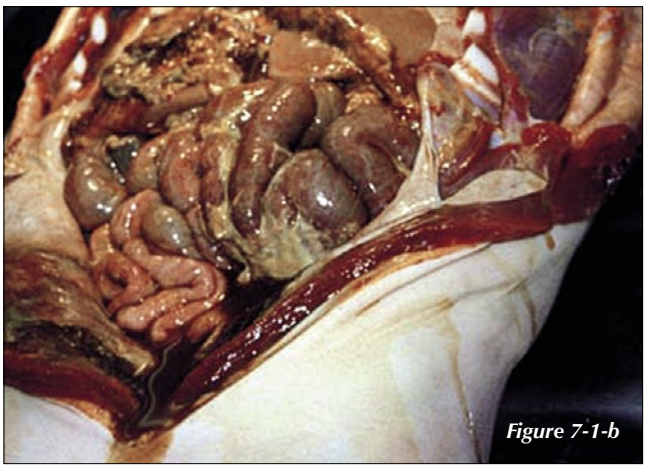


Figure 7-1-b

Abdominal Trauma Case Studies

Case Study 7-1

A 3-year-old Caucasian boy allegedly fell from the bed to the floor when trying to climb into bed with his mother. Police were told by a neighbor that the child fell out of a window. The mother called 911 after the child stopped breathing in her arms. The child was dead on arrival (DOA) at the emergency department (ED). The child had a casted broken left femur. There was an ongoing Department of Family Services (DFS) investigation because of a spiral fracture in the same femur earlier that year. At the previous hospital, the adult supervisor appeared intoxicated and kept leaving for "Pepsi." The child also had speech delays and multiple bite marks on his body, as well as finger marks, including some marks on his back that would have been impossible for him to self-inflict. The child abuse hotline indicated the DFS investigation, as well as another case involving the administration of unsuitable drugs. The mother's step-sister said the mother was "very abusive" to the child.

Cause of Death: Blunt abdominal trauma

Manner of Death: Homicide

Table 7-1-a. Autopsy Results

Examination in Hospital

— 2 abrasions on the right and left sides of neck, as well as an abrasion on chin

External Examination

— Drying of the conjunctivae bilaterally with tache noire

— 3 petechiae in left inferior palpebral conjunctiva and 2 in right inferior palpebral conjunctiva

— Cast on left femur covering entire extremity

Injuries

Head

Type	*Measurement*
Contusion, midline in lower occipital scalp	6 cm x 4 cm
— within which is an abrasion	3 cm x 5 mm
Contusion, midline of forehead	6 mm x 5 mm
Dried abrasion, right upper orbital region	2 cm x 0.5 cm
Contusion over bridge of nose	1 cm x 0.5 cm
3 contusions on left upper lateral cheek	5 mm each
3 abrasions, middle of left cheek	5 mm each
Linear abrasion	3.5 cm x 2 mm
— separated from another abrasion above left upper lip	2.5 cm x 1 cm
Abrasion above left upper lip	5 mm x 3 mm
Abrasion, left lower lip	2.5 cm x 1 cm
2 fresh lacerations on inner mucosa of lower lip with a contusion next to it	1 cm each
Laceration in upper frenulum with reopening of an old tear	5 mm
Abrasion, tip of chin	2 cm x 1 cm
Contusion, left anterior chin	7 mm x 5 mm
2 ecchymoses on right lower cheek region and jaw	5 mm each
Ecchymoses on lateral left mandible	1 cm x 0.5 cm
Contusion, left upper neck	5 mm
Contusion with abrasion below left ear	1.5 cm x 0.5 cm
Abrasion below right ear	1.5 cm x 0.5 cm
Abrasion, right pinna	2.5 cm x 0.6 cm
Ligature abrasion, right lateral neck	5 cm x 5 mm
2 parallel abrasions, left side of neck	1.5 cm x 0.2 cm each
3 abrasions, posterior neck	5 mm each

(continued)

Table 7-1-a. Autopsy Results *(continued)*

INJURIES *(CONTINUED)*

Chest/Abdomen

TYPE	*MEASUREMENT*
Abrasion, right upper chest at shoulder	1.5 cm x 0.5 cm
2 contusions, left upper chest	5 mm each
Scratch, left lower chest	2 cm x 1 mm

Extremities/Others

Contusion, right arm	2 cm x 1.2 cm
Multiple contusions, left elbow	0.5 to 1 cm
Abrasion, right scapula area	2 cm x 1 cm
Abrasion, left scapula area	1.2 cm x 0.5 cm
Multiple (12 to 15) ecchymoses, left lateral back	5 mm each
Ecchymoses, midline of lower back with superimposed contusions	3.5 cm x 1.5 cm
Abrasions on buttock under the cast	1 cm, 0.5 cm
Healing abrasion on left thigh	
Discoloration on left side of scrotum	

INTERNAL EXAMINATION

Body Cavities

— ***Abdomen:*** Peritoneal cavity contains 50 mL of bloody fluid mixed with fibrin; fresh hematoma involving mesentery of small bowel and right pelvic flexure and soft tissues of pelvis

— ***Gastrointestinal (GI) Tract:*** Partial transection of duodenum at the junction with the jejunum; in the distal portion, there is a tear across the anterior half of the circumference, and the adjacent mesentery is hemorrhagic with fibrinoid purulent exudate beginning to adhere to the adjacent portion of bowel

Male Genital System

— Fresh hemorrhage within the soft tissues surrounding left scrotum

Cranial Cavity

— Inner surface of scalp has large subgaleal hemorrhage, 9 cm x 5 cm, lower occipital scalp underlying previously described injury

MICROSCOPIC EXAMINATION

— Fresh hemorrhage in frenulum, lower lip, back, duodenum

— Fresh hemorrhage in small bowel at site of perforation with heavy, early inflammation with neutrophils throughout bowel wall

— Small bowel away from the perforation shows a thick layer of fibrin and neutrophils on the serosal surface

— Omentum shows fresh hemorrhage and numerous neutrophils

Table 7-1-b. Diagnoses

BLUNT ABDOMINAL TRAUMA

— Partial transection-laceration, distal duodenum

— Hemoperitoneum, 50 mL

— Peritonitis, acute suppurative

— Contusion, left scrotum

CLOSED HEAD TRAUMA

— Contusion and subgaleal hemorrhage, occipital

— Multiple contusions and abrasions, forehead (2), nose, right eye, left upper cheek (3), left mid-cheek (3), chin (2), right cheek (2), left mandible

RECENT BLUNT TRAUMA, MOUTH

— Fresh and healing lacerations, upper frenulum

— Abrasion and lacerations (2), lower lip

— Patterned abrasion above left upper lip

— Abrasion, left lower lip

BLUNT TRAUMA OF NECK

— Contusions below left ear

— Abrasions below right ear, posterior right pinna, posterior neck (3)

— Ligature abrasion, right lateral neck

— Patterned ligature abrasion, left anterior neck

— Petechial hemorrhages, right palpebral (2) and left palpebral (3) conjunctivae

BLUNT TRAUMA OF BACK AND CHEST

— Contusions, left lateral back (12 to 15), midline lower back (2 to 4), left upper chest (2)

— Abrasions, right and left scapular, right upper chest

— Scratch, left lower chest

CONTUSIONS, RIGHT ARM, POSTERIOR LEFT ELBOW (MULTIPLE)

Abdominal Trauma Case Studies

Case Study 7-2

The father of this 3-year-old African American boy said he found the child underwater in the bathtub. There were 2 previous accounts of abuse in the family with the father as the perpetrator, 1 account of physical abuse and 1 account of lack of supervision. The child was DOA in the ED.

Cause of Death: Blunt abdominal trauma

Manner of Death: Homicide

Table 7-2. Autopsy Results

Found at the Scene

— Loop marks on the back, bruise near the left clavicle, bump on the forehead, and scars all over the body

— There was a skin graft visible, taken from the back of the right leg for the left foot

External Examination

— Old scar above the right brow

— Small petechial hemorrhages present in right inferior palpebral conjunctiva

— Several small petechiae present in both the upper and lower gingivae

— Skin graft noted above

— Right foot, old burn scar involving the entire dorsal surface

— Old scar on the midline of the lower back

— Old scar on the left lateral portion of mid-back

— Old scar on right hand

Injuries

Type	*Measurement*
Fresh mucosal hemorrhage on the right buccal mucosa	2 mm x 4 mm
Healing scratch on left cheek	0.1 cm x 0.2 cm
Midline abrasion on abdomen above umbilicus	1.4 cm x 0.7 cm
Healing scratch on right shoulder	2 cm x 0.1 cm
Abrasion on right lateral neck covered with dried blood	1 cm
Abrasion on pinna of right ear	6 mm x 3 mm
Abrasion on the postauricular area	1.3 cm x 0.4 cm
3 purple contusions on right lateral chest	0.3 cm, 1.4 cm, 0.7 cm

Internal Examination

Body Cavities

— Fresh subcutaneous hemorrhage seen on the chest underlying contusions

— Old adhesions on the right upper lobe of lung

— Fracture of the eighth rib laterally with callus and hemorrhage

Abdomen

Blood in the peritoneal cavity	240 mL
Laceration involving the spleen and adjacent soft tissue hemorrhage	6 cm x 2 cm
Laceration through the mesentery of the small bowel at the ligament of Treitz	4 cm
Hemorrhage through the tail of the pancreas	1 cm x 2 cm

Fresh hemorrhage in the lower midline abdominal wall

Cranial Cavity

3 subgaleal hemorrhages

— 1 old	2 cm
— 2 fresh	2 cm each

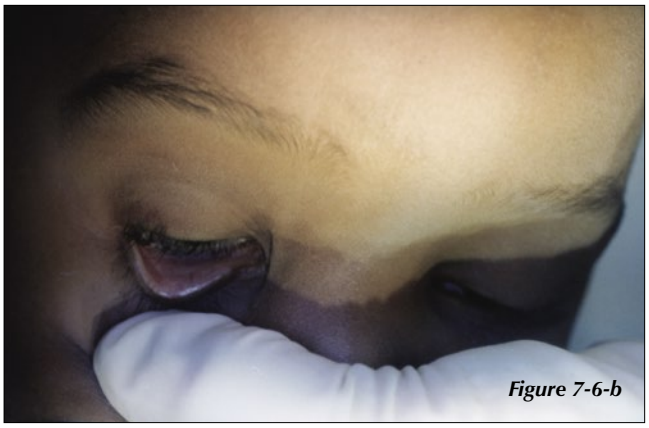


Figure 7-6-a. *Child before autopsy showing an old scar above the right brow.*

Figure 7-6-b. *Right inferior palpebral conjunctiva showing several small petechial hemorrhages.*

Figure 7-6-c. *Lower gingiva showing several small petechial hemorrhages.*

Figure 7-6-d. *Abrasion on pinna of right ear.*

Figure 7-6-e. *Lower back showing old scar.*

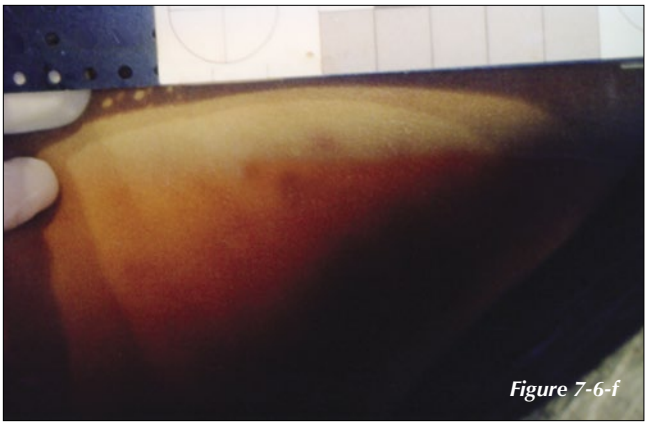


Figure 7-6-f. *Old scar on left lower back.*

Abdominal Trauma Case Studies


Figure 7-6-g


Figure 7-6-h

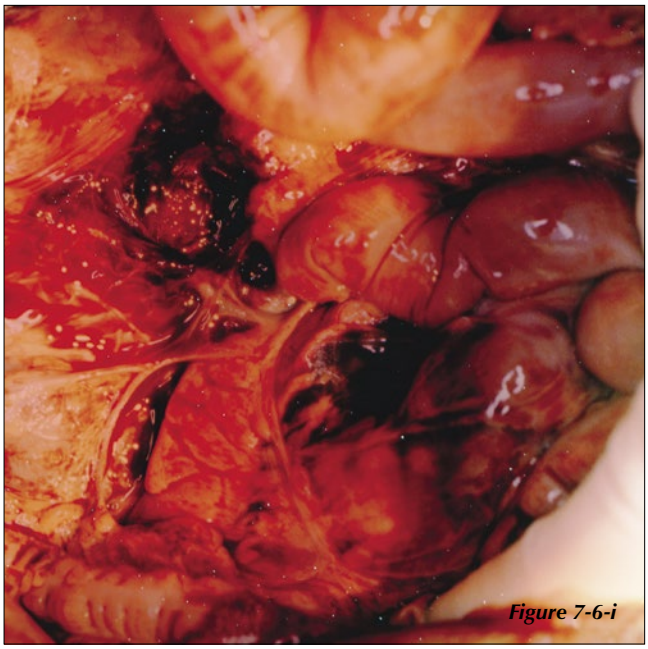


Figure 7-6-i

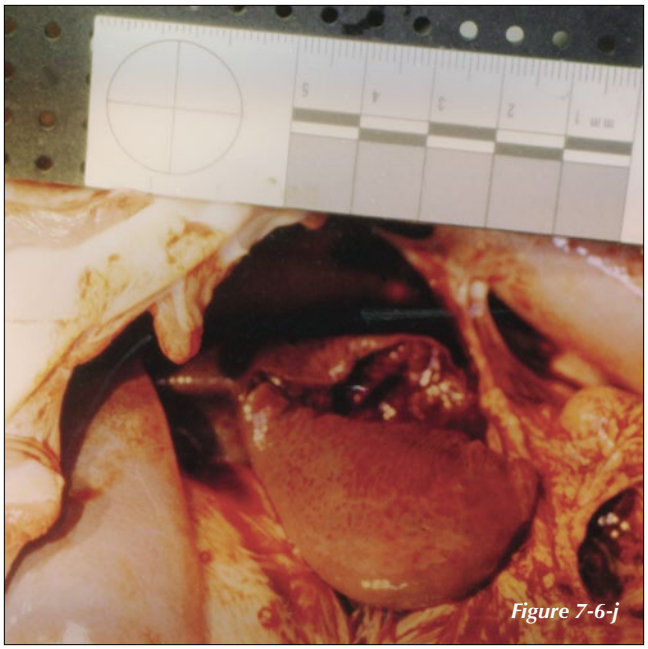


Figure 7-6-j

Figure 7-6-g. *Skin graft site scar on posterior right thigh.*

Figure 7-6-h. *Right foot with old burn scar over the dorsal surface.*

Figure 7-6-i. *Abdomen opened to show hemorrhage in soft tissue adjacent to spleen.*

Figure 7-6-j. *Abdomen opened to show laceration of mesentery.*

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