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# Child Abuse

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## *Pocket Atlas Series*

*Volume Three*  
*Head Injuries*



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## *Pocket Atlas Series*

*Volume Three*

### *Head Injuries*

**Randell Alexander,  
MD, PhD**

Professor of Pediatrics and Chief  
Division of Child Protection and  
Forensic Pediatrics  
Department of Pediatrics  
University of Florida  
Jacksonville, Florida

**Angelo P. Giardino,  
MD, PhD**

Vice President/Chief Medical Officer  
Medical Affairs  
Texas Children's Health Plan  
Clinical Professor, Pediatrics and  
Section Chief  
Academic Pediatrics  
Department of Pediatrics  
Baylor College of Medicine  
Houston, Texas

**Debra Esernio-Jensen,  
MD, FAAP**

Professor of Pediatrics  
University of Florida at Gainesville  
Medical Director  
Child Protection Team  
Gainesville, Florida

**Jonathan D. Thackeray,  
MD, FAAP**

Physician  
The Center for Family Safety and Healing  
Division of Child and Family Advocacy  
Department of Pediatrics  
Nationwide Children's Hospital  
Columbus, Ohio

**Robert Parrish, JD**

Managing Attorney  
Second District Office of the  
Guardian ad Litem  
Layton, Utah

**David L. Chadwick, MD**

Director Emeritus  
Chadwick Center for Children and  
Families  
Children's Hospital - San Diego  
Adjunct Associate Professor  
Graduate School of Public Health  
San Diego State University  
San Diego, California



**STM Learning, Inc.**

---

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Publishers: Glenn E. Whaley and Marianne V. Whaley  
Graphic Design Director: Glenn E. Whaley  
Managing Editor: Paul K. Goode, III  
Print/Production Coordinator: Jennifer M. Jones and G.W. Graphics  
Cover Design: Jennifer M. Jones and G.W. Graphics  
Color Prepress Specialist: Kevin Tucker  
Acquisitions Editor: Glenn E. Whaley  
Developmental Editor: Paul K. Goode, III  
Copy Editor: Paul K. Goode, III  
Proofreader: Paul K. Goode, III  
Editorial/Publishing Consultant: Kerry Blasingim

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Printed in the United States of America.

Publisher:  
STM Learning, Inc.  
Saint Louis, Missouri  
Phone: (314) 434-2424 Fax: (314) 434-2425  
<http://www.stmlearning.com> [orders@stmlearning.com](mailto:orders@stmlearning.com)

The Library of Congress has cataloged the printed edition as follows:

Names: Alexander, Randell, 1950- , editor.  
Title: Head injuries / [edited by] Randell Alexander, Angelo P. Giardino, Debra Esernio-Jenssen, Jonathan D. Thackeray, Robert Parrish, David L. Chadwick.  
Other titles: Head injuries (Alexander) | Child abuse pocket atlas series ; v. 3.  
Description: Florissant, MO : STM Learning, Inc., [2016] | Series: Child abuse pocket atlas series ; volume 3 | Includes bibliographical references and index.  
Identifiers: LCCN 2016012448 (print) | LCCN 2016012983 (ebook) | ISBN 9781936590605 (pbk. : alk. paper) | ISBN 9781936590650 (ebook)  
Subjects: | MESH: Craniocerebral Trauma | Child Abuse | Infant | Child | Case Reports | Atlases | Handbooks  
Classification: LCC RD521 (print) | LCC RD521 (ebook) | NLM WL 17 | DDC 617.5/1044--dc23  
LC record available at <http://lcn.loc.gov/2016012448>

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## CONTRIBUTORS

**Randell Alexander, MD, PhD**

Professor of Pediatrics and Chief  
Division of Child Protection and Forensic  
Pediatrics  
Department of Pediatrics  
University of Florida  
Jacksonville, Florida

**Deniz Altinok, MD**

Associated Professor in Radiology  
Wayne State University  
Pediatric Radiologist, Pediatric Neuroradiologist  
Detroit Medical Center  
Children's Hospital of Michigan  
Detroit, Michigan

**Gail V. Benton, DDS**

Clinical Assistant Professor of Pediatric  
Dentistry  
LSU School of Dentistry  
Audrey Hepburn Children at Risk Evaluation  
(CARE) Center  
Children's Hospital  
New Orleans, Louisiana

**Scott A. Benton, MD, FAAP**

Director of Pediatric Forensic Medicine  
Clinical Associate Professor of Pediatrics  
LSU & Tulane Departments of Pediatrics  
Audrey Hepburn Children at Risk Evaluation  
(CARE) Center  
Children's Hospital  
New Orleans, Louisiana

**Bradford W. Betz, MD**

Advanced Radiology Services, P.C.  
Grand Rapids, Michigan  
Medical Director, Department of Radiology  
DeVos Children's Hospital  
Grand Rapids, Michigan  
Associate Clinical Professor of Radiology  
Michigan State University  
East Lansing, Michigan

**Gil Binenbaum, MD, MSCE**

Attending Surgeon  
The Children's Hospital of Philadelphia  
Philadelphia, Pennsylvania  
Assistant Professor of Ophthalmology  
Perelman School of Medicine at the University  
of Pennsylvania  
Philadelphia, Pennsylvania

**Marguerite M. Caré, MD**

Assistant Professor of Pediatrics Radiology  
Division of Neuroradiology  
Cincinnati Children's Hospital Medical Center  
Cincinnati, Ohio

**Brian J. Forbes, MD, PhD**

Associate Professor of Ophthalmology  
Hospital of the University of Pennsylvania  
The University of Pennsylvania School of Medi-  
cine, The Children's Hospital of Philadelphia  
Philadelphia, Pennsylvania

**Detective Bruce Foremny**

Glendale Police Department (retired)  
Criminal Investigator  
Arizona Department of Juvenile Corrections  
Bruce Foremny Consulting LLC  
Litchfield Park, Arizona

**Lori D. Frasier, MD, FAAP**

Professor of Pediatrics  
Chief, Division of Child Abuse  
Pediatrics  
Penn State Milton S. Hershey Children's  
Hospital  
Hershey, Pennsylvania

**Todd C. Grey, MD**

Chief Medical Examiner  
State of Utah  
Adjunct Associate Professor of Pathology  
University of Utah School of Medicine  
Salt Lake City, Utah

**Karen Kirhofer Hansen, MD**

Associate Professor of Pediatrics  
University of Utah  
Pediatrician, Safe and Healthy Families Team  
Primary Children's Medical Center  
Salt Lake City, Utah

**Gary L. Hedlund, DO**

Associate Professor of Radiology  
University of Utah School of Medicine  
Pediatric Neuroradiologist  
Chairman, Department of Medical Imaging  
Primary Children's Medical Center  
Salt Lake City, Utah

**Peter Kan, MD**

Resident, Neurosurgery  
Department of Neurosurgery  
University of Utah  
Salt Lake City, Utah

**John P. Kenney, DDS, MS, D-ABFO,  
FAAPD, FACD**

President, Owner  
Children's Dentistry in Park Ridge  
Park Ridge, Illinois  
Forensic Consultant  
US DOD, Joint POW-MIA Accounting  
Command, Central Identification Laboratory  
DOD Joint Base Pearl Harbor  
Hickham, Hawaii

**Lynn Douglas Mouden, DDS, MPH,  
FICD, FACD**

Chief Dental Officer  
Centers for Medicare & Medicare Services  
US Department of Health and Human Services  
Baltimore, Maryland

**Vincent J. Palusci, MD, MS**

Helppie Endowed Professor of Pediatrics  
Wayne State University School of Medicine  
Medical Director, Child Protection Center  
Children's Hospital of Michigan  
Detroit, Michigan

**Robert Parrish, JD**

Managing Attorney  
Second District Office of the  
Guardian ad Litem  
Layton, Utah

**Robert T. Paschall, MD**

Assistant Professor of Pediatrics  
Washington University School of Medicine  
Saint Louis, Missouri  
Medical Director, Child Protection Program  
Saint Louis Children's Hospital  
Saint Louis, Missouri

**Gregory A. Schmunk, MD, FACP, FASCP**

Forensic Pathologist  
Polk County Medical Examiner  
Des Moines, Iowa

**Andrew Sirotnak, MD, FAAP**

Professor of Pediatrics and Vice Chair for  
Faculty Affairs  
Department Head, Child Abuse and Neglect  
University of Colorado School of Medicine  
Director, Child Protection Team  
Children's Hospital Colorado  
Aurora, Colorado

**Wilbur L. Smith, MD, PhD**

Professor and Chair  
Department of Radiology  
Wayne State University  
Detroit, Michigan

**David A. Start, MD**

Forensic Pathologist  
Spectrum Health—Blodgett Campus  
Department of Pathology  
Medical Examiner  
Kent and Ottawa County  
Grand Rapids, Michigan

**Marion L. Walker, MD**

Professor of Neurological Surgery  
Chairman, Division of Pediatric Neurosurgery  
University of Utah  
Primary Children's Medical Center  
Salt Lake City, Utah

---

## PREFACE

As more communities work to develop effective methods for recognizing and treating victims of abusive head trauma, investigating cases, protecting victims from further harm, prosecuting offenders, and pursuing education and prevention efforts, there has been a growing interest in educating and training the professionals involved in all phases of response to this problem. The time has come to synthesize what we know, what questions remain, and what scientific studies still need to be done. It is time to share information in an organized manner among professionals working in the field in order to provide improved recognition, treatment, investigation, prosecution, education, and prevention of this deadly form of abuse.

This text is designed to serve as a reference for medical, investigative, legal, social service, and prevention professionals. All of these disciplines are affected by AHT in children and all have made notable progress in handling the results of child maltreatment in general. Prevention efforts have also been cultivated, focusing specifically on avoiding the development of patterns of child abuse within the family. The goal of educating all professionals is to help children and families with the corollary of improving society's concern and care for the most helpless of its citizens.

We have sought to offer a balanced approach to the problem of AHT while exploring current efforts and recommendations to address the concerns of professionals. It is hoped that this publication will become a reliable reference for professionals in the medical, investigative, legal, social service, and prevention areas.

**Randell Alexander, MD, PhD**

**Robert N. Parrish, JD**

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# CONTENTS IN BRIEF

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<b>CHAPTER 1: UNINTENTIONAL HEAD INJURIES . . . . .</b>	<b>1</b>
<b>CHAPTER 2: ABUSIVE HEAD TRAUMA . . . . .</b>	<b>11</b>
<b>CHAPTER 3: ASSOCIATED INJURIES. . . . .</b>	<b>81</b>
<b>CHAPTER 4: OPHTHALMOLOGY . . . . .</b>	<b>101</b>
<b>CHAPTER 5: ORAL INJURIES. . . . .</b>	<b>111</b>
<b>CHAPTER 6: MEDICAL MIMICS . . . . .</b>	<b>127</b>
<b>CHAPTER 7: NEURORADIOLOGY. . . . .</b>	<b>151</b>
<b>CHAPTER 8: NEUROSURGERY . . . . .</b>	<b>169</b>
<b>CHAPTER 9: OUTCOMES . . . . .</b>	<b>179</b>
<b>CHAPTER 10: PATHOLOGY . . . . .</b>	<b>195</b>
<b>CHAPTER 11: INVESTIGATION . . . . .</b>	<b>223</b>





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# CONTENTS IN DETAIL

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<b>CHAPTER 1: UNINTENTIONAL HEAD INJURIES</b> . . . . .	1
Motor Vehicles . . . . .	2
Passenger Fatality . . . . .	2
Traffic-Related Pedestrian Fatality . . . . .	3
Non-Traffic-Related Pedestrian Fatality . . . . .	4
Falls Onto Children . . . . .	6
By Caregiver . . . . .	6
By Horse . . . . .	7
By Television Set . . . . .	8
<b>CHAPTER 2: ABUSIVE HEAD TRAUMA</b> . . . . .	11
Head Injuries . . . . .	18
Rotational Injuries . . . . .	52
Subdural Hematoma . . . . .	52
Space-Occupying Subdural Hematoma . . . . .	55
Respiratory Distress . . . . .	57
Subdural and Retinal Hemorrhages . . . . .	57
Blunt Force Trauma . . . . .	59
Skull Fracture and Cerebellar Hematoma . . . . .	59
Brain Injury and Long Bone Fractures . . . . .	62
Bruises to Head and Chest . . . . .	64
Head and Abdominal Trauma . . . . .	66
Missed Abusive Head Trauma . . . . .	69
Multiple Fractures and Findings . . . . .	72
Undetermined Manner of Death . . . . .	72
Subdural and Retinal Hemorrhages . . . . .	74
Skull and Rib Fractures . . . . .	74
Bruises to Head . . . . .	78
Subdural Hematoma . . . . .	78
References . . . . .	80
<b>CHAPTER 3: ASSOCIATED INJURIES</b> . . . . .	81
Accidental Trauma . . . . .	89
Isolated Abrasions . . . . .	89
Patterned Injuries . . . . .	89
Slap Marks . . . . .	89
Intracranial Trauma . . . . .	90

Skull Fractures and Hematoma . . . . .	91
Bite Marks . . . . .	91
Marks From Looped Objects . . . . .	92
Burns . . . . .	93
Iron. . . . .	93
Hair Dryer . . . . .	93
Area of Injury . . . . .	94
Scalp . . . . .	94
Subgaleal Hematomas . . . . .	94
Ears, Eyes, and Periorbital Issues . . . . .	95
Hematoma Resulting From Fall . . . . .	95
Blunt Trauma to Eyes. . . . .	95
Blunt Impact Trauma. . . . .	96
Osteogenesis Imperfecta . . . . .	97
Mouth and Oral Cavity . . . . .	97
Torn Frenulum . . . . .	97
Condyloma Acuminata . . . . .	97
Neck . . . . .	98
Suction Ecchymoses Resulting From Sexual Assault . . . . .	98
Assault . . . . .	98
Ligature Marks . . . . .	99
References . . . . .	100

**CHAPTER 4: OPHTHALMOLOGY . . . . . 101**

Unresponsive Victim of SBS/AHT . . . . .	103
Seizures Caused by SBS/AHT . . . . .	105
Hematoma With SBS/AHT . . . . .	106
Retinal and Macular Hemorrhages . . . . .	107
Papilledema . . . . .	107
Retinal Hemorrhage. . . . .	108
Residual Findings . . . . .	109
Injuries as Result of AHT . . . . .	109

**CHAPTER 5: ORAL INJURIES . . . . . 111**

Avulsion . . . . .	116
Accidental Injury . . . . .	116
Multiple Inflicted Injuries . . . . .	116
Burns . . . . .	116
Electrical Burn . . . . .	116
Branding of Multiple Surfaces . . . . .	117
Bruises. . . . .	117
Pattern Injuries . . . . .	118
Bite Marks. . . . .	119
Animal Bite Marks. . . . .	119
Human Bite Marks . . . . .	120
Sexual Abuse . . . . .	125

Multiple Injuries . . . . .	125
Ecchymosis . . . . .	126
Neglect . . . . .	126
Caries . . . . .	126
<b>CHAPTER 6: MEDICAL MIMICS . . . . .</b>	<b>127</b>
Newborn Disorders and Birth Trauma . . . . .	130
Hemorrhagic Disease of the Newborn . . . . .	130
Central Nervous System Infections . . . . .	131
Herpes Simplex Virus With Meningoencephalitis . . . . .	131
Bacterial Meningitis . . . . .	132
Central Nervous System Malignancies . . . . .	132
Lymphoblastic Leukemia . . . . .	132
Neuroblastoma. . . . .	133
Central Nervous System Malformations. . . . .	134
Arachnoid Cyst . . . . .	134
Hereditary Hemorrhagic Telangiectasia . . . . .	134
Connective Tissue Disorders . . . . .	137
Osteogenesis Imperfecta . . . . .	137
Ehlers-Danlos Syndrome Type II. . . . .	138
Inherited Bleeding Disorders . . . . .	139
Hemophilia A . . . . .	139
Hemophilia B . . . . .	139
Metabolic Disturbances . . . . .	140
Hypernatremic Dehydration . . . . .	140
Metabolic Diseases . . . . .	141
Glutaric Aciduria Type I. . . . .	141
Hemophagocytic Lymphohistiocytosis. . . . .	144
Nutritional Deficiency . . . . .	146
Rickets Appearing as Abusive Head Trauma . . . . .	146
References . . . . .	148
<b>CHAPTER 7: NEURORADIOLOGY. . . . .</b>	<b>151</b>
Intracranial Hemorrhages . . . . .	152
Hyperacute Subdural Hematoma . . . . .	152
Coexistent Skeletal Injury . . . . .	152
Extra-Axial. . . . .	153
Subarachnoid . . . . .	154
Epidural Hematoma . . . . .	155
Edema . . . . .	155
Diastatic Bone Structure . . . . .	155
Hypoxic-Ischemic Injury. . . . .	156
Subdural Hemorrhage . . . . .	156
Venous Thrombosis . . . . .	158
Extracranial Injuries. . . . .	159
Skull and Chest Fractures . . . . .	159

Injuries Not Involving the Head . . . . .	161
Rib Fractures . . . . .	161
Callus Formation . . . . .	161
Abdominal Injury . . . . .	162
Bowel . . . . .	162
Distention . . . . .	163
Metaphyseal Fracture . . . . .	164
Humerus . . . . .	164
Differential Diagnoses . . . . .	165
Suspected Metabolic Disease . . . . .	165
Hemophagocytic Lymphohistiocytosis . . . . .	166
Traumatic Vaginal Delivery . . . . .	167
<b>CHAPTER 8: NEUROSURGERY . . . . .</b>	<b>169</b>
Skull Fracture . . . . .	170
Brain Laceration . . . . .	170
Epidural Hematoma . . . . .	171
Overlying Skull Fracture . . . . .	171
Depressed Skull Fracture . . . . .	171
Subdural Hematoma . . . . .	172
Raised Intracranial Pressure . . . . .	172
Swelling and Contusions . . . . .	173
Injuries of Different Ages . . . . .	174
Cerebral Hypoxia-Ischemia . . . . .	174
Subarachnoid Hemorrhage . . . . .	175
Tentorial Subdural Hematoma . . . . .	175
Encephalomalacia . . . . .	175
Left Occipital Area . . . . .	175
Hyperdense Cerebellum . . . . .	176
Strangulation . . . . .	176
Reversal Sign . . . . .	176
Coronal CT Scan . . . . .	176
Infarction . . . . .	176
Strangulation . . . . .	176
Left Hemisphere, Cerebellum, and Right Temporal Lobe . . . . .	177
Contusion . . . . .	177
Right Frontal Lobe . . . . .	177
References . . . . .	178
<b>CHAPTER 9: OUTCOMES . . . . .</b>	<b>179</b>
Physical Outcomes . . . . .	180
Contact Injury . . . . .	180
Subdural Hematomas With Enlarging Head Circumference . . . . .	181
Physical and Cognitive Outcomes . . . . .	182
Cognitive Delay . . . . .	182
Visual Outcomes . . . . .	184

Rotational Injuries . . . . .	186
Morbid and Visual Outcomes . . . . .	187
Rotational Injuries . . . . .	187
Morbid and Developmental Outcomes . . . . .	190
Delayed Death . . . . .	190
Morbid Outcome . . . . .	191
Rotational Injuries . . . . .	191
References . . . . .	192
<b>CHAPTER 10: PATHOLOGY . . . . .</b>	<b>195</b>
Unintentional Injuries . . . . .	199
Fall From a Chair . . . . .	199
Drowning . . . . .	200
Motor Vehicle Crash . . . . .	200
Conditions That Mimic Abusive Head Trauma . . . . .	202
Suspicious of Shaking . . . . .	202
Laryngotracheobronchitis (“Croup”) . . . . .	203
Tracheobronchitis . . . . .	204
Bronchopneumonia . . . . .	205
Vacuum Extraction . . . . .	205
In Utero Subdural Hemorrhage . . . . .	205
Abusive Head Trauma . . . . .	206
Impact Trauma . . . . .	208
Shaking Trauma . . . . .	210
Shaken Impact Trauma . . . . .	218
Undetermined Manner of Death . . . . .	219
Intact Bridging Veins . . . . .	219
Craniocerebral Trauma . . . . .	219
Cerebral Edema . . . . .	220
Sudden Infant Death Syndrome . . . . .	221
<b>CHAPTER 11: INVESTIGATION . . . . .</b>	<b>223</b>
Background Information . . . . .	223
Clinical Presentation and Investigation . . . . .	226
Conclusion . . . . .	228
Clinical Presentation and Investigation . . . . .	229



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# UNINTENTIONAL HEAD INJURIES

Todd C. Grey, MD

---

The patterns of injury seen in accidental lethal head trauma are striking. The typical findings in a case of immediately or rapidly fatal accidental head injury, in which the child is pronounced dead at the scene or within a short time of arriving at the hospital, have an array of cutaneous, skeletal, and intracranial findings. While the extent of injury in the various structural layers of the head may at times be discrepant, there is always something in the pattern and extent of injury that is indicative of a significant amount of force being delivered to the head. What is even more striking is the clear correlation between the severity of injury and the mechanism of injury provided in the history. The injuries present in the patient are reasonable given the explanation provided for these injuries, which is in sharp contrast to the often trivial mechanisms offered as an explanation for a child's injuries in cases of abusive trauma. The cases in this chapter are graphic in their presentation but serve to emphasize the dramatic and distinct nature of the injuries. It is also notable that tremendous forces are involved when accidental fatal head trauma occurs in the case of motor vehicle collisions, a horse falling on a child, or an adult falling down stairs and landing on a child.



# ABUSIVE HEAD TRAUMA

Wilbur Smith, MD, PhD  
Deniz Altinok, MD  
Lori D. Frasier, MD  
Robert N. Parrish, JD  
Robert T. Paschall, MD  
Vincent J. Palusci, MD  
Bradford W. Betz, MD  
David A. Start, MD

---

Abusive head injury (AHT) has several synonyms including non-accidental head trauma or inflicted traumatic brain injury. Terms such as shaken baby syndrome and shake impact syndrome are often used as well, but they are not as inclusive as the terms aforementioned. The American Academy of Pediatrics noted in their policy statement that the intention of leaning away from terms such as shaken baby syndrome, “is not to detract from shaking as a mechanism of abusive head trauma but to broaden the terminology to account for the multitude of primary and secondary injuries that result from abusive head trauma.”<sup>1,2</sup> Regardless of the label, abusive head trauma frequently results in serious and permanent brain damage. The forces to which the infants’ brains are subjected tend to be severe. The prevalence of abusive head trauma is highest in children younger than 2 years of age, probably because the size of an older infant makes it difficult to create the extreme forces necessary to inflict such severe injury to the brain and its coverings. The incidence of abusive head trauma is estimated at approximately 14-30 per 100 000 children within the first year of life; the mean age of accidental injuries is 2.5 years whereas the abused are on average 0.7 years (8 months) old.<sup>3-5</sup> Abusive head trauma in infants is more common than all childhood cancers and type 1 diabetes.<sup>1</sup>

When evaluating abusive head trauma, it is best to consider each injury individually since it involves the internal layers of tissue as well as those surrounding the brain. While this is a logical approach to describing the injuries, it is important to recognize that multiple anatomical areas of injury are the rule, not the exception.

External to the brain, the scalp is often the site of a subgaleal hemorrhage after impact (**Figure 2-1**). Hemorrhage within the scalp creates the proverbial “egg” on the head. The subgaleal space is a large potential space; therefore, the blood often flows into a dependent region. This explains why the palpable or visible bump is not always in the region of the trauma. Unless the child has a bleeding disorder or some other abnormality, the presence of a subgaleal hematoma always suggests that there was an impact injury. There is another, less common variant of scalp injury: the cephalhematoma, which is a hemorrhage in the subperiosteal space, external to the bone but localized anatomically to the bone since it is confined by the periosteal layer of each bone of the skull. Cephalhematomas are rarely seen in child abuse and always remain local to the area of hemorrhage or impact.

A patient presenting with skull fracture (**Figure 2-2**), shows evidence of significant traumatic injury; however, injuries following uncomplicated normal vaginal delivery have (rarely) included skull fractures. A tender soft tissue swelling associated with such an injury points to a recent impact, but often injuries such as cephalohematoma will take time to become evident and resolve over the course of several weeks.<sup>6</sup>



**Figure 2-1.** Multifocal contusions involving the left frontal and parietal lobe with evidence of subarachnoid hemorrhage and subgaleal hematoma (white arrow).

**Figure 2-2.** Lateral view of the skull demonstrates linear diastatic parietal fracture.



As a whole, young patients who present to a health care provider with traumatic injuries often have common events in their history, which often include a recount of a “short fall” (>90cm), falling off a couch, etc. Height from fall, however, is often an inaccurate estimate on the part of parents and the most reliable estimate of short falls are in-hospital falls.<sup>7</sup> Analysis of short falls by Helfer et al, compared the results of short fall events in the hospital versus at home. In the home group (n=176) there were 2 skull fractures whereas in the hospital (n=57) there was only 1 such fracture. None of these fractures was diastatic or defined as greater than 1 mm in width (**Figure 2-2**). No children suffered neurological complications as a result of this head injury. The best current estimate of mortality for short falls affecting infants and children is near zero.<sup>7,8</sup>

Certain fractures are found to occur significantly more often in AHT, these include: multiple or complex fractures, depressed or wide diastatic fractures, those with involvement of more than one bone and those involving other than the parietal bone.<sup>6,9</sup> Skull fractures typically associated with abusive head trauma are similar to those due to high velocity impact. These fractures are long (longer than 5 cm), stellate (many limbs from one point of impact), or diastatic (the edges of the fracture are widely spread). It is possible to have skull fracture from a short fall and in rare cases, some overlap of features between high impact and short fall injuries may occur; however, the presence of long, stellate, or diastatic fractures should lead to enhanced suspicion if they are ascribed to a short fall.

The epidural hematoma is an unusual injury in child abuse (**Figure 2-3**). This type of hematoma occurs because of bleeding, usually arterial, into the epidural space between the inner table of the skull and the dura mater. This lesion is classically associated with a lucid interval and skull fracture. The theory of the lucid interval is that the initial impact causes the fracture and concussion, rendering the victim unconscious. The subsequent bleeding from ruptured branches of the middle meningeal artery then causes the epidural hematoma, which grows rapidly, owing to arterial (as opposed to venous) bleeding, and causes further deterioration of mental status after the patient stabilizes from the concussion.

The subdural hematoma (SDH) is a hallmark of abusive head

**Figure 2-3.**  
Axial CT of the head demonstrates right frontal epidural hematoma with mass effect and midline shift to the left side.

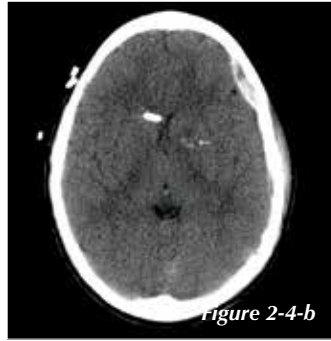
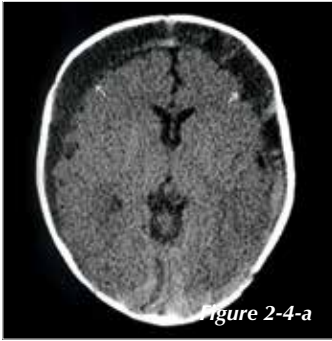


**Figure 2-3**

injury and is the most frequently diagnosed intracranial injury in child abuse. More specifically, subdural supratentorial convexity and interhemispheric SDH are seen significantly more often in nonaccidental head injury. SDH in accidental injury are uncommon, but when it does occur it appears to be focal and adjacent to the site of impact.<sup>10</sup> Bleeding in the subdural space occurs because of a rupture of the bridging veins that drain blood from the surface of the brain to the dural venous sinuses. The principal route of drainage of surface veins is to the sagittal sinus. As a result, subdural hematomas due to child abuse most often occur over the convexities of the parietal, frontal, and occipital lobes (**Figures 2-4-a and b**). Frequently, subdural hematomas can be identified as new or old depending upon the characteristics of the blood degradation products on a computed tomographic (CT) scan or magnetic resonance imaging (MRI) scan (**Figure 2-5**). The relative insensitivity of CT scans for definition of anatomical spaces has led to some confusion in older literature, particularly regarding benign subdural hygromas, most of which are merely enlarged or prominent subarachnoid spaces, and are of no clinical or pathological significance.

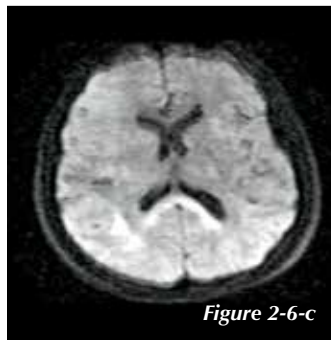
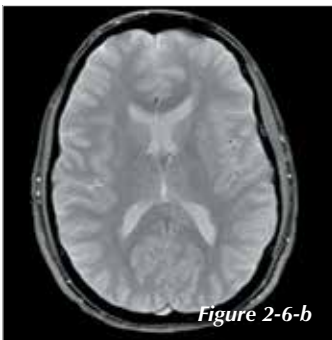
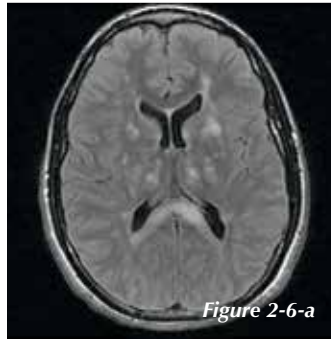
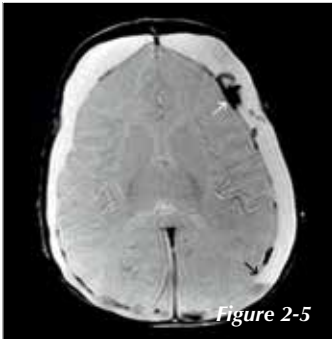
Bleeding into the subarachnoid space occurs when the vessels are ruptured between the arachnoid membrane and the pia mater. The subarachnoid space readily communicates with the cerebrospinal fluid (CSF) cisterns and the spinal subarachnoid space. Blood obtained on spinal taps in abused children can be used to indicate subarachnoid hemorrhages (SAH). Subarachnoid hemorrhages can be identified on imaging by bleeding into the cerebrospinal fluid cisterns surrounding the brain or by a serpiginous, gyriform pattern of hemorrhage. Subarachnoid blood also accumulates along the cerebral tentorium or within the thecal sack over the spine. Subarachnoid hemorrhages are very important clinically because there is almost universal agreement among experts that they have distinct symptoms. Adults with subarachnoid hemorrhages, most commonly victims of rupture of an intracranial aneurysm, describe a typical “thunderclap” headache as the worst of their lives. In infants, the symptoms manifest as extreme irritability, discomfort, and pain. An infant with a subarachnoid hemorrhage is highly unlikely to act normally.

Parenchymal injuries to the brain include both bland and hemorrhagic contusions. There are injuries to the surface of the brain from an impact mechanism similar to a contusion elevation in the body. There is a tendency for the brain to suffer contrecoup injuries, an injury opposite the side of impact. The contrecoup injury is usually larger than the direct impact injury. The other characteristic hemorrhagic injury to the brain is the *diffuse axonal injury* (DAI), an injury to the axons of the neurons that has a preponderance at areas of differing physical density in the brain, such as the watershed areas along the cortex or the deep gray and pericollousal white matter areas. Parenchymal injuries of the brain tend to be rapidly and severely symptomatic (**Figure 2-6-a to c**).



**Figure 2-4-a.** Axial CT of the head shows acute and chronic bilateral subdural hematoma.

**Figure 2-4-b.** Small left frontal acute subdural hematoma (black arrow) with hemorrhagic shearing injury to left internal capsule (white arrow).



**Figure 2-5.** GRE T2W image shows large bilateral chronic subdural hematoma with new acute subdural hemorrhage on the left (black arrow) with blood sediment level.

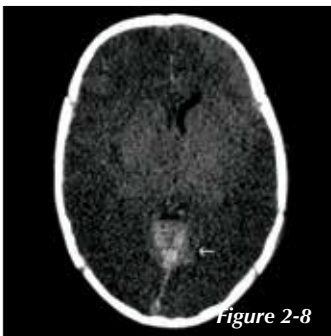
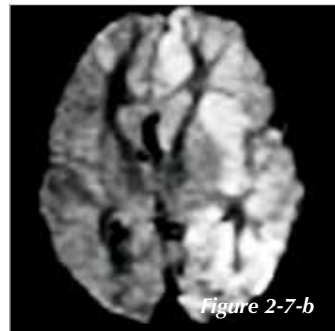
**Figure 2-6-a.** Axial flair T2W image shows multiple foci of shearing injury.

**Figure 2-6-b.** Axial GRE T2W images obtained immediately after trauma demonstrates no obvious evidence of hemorrhage.

**Figure 2-6-c.** Axial DWI image of the brain shows diffusion restriction along the corpus callosum (black arrow) (shearing injury) and right posterior parietal subcortical white matter (white arrow) (contusion).

The final serious injury of the brain ascribable to child abuse is hypoxic ischemic injury. This injury occurs due to a complex interaction of events that leads to either a lack of perfusion of brain tissue or a lack of sufficient oxygenation of the blood perfusing the brain tissue (**Figure 2-7-a and b**). As the brain tissue begins to die, a complex event called a neuronal cascade begins, further increasing intracranial pressure and compromising both blood flow and oxygen delivery. The visible result is cerebral edema, which, in its extreme, results in a pattern of injury known as the “bad black brain” or “reversal sign” (**Figure 2-8**). In this imaging picture the structures of the brain are obscured and the ventricles are often compressed due to the increased intracranial pressure. This results in an extremely poor prognosis.

Type of injury, age, and presentation of the patient help to determine the best mode of imaging to perform. Children with skull fractures, clinical abnormalities, and symptoms of intracranial injury should be evaluated with an immediate noncontrast CT scan of the head. If this CT does not indicate a lesion requiring immediate neurosurgical intervention, and the clinical presentation requires further analysis thus an MRI scan of the head should be performed. This MRI series should include T1-weighted and T2-weighted sequences with inversion recovery and gradient echo sequences (**Figure 2-9**). In addition, diffusion-weighted sequences (**Figure 2-10-a**) help to elucidate the presence of acute cerebral injury. Additional MR



**Figure 2-7-a.** Axial CT of head shows small left frontal and interhemispheric acute subdural hematoma with mass effect.

**Figure 2-7-b.** Diffusion-weighted image demonstrates extensive diffusion restriction secondary to likely combination of shearing injury and hemispheric infarct of left frontal temporal parietal lobes.

**Figure 2-8.** Diffuse low attenuation involving the bilateral frontal temporal parietal gray and white matter secondary to nonaccidental trauma (reversal sign).

spectroscopy (**Figure 2-10-b**), MRA of the circle of Willis, and MRV of the dural venous sinuses will be helpful to include in the protocol and should be strongly considered. Diffusion tensor imaging is a new and promising application of MRI, which is a form of DWI and help better evaluation of white matter tracts on the bases of intrinsic directionality (anisotropy) of water diffusion in brain. Perfusion CT (**Figure 2-11**) and MRI is also important potential application of advanced neuroimaging in AHT, which allow us to understand underlying vascular injury secondary to AHT.

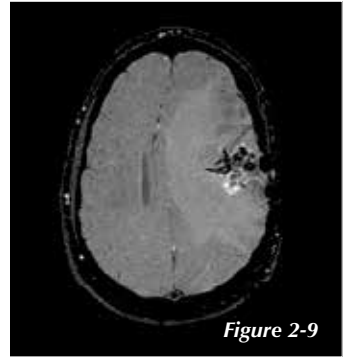


Figure 2-9

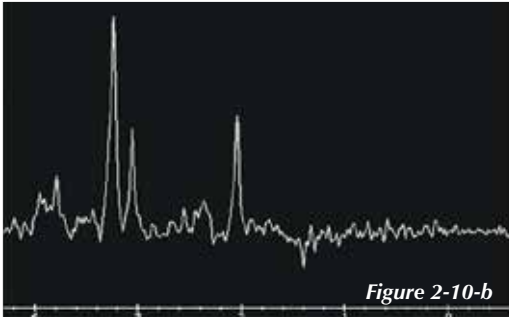


Figure 2-10-b

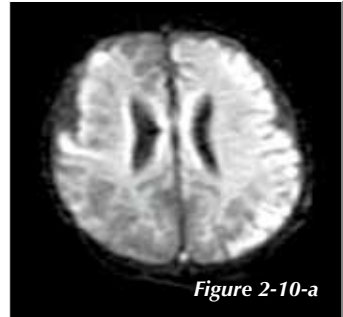


Figure 2-10-a

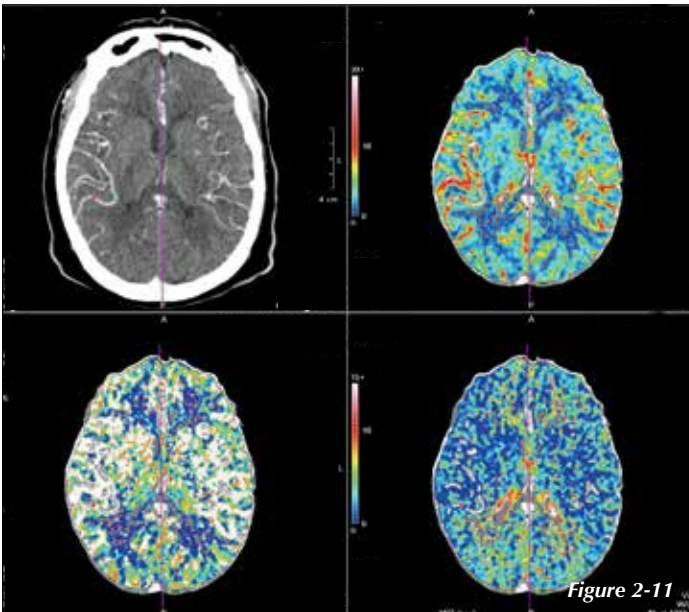


Figure 2-11

**Figure 2-11.** CT perfusion image after single I.V. injection of contrast with volumetric scanner shows cerebral blood volume, cerebral blood flow (ml/100g/min) and mean transit time.

**Figure 2-9.** Susceptibility-weighted image shows evidence of blood.

**Figure 2-10-a.** DWI (diffusion-weighted Image) shows citotoxic edema (white) within the left cerebral hemisphere.

**Figure 2-10-b.** MR Spectroscopy obtained from left cerebral hemisphere shows evidence of lactate (arrow) in a patient with non-accidental trauma; this indicates poor prognosis.

# INDEX

---

## A

abdominal injury, 66–68  
    bowel, 162  
    distention, 163  
    metaphyseal fracture, 164  
abuse, child. *See* child abuse  
abuse, sexual. *See* sexual abuse  
abusive caregivers, 81  
abusive head trauma (AHT),  
    11–17, 71, 127–129,  
    151, 206–207  
    advanced neuroimaging in, 17  
    blunt force trauma. *See* blunt  
    force trauma  
    bronchopneumonia, 205  
    diagnosis of, 127  
    disorders/conditions, 127–129,  
    202–205  
    evaluation of, 11  
    impact trauma, 208–209  
    incidence of, 11  
    injuries as result of, 109–110  
    in utero subdural hemorrhage,  
    205  
    key indicators of, 197  
    laryngotracheobronchitis, 203  
    multiple fractures and findings,  
    72–79  
    outcomes of, 179–192  
    rotational injuries. *See* rotational  
    injuries  
    SDH, 13–14  
    shaking trauma, 210–218  
    subdural hematomas in, 179  
    suspicions of shaking, 202  
    tracheobronchitis, 204  
accidental injury, 116  
acute epidural hematoma, 41, 171

acute hemorrhage, 57  
AHT. *See* abusive head trauma  
(AHT)  
animal bite marks, 119–120  
arachnoid cyst, 134  
assault, 62, 64, 98, 195  
    sexual, 60  
associated injuries  
    accidental trauma, 89  
    area of injury, 94–99  
    bite marks, 91  
    patterned injuries, 89–93  
avulsion, 111, 116

## B

bacterial meningitis, 127, 132  
bad black brain, 16  
basal ganglia, 47, 158  
bilateral periorbital ecchymosis, 85  
bite marks, 83, 91, 112–115  
    animal, 119–120  
    human, 120–124  
    impression of, 113  
bleeding in subarachnoid space, 14  
blood degradation, 14  
blunt force trauma  
    brain injury and longbone  
    fractures, 62–64  
    bruises to head and chest, 64–65  
    to eyes, 95–96  
    head and abdominal trauma,  
    66–68  
    missed abusive head trauma,  
    69–71  
    skull fracture and cerebellar  
    hematoma, 59–61  
blunt impact trauma, 96  
bowel, abdominal injury, 162



brain injury, 26–28, 46, 169, 174  
  ischemic and metabolic, 179  
  and longbone fractures, 62–64  
brain laceration, 170  
bronchopneumonia, 205  
bruises, 117–118  
burns, 116–117  
  branding of multiple surfaces,  
    117  
  electrical burn, 116  
  by hair dryer, 93  
  by iron, 93

## C

callus formation, 161  
cardiopulmonary resuscitation  
  (CPR), 210  
caries, 126  
central nervous system (CNS)  
  infections, 131–132  
  injuries, 169  
  malformations, 128, 134,  
    135–136  
  malignancy, 128, 132, 133  
cephalhematomas, 12, 27, 51  
cerebellar hematoma, 59–61  
cerebral convexities, 25  
cerebral edema, 16, 50, 220  
cerebral hypoxia-ischemia, 174  
cerebrospinal fluid (CSF) cisterns, 14  
chest fractures, 159–160  
child abuse, 12, 151  
  epidural hematoma in, 13  
  hypoxic ischemic injury in, 16  
  subdural hematomas due to, 14  
child protective services (CPS),  
  69, 145  
clinical outcomes, 179  
CNS. *See* central nervous system  
  (CNS)  
coexistent skeletal injury, 152  
cognitive delay, 182–183  
condyloma acuminata, 97  
connective tissue disorders, 128  
  Ehlers-Danlos syndrome type II,  
    138  
  osteogenesis imperfecta, 137  
contact injury, 180  
contrecoup contusions, 195

contrecoup injury, 14  
contusion, 177  
  scalp, 8  
  subgaleal, 8  
corpus callosum, 15, 48, 69  
cortical laminar necrosis, 45  
CPR. *See* cardiopulmonary  
  resuscitation (CPR)  
CPS. *See* child protective services  
  (CPS)  
craniocerebral trauma, 219  
CSF cisterns. *See* cerebrospinal  
  fluid (CSF) cisterns

## D

DAI. *See* diffuse axonal injury (DAI)  
delayed death, 190  
developmental outcomes, delayed  
  death, 190  
diastatic bone fracture, 155  
diastatic fracture, 32  
diffuse axonal injury (DAI), 14, 198  
diffuse hyperintensity, 45  
distention, abdominal injury, 163  
drowning, 200

## E

ecchymosis, 81, 83–85, 126, 146  
edema, 155  
Ehlers-Danlos syndrome type II, 138  
electrical burn, 116  
emergency medical services  
  (EMS), 55  
EMS. *See* emergency medical  
  services (EMS)  
encephalomalacia, 55, 57, 62, 175  
epidural hematoma, 6, 41, 155, 171  
  causes of, 13  
  in child abuse, 13  
epidural hemorrhage, 31, 34, 51  
extensive subgaleal contusion, 2  
extra-axial, intracranial  
  hemorrhages, 153  
extracranial injuries, skull and chest  
  fractures, 159–160  
eyes  
  blunt trauma to, 95–96  
  lateral view of, 104

**F**

- falls, children
  - by caregiver, 6
  - from chair, 199
  - by horse, 7
  - by television set, 8–9
- FLAIR sequences. *See* fluid attenuating inversion recovery (FLAIR) sequences
- fluid attenuating inversion recovery (FLAIR) sequences, 74–75
- fontanelle, 40
- fracture, 13
  - chest, 159–160
  - diastatic, 32
  - diastatic bone, 155
  - long bone, 62–64
  - metaphyseal, 164
  - rib, 161
  - skeletal, 94
  - skull. *See* skull fracture
- frenulum labii superioris, 20
- frontal temporal parietal lobes, 16

**G**

- glutaric aciduria type I, 141–143

**H**

- head injuries, 18–51, 66–68
- head, structural layers of, 1
- hematoma, 91
- hemiparesis, 184
- hemispheric cerebral edema, 184
- hemophagocytic lymphohistiocytosis (HLH), 144–145, 166
- hemorrhage, 106
  - acute, 57
  - epidural, 31, 34, 51
  - intracranial. *See* intracranial hemorrhages
  - retinal, 57–58
  - subdural, 57–58, 156–157
- hemorrhagic diseases of newborn, 127
- hemosiderin, 24
- hereditary hemorrhagic telangiectasia (HHT), 135–136
- HHT. *See* hereditary hemorrhagic telangiectasia (HHT)

- HLH. *See* hemophagocytic lymphohistiocytosis (HLH)
- homonymous hemianopia, 184
- human bite marks, 120–124
- hyperacute subdural hematoma, 152
- hyperdense cerebellum, 176
- hyperdense (acute) hemorrhagic contusion, 28
- hypernatremic dehydration, 140
- hypoxic ischemic injury, 16
  - subdural hemorrhage, 156–157
  - venous thrombosis, 158

**I**

- impact trauma, 208–209
- incised wound, 83
- infarction, 176–177
- inherited bleeding disorders, 129
  - hemophilia A, 139
  - hemophilia B, 139
- injuries
  - abdominal. *See* abdominal injury
  - contrecoup, 14
  - diffuse distribution of, 111
  - extracranial, 159–160
  - infliction of, 195
  - lip, 87
  - parenchymal, 14
  - patterns of, 1, 84
  - rib fractures callus formation, 161
  - unintentional. *See* unintentional injuries
- intact bridging veins, 219
- intracranial hemorrhages
  - coexistent skeletal injury, 152
  - diastatic bone fracture, 155
  - edema, 155
  - epidural hematoma, 155
  - extra-axial, 153
  - hypoxic-ischemic injury, 156–157
  - subarachnoid, 154
- intracranial injury, 16
- intracranial pressure, 62, 172
- intracranial trauma, 90
- intraocular inflammation, 101
- intraoral condyloma, 87
- intraretinal hemorrhages, 105
- in utero subdural hemorrhage, 205
- investigation
  - background information, 223–225
  - clinical presentation and, 226–234
  - isolated abrasions, 89

## L

laryngotracheobronchitis, 203  
ligature marks, 99  
longbone fractures, brain injury  
and, 62–64  
lucid interval theory, 13  
lymphoblastic leukemia, 132

## M

metabolic diseases, 129, 165  
glutaric aciduria type I, 141–143  
metabolic disturbances, 129  
hyponatremic dehydration, 140  
metaphyseal fracture, 164  
morbid outcomes, rotational  
injuries, 191–192  
motor vehicles  
non-traffic-related pedestrian  
fatality, 4, 5  
passenger fatality, 2  
traffic-related pedestrian fatality, 3  
multiple inflicted injuries, 116

## N

neck, 98  
neuroblastoma, 133  
neuroradiology, intracranial  
hemorrhages, 152  
neurosurgery  
contusion, 177  
encephalomalacia, 175  
epidural hematoma, 171  
hyperdense cerebellum, 176  
infarction, 176–177  
reversal sign, 176  
skull fracture, 170  
subarachnoid hemorrhage, 175  
subdural hematoma, 172–174  
newborn  
disorders and birth trauma, 130  
hemorrhagic diseases of, 127  
non-traffic-related pedestrian  
fatality, 5  
nutritional deficiency, rickets  
appearing as abusive  
head trauma, 146–147

## O

ocular injuries, pattern of, 102

## ophthalmology

injuries as result of AHT, 109–110  
macular hemorrhages, 107  
papilledema, 107  
residual findings, 109  
retinal hemorrhages, 107, 108  
SBS/AHT. *See* syndrome/abusive  
head trauma (SBS/AHT)  
optic nerve hemorrhages, 106  
oral injuries, 111–115  
avulsion, 116  
bite marks. *See* bite marks  
burns. *See* burns  
multiple inflicted, 116  
neglect, caries, 126  
pattern injuries, 118  
sexual abuse, 125–126  
orbital craniectomy, 144  
Osler-Weber-Rendu syndrome, 136  
osteogenesis imperfecta, 97

## P

papilledema, 107  
parenchymal injuries, 14  
pathology, 195–198  
patterned injuries, 92–93, 118  
pediatric intensive care unit  
(PICU), 57  
physical abuse, 25  
physical outcomes  
cognitive delay, 182–183  
contact injury, 180  
subdural hematomas with  
enlarging head  
circumference, 181  
PICU. *See* pediatric intensive care  
unit (PICU)  
preretinal hemorrhage, 105

## R

residual ataxia, 59  
respiratory distress, 57–58  
retinal hemorrhages, 20, 22, 42, 52,  
56, 57–58, 71, 74–77,  
101–102, 106–108, 186  
retinal schisis cavity, 22  
reversal sign, 169, 176  
rib fracture, 77, 161  
callus formation, 161

- rotational injuries  
 morbid outcomes, 191–192  
 respiratory distress, 57–58  
 space-occupying subdural  
 hematoma, 55–56  
 subdural hematoma, 52–54
- S**
- SAH. *See* subarachnoid  
 hemorrhages (SAH)  
 SBS. *See* shaken baby syndrome (SBS)  
 SBS/AHT. *See* syndrome/abusive  
 head trauma (SBS/AHT)
- scalp, 8, 94  
 contusions, 8
- scanning electron microscopy  
 (SEM), 113
- scattered dot hemorrhages, 186
- scleral depression, 109
- SDH. *See* subdural hematoma (SDH)
- SEM. *See* scanning electron  
 microscopy (SEM)
- sexual abuse  
 ecchymosis, 126  
 multiple injuries, 125
- sexual assault, suction ecchymoses  
 resulting from, 60, 98
- shake impact syndrome, 11
- shaken baby syndrome (SBS), 11,  
 22, 101, 198
- shaking trauma, 210–218
- SIDS. *See* sudden infant death  
 syndrome (SIDS)
- skeletal fractures, 94
- skull fracture, 12, 19, 35, 36, 59–61,  
 77, 91, 159–160, 170  
 depressed, 171  
 overlying, 171
- slap marks, 89–91
- space-occupying subdural  
 hematoma, 55–56
- spinal arteriovenous malformation,  
 136
- strangulation, 176
- subarachnoid hemorrhages (SAH),  
 2, 6, 14, 41, 43, 175
- subarachnoid space, bleeding in, 14
- subdural hematoma (SDH), 2, 13–15,  
 20, 23, 37–40, 43, 46,  
 52–56, 71, 78–79,  
 172–174  
 in AHT, 179  
 due to child abuse, 14  
 ecchymotic pattern of, 94  
 with enlarging head  
 circumference, 181
- subdural hemorrhages, 44, 57–58,  
 74–77
- subfalcine herniation, 184
- subgaleal contusion, 6, 8
- subgaleal hematoma, 28, 30
- subgaleal hemorrhage, 12, 18, 21,  
 26, 33, 36
- sudden infant death syndrome  
 (SIDS), 30, 221
- suspected metabolic disease, 165
- sylvian fissure, 41
- syndrome/abusive head trauma  
 (SBS/AHT), 101–102  
 hematoma with, 106  
 seizures caused by, 105  
 unresponsive victim of, 103–104
- T**
- tentorial subdural hematoma, 175
- “thunderclap” headache, 14
- torn frenulum, 97
- tracheobronchitis, 204
- traffic-related pedestrian fatality, 3
- transverse linear skull fracture, 9
- traumatic axonal injury, 198
- traumatic vaginal delivery, 167
- twin-to-twin transfusion  
 syndrome, 109
- U**
- unintentional injuries  
 drowning, 200  
 fall from chair, 199  
 motor vehicle crash, 200–201
- V**
- vacuum extraction, 205
- venous thrombosis, 158
- visual outcomes, 184–185  
 rotational injuries, 186–189