Diagnostic Imaging of Child Abuse

Third Edition

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Every effort has been made in preparing this book to provide accurate and up-to-date information which is in accord with accepted standards and practice at the time of publication. Although case histories are drawn from actual cases, every effort has been made to disguise the identities of the individuals involved. Nevertheless, the authors, editors, and publishers can make no warranties that the information contained herein is totally free from error, not least because clinical standards are constantly changing through research and regulation. The authors, editors, and publishers therefore disclaim all liability for direct or consequential damages resulting from the use of material contained in this book. Readers are strongly advised to pay careful attention to information provided by the manufacturer of any drugs or equipment that they plan to use.

Dedicated to Sandy Marks

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Editor's note on the Foreword to the third edition

In the 1987 first edition of *Diagnostic Imaging of Child Abuse*, the Foreword was written by John Kirkpatrick, Radiologist-in-Chief at Boston Children's Hospital and Professor of Radiology at Harvard Medical School. For me, he was the consummate pediatric radiologist in intellect, spirit, and conduct.

A special relationship has existed between North American and European pediatric radiology, and for this reason I asked the eminent French pediatric radiologist Professor Clément Fauré to write the Foreword to the second edition. This highly respected scholar and teacher had a long interest in the subject of child maltreatment and made many significant contributions to the field. I was privileged that this distinguished radiologist agreed to share his recollections and perspectives with us.

For the third edition, I sought a gifted and distinguished pediatric radiologist, who like his predecessors garnered both the respect and affections of the radiologic community. The choice was obvious – Diego Jaramillo. No radiologist has contributed more to our understanding of normal bone growth and development. Our interests intersect in a variety of planes, most notably in the response of the physis to traumatic injury. Diego shares many of the remarkable traits of his predecessors in this task and I am in his debt for taking the time from his busy schedule to contribute to this volume.

Paul. K. Kleinman MD

Foreword to the third edition

The only real voyage of discovery consists not in seeking new landscapes, but in having new eyes.

Marcel Proust, In Search of Lost Time

Throughout history, humanity has tended either to turn a blind eye on the abuse of children or to deny its existence. Since 1962, when Kempe and Silverman wrote their landmark article on the battered child, the scientific community has developed an increasing awareness of the issue. In recent years, our understanding of the imaging findings in battered children has increased substantially thanks to the two previous editions of the most authoritative book on the subject, *Diagnostic Imaging of Child Abuse*, by Dr. Paul Kleinman. The book is not just a review of findings in the literature; it is the summation of decades of outstanding research, deep thought and great teaching. In his journey to clarify the nature of the radiologic manifestations of child abuse, Dr. Kleinman now looks at the subject for a third time, with "new eyes." With this third edition, Dr. Kleinman has taken a large step to increase the depth and extent of what was included in the prior editions.

The new edition begins with a chapter about the structure, growth, and development of the skeleton by Professor Andrew Rosenberg, a premier pathologist in the United States. The first two chapters also deal with important concepts about the pathophysiology of skeletal injury, which are fundamental to the understanding of the imaging manifestations of skeletal trauma. The following chapters are divided regionally, dealing with specific findings that are related to the particular bone that is injured. Six chapters address the differential diagnosis of abusive skeletal injury. At a time where there is discussion about the etiology of many radiologic findings, particularly in the metaphysis, this book provides a brilliant guide to differentiating inflicted traumatic findings from many potential mimickers. The chapters on the differentiation from normal variants and other sources of trauma reflect the meticulous research performed by Dr. Kleinman. The chapter on disorders of calcium and phosphorus metabolism, co-authored by Dr. Ingrid Holm, an expert in metabolic bone disease, and Dr. Jeannette Perez-Rossello, who has studied the subject in great depth, is particularly important. There is a balanced and very well-supported discussion of how the radiologic manifestations of vitamin D deficiency and rickets differ from those of inflicted trauma, which should bring light to current "controversial" issues. Chapters on skeletal dysplasias and osteogenesis imperfecta are authored by some of the best experts in the field. The chapter on evidence-based radiology provides useful information about how to judge the literature and specifically analyze the soundness (or lack thereof) of the diagnosis of "temporary brittle bone disease."

The second part of the book addresses the manifestations of trauma to the head and spine. In multiple chapters by a group of prominent experts in the pediatric central nervous system and biomechanics, there are detailed descriptions of the imaging manifestations of trauma to the scalp and cranium, and to the extra-axial and parenchymal structures. Imaging strategies are discussed in a succinct, practical way, both for the head and the spine. The third part deals with visceral trauma and other important manifestations of abuse and neglect.

Section IV is very useful for radiologists, as it clarifies the psychosocial picture as well as the legal considerations and the obligations of the radiologists. The final part is dedicated to technical considerations in radiography, CT, and MRI; and serves as an invaluable reference for the practicing radiologist.

In the foreword to the second edition of this book, Professor Clement Fauré said, "Today, of course, the syndrome of the abused and neglected child is generally accepted." This remains true, but now more than ever it is crucial to expand our knowledge about mechanisms of injury and their manifestations. Those of us dealing with investigations of child abuse will do well by heeding the advice of Hippocrates: "Leave nothing to chance. Overlook nothing. Combine contradictory observations. Allow yourself enough time." We come closer to the truth by having more data, and by understanding it better. With this invaluable contribution of the third edition, Dr. Paul Kleinman and his co-authors have done society a great service: they have brought us closer to the truth in matters of child abuse.

Diego Jaramillo MD, MPH

Foreword to the second edition

"It is not given to everyone to be an orphan," deplores Poil de Carotte (Carrot Top), hero of a French novel most of us have read. This wretched boy, our French counterpart to the American Huckleberry Finn, was rejected, neglected, and battered by a mother who nonetheless loved her other children. We have also learned that in past centuries, children were inflicted with severe limb injuries to produce permanent deformities that would make them more efficient beggars. But society tended to consider these facts a good subject for novels and did not appreciate their true frequency. Forgotten were the works of Ambroise Tardieu, a French forensic physician, who in 1860 described the injuries he found in infants or children who died of inflicted trauma. Until the 1940s, these lesions often remained undiagnosed, and when a baby was found dead, the diagnosis of natural "sudden infant death" was commonly accepted.

Radiology has been used in infants and children since its origins, but images were generally of poor quality, often blurred by patient movement. It was with the introduction of newer x-ray tubes enabling shorter exposure times that pediatric radiology made a quantum leap. This improved radiographic technology led to the discovery in 1946 of what the pediatric radiologist John Caffey MD recognized as inflicted trauma.

In France, it took years for this concept of "unrecognized skeletal trauma" to be accepted. As a fellow in pediatric radiology at the Hôpital des Enfants Malades in Paris in the early 1950s, I shared the difficulties encountered by my chief, Jacques Lefebvre, in convincing our clinicians of its occurrence. Having as our bible Caffey's *Pediatric X-Ray Diagnosis*, as well as other American publications in pediatric radiology, we were perfectly aware of the "battered child syndrome." However, when we proposed this diagnosis to our colleagues, we were told we were wrong, mistaken by lesions due to scurvy, rickets, or hereditary (sic) syphilis. When a subdural hematoma was encountered without an associated skull fracture, trauma was unsuspected and the finding was often attributed to pachymeningitis, or to cerebral collapse secondary to hypovolemic shock. Associated bone lesions of extremities were considered "neurotrophic," related to central nervous system disorders. Even our great professor of pediatrics, Robert Debré, who later popularized this entity as Silverman's syndrome, was reluctant at first to accept our conclusions.

Why Silverman's syndrome and not Caffey's or Kempe's? I can relate the story. Robert Debré was a great friend of George M. Guest MD, Professor of Pediatrics in Cincinnati. Each time the two met, whether in Paris or Cincinnati, there was an opportunity for case presentations. Professor Debré also sent some of his best pupils each year for residency training in Guest's department. During one of Debré's visits to Cincinnati in the early 1950s, Fred N. Silverman MD, at that time the hospital's pediatric radiologist, presented a case of a "battered child." After the presentation, Debré told one of his residents who had attended the meeting that he was reluctant to accept Silverman's diagnosis.

One year later in France, at a weekly gathering of Professor Debré and his assistants and pupils, that same resident presented a compelling case of child abuse. After the presentation, Debré's comment was "But of course, this is a case of Silverman's syndrome!" remembering the syndrome Fred Silverman had presented in Cincinnati. Hearing this, the audience asked to learn more of Silverman's "discovery" from their respected teacher. Since that day, child abuse has been known as Silverman's syndrome in French medical literature. What we had tried to make evident for two or three years was now suddenly accepted. As the French saying goes, "*On ne prête qu'aux riches*" (Only to the rich is money lent).

Where are we in France at the end of the century? Today, of course, the syndrome of the abused and neglected child is generally accepted. It is taught to our medical students, and then more completely explored with our residents in pediatrics, radiology, and orthopedic surgery. But we still face some difficulties – when bone lesions are not evident at first glance and even more so when a diagnosis appears to some observers to contradict the "social status" of the caretakers.

By this long preamble I wish to highlight the general assistance that American pediatric radiology has brought its French and other European counterparts. And in this field of child abuse, Paul Kleinman's book *Diagnostic Imaging of Child Abuse* will continue to improve our fund of knowledge. A major contribution from the author is the radiologic and pathologic descriptions of the subtle lesion he calls the "classic

metaphyseal lesion" (CML). To familiarize our eyes to its appearance, the book offers a large display of CMLs in several locations and in different stages of evolution. In a similar manner, the chapter devoted to bony thoracic trauma injury is particularly informative, explaining the location of rib fractures according to their mechanisms of injury. This can help in questioning the caretaker about the origin of the rib fractures noted radiographically. This chapter, as well as the others, offers a rich iconography.

All the classic bone lesions of the abused child are thoroughly described and illustrated. Bone scintigraphy plays an important role in the early detection of skeletal lesions that are initially undetected radiographically and revealed only by the development of callus some weeks later. Initial scintigraphic data can prevent a defendant's attorney from convincing the jury that the fractures noted were sustained during the patient's hospitalization and were therefore due to underlying bone fragility; we have found ourselves involved in such a case. The book also provides an in-depth description of the diseases simulating abuse, particularly osteogenesis imperfecta. The great contribution of cross-sectional imaging modalities is evident when we evaluate craniocephalic or visceral lesions. Indeed, this book covers all that is known regarding the imaging of child abuse at the turn of the century.

The last chapters of the book are of paramount interest. They share information about child abuse and the law. Readers will appreciate, as I have, all the pertinent advice offered to the radiologist involved in civil or criminal cases as an expert witness. In such cases, the radiologist is called upon to use his or her expertise to determine whether lesions discovered by imaging can be attributed to a pre-existing disease or clearly point to inflicted trauma. The radiologist is not a judge, however; his or her main concern is the child's safety. In cases where the child survives, the best we can hope for is the child's placement in a safe and loving home. What punishment should be given to the abuser is beyond our mission. When the maltreatment results in death, determining whether it is due to the ignorance, irritability, stupidity, or perversity of the caretakers is the domain of social workers and the courts.

Clément J. Fauré

Foreword to the first edition

The concept of willful assault upon children by their caretakers is almost incomprehensible. Sometimes the physician needs reassurance that what is seen by physical examination of radiography can be believed. The chapters on the radiologic aspects of child abuse, 2 through 9, present in exquisite detail, with gross microscopic pathologic correlation, the many radiographic findings caused by willful injury to the skeleton and solid organs. The discussion of the incidence and patterns of injury reminds us of the underestimation of the incidence of skeletal injury and that the overall concept of child abuse has been expanded. The discussion of the skeletal survey and the scintigraphic examination of the skeleton shows that each has value – they are more complementary than supplementary.

The chapter dealing with the radiologic dating of fractures is important in the diagnosis of the abused child and also has everyday applicability. The pathophysiology of fracture healing is lucidly presented, as is its modification by repetitive trauma. The discussion of trauma to solid viscera and the central nervous system includes the use of computed tomography and mechanisms of injury; for example, mesenteric injury can result from blunt trauma or sudden deceleration. Involvement of the distal colon and rectum is most often caused by sexual abuse. Inflicted abuse seldom injures the spleen, the kidneys, or the lower urinary tract.

Dr. Kleinman has had a long and fruitful relationship with his colleagues in pathology. The material derived from autopsies is of interest to both disciplines. The value of postmortem radiographic study and of its correlation to the actual pathologic anatomy is persuasively presented. The differential diagnosis of inflicted skeletal injury is discussed in Chapter 11, followed by a chapter dealing with the legal aspects of child abuse.

In the chapter dealing with legal issues, it is stated that "sensitive management of family violence cases requires both medical and legal input." The radiologist has a role in determining the nature and degree of inflicted injury – information that often can be obtained in no other way. Of further interest to the radiologist is the discussion concerned with legal consent, medical records, reporting statutes, and procedures relative to service as a witness or expert witness. This is followed by a chapter on psychological considerations associated with abuse that includes the role of the radiologist in the initial detection of skeletal injury, its documentation, and the subsequent support provided for psychological or legal intervention.

The last chapter reviews technical considerations in dosimetry and includes a discussion of radiation risks entailed in the examination as well as methods for the reduction of exposure through appropriate selection of equipment, techniques, and the application of clinical judgment.

All in all, one can be enthusiastic about this work and thankful to Dr. Kleinman and his co-authors for presenting a cogent examination of the radiologic aspects of child abuse. The radiologist may be the first to note the possibility of an unfortunately common occurrence.

John A. Kirkpatrick, Jr. MD

Preface

The origins of my interest in the subject of child abuse rest in part with a bizarre incident that occurred during my pediatric residency. The episode began with a middle-of-the-night phone call from a woman who introduced herself as only "Clara." She spoke in an authoritative and well-polished manner and quickly drew me from my groggy state. Without any apology for waking me, she said my court testimony was required in a child custody trial set to take place the following day. The matter entailed a dispute between estranged parents who were each seeking to gain custody of their children, one of whom was allegedly abused. She indicated that the child had been seen in our acute care clinic by a physician who was not available to testify and so, as I had been assigned to the same clinic, my testimony was required to validate the clinical record of the visit. Because I did not recall seeing the patient and the examining physician was unfamiliar to me, I suggested she seek the assistance of the director of the clinic where the child was seen. She would not relent and explained in further detail the abusive assaults perpetrated by the mother and the vital importance of placing the children with the father. The conversation drew to a close only after I pressed her to explain her special interest in the case. I soon fell back to sleep, and the following morning I wondered if I had dreamt the entire incident.

Shortly after morning rounds, I was summoned to the office of the chief of staff and was escorted into a stately wood-paneled board room. Seated around a huge imposing table were the chief of staff, the director of the pediatric clinic, a lawyer, and a number of other unfamiliar individuals. They asked if I had been contacted by anyone requesting my testimony in a current child custody case. I shared with them what I could recall from the prior evening's telephone conversation and asked them to explain what was going on.

They provided me with the details of a custody case presently in court in which child abuse had been alleged and in which the validity of the medical record was being contested. The clinic director held a copy of a page taken from the child's medical record that detailed the physical, laboratory, and radiologic findings of one of the children in the custody dispute. The clinical findings read like a page out of Helfer and Kempe's textbook, *The Battered Child Syndrome*. The radiologic descriptions could have been taken directly from Caffey's *Pediatric X-Ray Diagnosis* and included terms such as "corner fractures" and "bucket handle" lesions. Although much of the terminology was appropriate, the organization of the note, the use of language, and the flow of the narrative clearly indicated that the note had not been written by a physician. The bogus nature of the record was confirmed when it was determined that none of the laboratory studies and x-rays referred to in the note had been performed.

As the various elements of the story were pieced together, it became clear that someone had doctored the medical record to support an allegation of maternal child abuse. This was achieved simply by securing hospital progress note forms, entering the false historical, physical, and laboratory data, and bolstering the account with suitable language from appropriate textbook discussions on the subject of child abuse. The papers were then forwarded to the record room and dutifully added to the patient's existing chart. The true identity of the midnight caller remains a question to this day. However, the father in this case was described to me as a major figure in high New York circles with many important friends, and I suspect the caller was one of them.

My scientific interests in the field of child abuse grew from simple intellectual curiosity. In my early years as a pediatric radiologist, I was struck by the unique character of certain skeletal injuries found in cases of abuse, particularly those encountered in young children. One infant had sustained a fatal head injury and also manifested the classic metaphyseal lesions described by one of the fathers of pediatric radiology, John Caffey. Caffey speculated regarding the basic morphologic alterations and their significance, but provided no pathologic basis for his views. When the infant in question died, I called my friend and colleague, Brian Blackbourne, then the Chief Medical Examiner of the Commonwealth of Massachusetts, and asked him if he would be willing to remove the injured bones so that we might examine them further. He resected the injured metaphyseal regions and we subsequently subjected the specimens to high-detail radiography performed by radiologic technologist Patricia Belanger, with the help of physicist Andrew Karellas. To assist in the analysis of the histologic material, we sought the aid of anatomist Sandy Marks, an expert in bone structure, growth, and repair. The

radiologic–histopathologic correlations that grew from these collaborative efforts over the ensuing years have increased our understanding of both the fundamental structural alterations of skeletal injury and the mechanical factors involved in their production. From these studies, our interest expanded to encompass the wide array of inflicted injuries involving the entire skeleton, the viscera, and the central nervous system.

The first edition of *Diagnostic Imaging of Child Abuse* was an attempt to collect these imaging observations in a single detailed resource that also addressed various related technical, social, and legal issues designed to assist in the imaging evaluation of suspected child abuse. In the second edition, published in 1998, additional imaging patterns of abuse and neglect were described. The evolution of cross-sectional imaging techniques offered new perspectives on familiar physical injuries and revealed additional unusual manifestations of child maltreatment. Perhaps the most stunning insights were gained by the application of magnetic resonance imaging to inflicted central nervous system injuries.

The broadening of the imaging spectrum and the advances in our understanding of inflicted injuries are reflected in the substantial growth of the core imaging chapters in this third edition. The incorporation of color imagery has enhanced Andrew Rosenberg's new discussion of the structure, growth, and development of bone as well as the pathologic basis of skeletal injury. Color photomicrographs are also liberally employed in the following chapters complementing the imaging features of various fracture patterns.

The first edition contained a single chapter devoted to differential diagnosis. The second expanded the array to four chapters. The differential diagnosis of abuse has gained even greater importance in the medical and legal environments, and the discussion has been expanded to six chapters, with special attention given to metabolic bone disease. Given the advances in our understanding and imaging complexities of abusive head and spinal trauma, an entire section of six chapters has been devoted to the clinical, biomechanical, and imaging features of these often devastating injuries.

The imaging of child abuse draws the members of the Radiology team into the larger societal realm in ways that can pose unique challenges for even the most seasoned professional. Alice Newton, a Child Abuse Pediatrician and Amy Tishelman, a child psychologist working with our Child Protection Team offer special information and advice to imaging professionals on dealing with possible victims of abuse/neglect and their families.

In the first of three legal chapters, Sandeep K. Narang MD, JD covers the principal legal requirements in the area of child abuse, with an emphasis on those materials relevant to radiologists. In a revised chapter Martha Coakley JD, former Chief of the Middlesex County Child Abuse Prosecution Unit and Attorney General of the Commonwealth of Massachusetts, familiarizes the reader with the US court system, providing guidance to physicians in negotiating their way through the potentially daunting task of testifying to the details of imaging findings in court. In this edition, I have again offered my personal perspective on the role that radiologists play in assisting investigative and other legal authorities in resolving cases of suspected abuse. Although there is no substitute for actual personal experience, it is hoped that some of my own observations and recommendations may give the reader an idea of how to deal with the judicial system.

Finally, Andrew Karellas PhD, Srinivasan Vedantham PhD, and Robert V. Mulkern PhD, provide technical discussions to aid in understanding modern diagnostic imaging examinations. Patricia Kleinman MPH, RT, then defines the role of quality assurance in diagnostic radiology and details the standard skeletal survey examination for suspected child abuse.

Because this volume is directed toward a radiologic audience, the reader can be assured that every effort has been made to provide a comprehensive and reliable discussion of the body of knowledge in this specialized field. It is hoped that colleagues in pediatrics, orthopedics, surgery, and other primary care disciplines caring for children may find this text useful in their practices. Professionals in the fields of child protection, law enforcement, and the legal community should also find this work an authoritative resource.

As the spectrum of imaging alterations expands, so do the complex issues entailed in the differentiation of child abuse from its imitators. Although a great deal has been learned since Caffey's original description, there is still much to be discovered, particularly with respect to the biomechanics of inflicted injury. Physicians and other professionals practicing in this field may seek to simplify matters, taking extreme positions that reflect either an overly zealous approach to diagnosing abuse or an unwillingness to consider abuse in all but the most flagrant cases. The most effective approach to diagnosis is one based on thoughtful and measured acquisition of data that are carefully analyzed in light of one's knowledge and experience. With the third edition of *Diagnostic Imaging of Child Abuse*, I have tried to provide a thorough review of the subject and, with the assistance of my esteemed co-authors, equip the reader with the tools to serve the best interests of children.

Paul K. Kleinman MD

Acknowledgments

Many fine individuals contributed to the first and second editions of *Diagnostic Imaging of Child Abuse*, and their efforts were acknowledged in those volumes. As with all scientific texts that focus on conditions that we do not fully understand, it is a work-in-progress. Each volume builds upon its predecessor, and thus any expression of gratitude for the current edition must also include those who helped bring the earlier editions to life. I have expressed those appreciations in the prior editions, but wish to again give special praise to my former assistant Kathy Delongchamp, who provided extraordinary clerical and administrative support for both the first and second editions.

These exercises take their toll on the family life and test the strength of the bonds that connect us. This project has taken over four years to complete and without the guidance, support, and profound understanding provided by my dear wife Patricia, this most daunting and frustrating of tasks might well have been abandoned long ago. The work not only invaded our home life: the dreaded laptop was with us on the beach, at all our getaways, and on all forms of transportation – including the sailboat. Her commitment to the care and well-being of children, ever-present in her own distinguished career, has fostered her support, informal and formal (see Chapter 30), for this text.

Another strong woman who has shepherded this work from inception to completion is my current administrative assistant, Susan Ivey. Her intellect and unrelenting personal commitment to the goals of this enterprise have ensured that all the material included in the 3rd edition will be of the highest quality. Putting together and maintaining the integrity of the raw materials of this text – reams of pages, thousands of images with countless annotations, innumerable references – as well as keeping track of all the materials submitted by our esteemed, but often idiosyncratic, contributors, is a truly remarkable accomplishment. She shares the credit for any good that comes from this monumental effort.

More than ever, I have depended on my contributors to guarantee that we have delved into all the facets and nuances of the problem – from the microscopic skeletal alterations through the diagnostic imaging of abuse and its mimics – and into the broader societal context with all the vagaries of current medico-legal proceedings. In an environment where we are all more connected to our work and personal time is in short supply, the contributors to this edition have poured their precious time and effort into this project, and to them I also say thank you.

Of necessity, the case material illustrated in this book has been drawn from many sources. As with the earlier editions, I have attempted to acknowledge these important contributors; again, special thanks to Mike Thomason for his many interesting and elegantly imaged cases. He is the consummate scholar / clinical radiologist.

In an era of bottom-line-driven publishing, a monograph on a subject of great public health importance, but with a focused audience, may not receive attention from publishing houses that is commensurate with the book's potential value to the community. I wish to thank Deborah Russell, formerly of Cambridge University Press, for believing in this text, and for fostering our collaboration. I also thank the Cambridge University Press in-house team and all their affiliates for their efforts throughout this long journey.

This book has been written during my tenure at Boston Children's Hospital and I thank all my radiology colleagues for their encouragement and support, especially during those chaotic deadline-driven periods. This precious work has been fostered at this remarkable institution and I cannot think of a more suitable place at which to write a text dedicated to the health and well-being of all children.

Paul K. Kleinman MD

List of acronyms

Acronym	Description
1,25D2	1,25-dihydroxyvitamin D, active form of vitamin D
^{18}F-NaF PET	Fluorine 18-labeled sodium fluoride PET
25(OH)D-1-alpha-hydroxylase	25-Hydroxyvitamin D-1-alpha-hydroxylase
25D	25-Hydroxyvitamin D
2D	Two dimensional
2D-FT	2D Fourier transform
3D	Three dimensional
3D-FT	3D Fourier transform
^{99m}Tc MDP	Technetium-99m methylene diphosphonate
AAP	American Academy of Pediatrics
AAPM	American Association of Physicists in Medicine
AccT	Accidental head trauma
ACR	American College of Radiology
ACTH	Adrenocorticotropic hormone
ADC	Apparent diffusion coefficient
AEC	Automatic exposure control
AHIMA	American Health Information Management Association
AHT	Abusive head trauma
AJR	*American Journal of Roentgenology*
ALL	Acute lymphoblastic leukemia
ALL	Anterior longitudinal ligament
ALT	Alanine aminotransferase
ALTE	Apparent life-threatening event
AML	Acute myelogenous leukemia
AP	Anteroposterior
aSDH	Acute SDH
ASL	Arterial spin labeling
AST	Aspartate aminotransferase
ATP	Adenosine triphosphate
AVF	Arteriovenous fistula
AVM	Arteriovenous malformation
BBB	Blood brain barrier
BESSI	Benign enlargement of the subarachnoid spaces in infancy
BMC	Bone mineral content
BMD	Bone mineral density
BMI	Body mass index
B_O	Magnetic field strength
BW	Bandwidth
CAP	Child Abuse Pediatrician
CARES	Child Abuse Reporting Experience Study
CaSR	Calcium-sensing receptor
CAT	Computed axial tomography
CCJ	Costochondral junction
CDC	Centers for Disease Control
CECT	Contrast-enhanced computed tomography
CF	Capital femur
CHESS	Chemical shift selective suppression
CHH	Cartilage hair hypoplasia
CI	Confidence interval
CML	Classic metaphyseal lesion
CNS	Central nervous system
COJ	Chondro-osseous junction
CPR	Cardiopulmonary resuscitation
CPS	Child Protective Services
CPT	Child Protection Team
CR	Computed radiography
CR/DR	Computed radiography/digital radiography
cSDH	Chronic subdural hematoma
CSF	Cerebrospinal fluid
CSVT	Cerebral sinovenous thrombosis
CT	Computed tomography
CTA	CT angiography
CTDI	CT dose index
$CTDI_{vol}$	Volume CTDI
CTV	CT venography
D2	Vitamin D2 (ergocalciferol)
D3	Vitamin D3 (cholecalciferol)
DAI	Diffuse axonal injury
DBCL	Dural border cell layer
DCE	Dynamic contrast-enhanced

DDH	Developmental dysplasia of the hip
D_{eff}	Effective Dose
DI	Dentinogenesis imperfecta
DIR	Double inversion recovery
DLP	Dose length product
DNA	Deoxyribonucleic acid
DP	Dural venous plexus
DQE	Detective quantum efficiency
DR	Digital radiography
DSA	Digital subtraction angiography
DT	Digital tomosynthesis
DTI	Diffusion tensor imaging
DTPA	Diethyl-triamine-penta-acetic acid
DTT	Diffusion tensor tractography
DWI	Diffusion-weighted imaging
DXA	Dual-energy X-ray absorptiometry
EBM	Evidence-based medicine
EBR	Evidence-based radiology
ECG	Electrocardiogram
ECMO	Extracorporeal membrane oxygenation
ED	Emergency department
EDH	Epidural hemorrhage or hematoma
EI	Exposure indicator
EMR	Electronic medical record
EMS	Emergency Medical Services
EPI	Echo planar imaging
ER	Emergency room
ETE	Effective echo time
^{18}F	Radioactive fluorine-18
F-FDG	2-deoxy-2-fluoro-D-glucose
FA	Fractional anisotropy
FAST	Focused assessment with sonography for trauma
FE	Finite element
FIESTA	Fast imaging employing steady state acquisition
FIRES	Febrile infection-related epilepsy syndrome
FLAIR	Fluid-attenuated inversion recovery
fMRI	Functional MRI
F-PET *or* ^{18}F-PET *or* ^{18}F-NaF PET	Fluorine 18-labeled sodium fluoride PET
fps	Frames per second
FS	Fat staturated
FSE	Fast spin echo
FSEIR	Fast SE with inversion recovery
FT	Fourier transform
FTT	Failure to thrive
GA1	Glutaric Aciduria Type 1
GCS	Glasgow Coma Score
GE	Gradient echo
GI	Gastrointestinal
GM-CFU	Granulocytic-macrophage colony-forming unit
GRE	Gradient recalled echo
GT	Greater trochanter
Gy	Gray
^{1}H-MRS	Hydrogen-1 MR spectroscopy
HC	Head circumference
HLH	Hemophagocytic lymphohistiocytosis
HIE	Hypoxic ischemic encephalopathy
HII	Hypoxic ischemic injury
HIPAA	Health Insurance Portability and Accountability Act
HSAN	Hereditary sensory and autonomic neuropathies
HSV	Herpes simplex virus
HU	Hounsfield unit
HUS	Head ultrasound
HVL	Half-value layer
hZPC	Histologic ZPC
ICI	Intracranial injury
ICRP	International Commission on Radiological Protection
ICU	Intensive care unit
IDH	Intradural hematoma
IOS	Interoccipital synchondrosis
IPV	Intimate partner violence
IQ	Intelligence quotient
ISOD	Isolated sulfite oxidase deficiency
ITP	Immune thrombocytopenic purpura
IU	International units
IV	Intravenous
IVC	Inferior vena cava
IVH	Intraventricular hemorrhage
IVP	Intravenous pyelogram
JCAHO	Joint Commission for the Accreditation of Hospital Organizations
J/kg	Joules per kilogram
keV	Kilo electron volts
kVp	Peak kilovoltage
LCH	Langerhans cell histiocytosis
LDH	Lactate dehydrogenase
LP	Lumbar puncture
lp/mm	Line pairs per millimeter
LPO	Left posterior oblique
LSDI	Line scan diffusion imaging
LT	Left
mA	Milliamps
M-CFU	Macrophage colony-forming units
MD	Mean diffusivity
MD	Metaphyseal dysplasias
MDCT	Multi-detector CT
MDP	Methylene diphosphonate
MELAS	Myopathy encephalopathy lactic acidosis and stroke-like episodes
MHE	Multiple hereditary exostoses

List of acronyms

MIM	Mendelian Inheritance in Man
MIP	Maximum intensity projection
MIP	Multiplanar reconstruction
MPGR	Multiplanar gradient recalled
MPR	Multiplanar reformation
MR	Magnetic resonance
MRA	MR angiography
MRI	Magnetic resonance imaging
MRS	MR spectroscopy
MRV	MR venogram
MSBP	Munchausen syndrome by proxy
MTF	Modulation transfer function
MVA	Motor vehicle accident
NAA	N-acetylaspartate
NECT	Noncontrast-enhanced CT
NEX	Number of excitations
NF1	Neurofibromatosis type 1
NIH	National Institutes of Health
NMDA	N-methyl-D-aspartate
NMR	Nuclear magnetic resonance
OI	Osteogenesis imperfecta
OMIM	Online Mendelian Inheritance in Man
OPG	Osteoprotegerin
OR	Odds ratio
OSH	Outside hospital
PA	Posteroanterior
PASL	Pulsed arterial spin labeling
PCASL	Pseudo-continuous arterial spin labeling
PCD	Programmed cell death
PCPCS	Pediatric Cerebral Performance Category Scale
PD	Proton density
PET	Positron emission tomography
PHI	Protected health information
PITS	Parent–infant traumatic stress syndrome
PMMA	Polymethyl-methacrylate
PNET	Primitive neuroectodermal tumor
PO	Intake by mouth
PPV	Positive predictive value
PTH	Parathyroid hormone
PTHrP	Placental parathyroid-related protein
QA	Quality assurance
QALY	Quality-adjusted life years
QC	Quality control
QCT	Quantitative CT
rad	Radiation absorbed dose
RANK	Receptor activator for nuclear factor κβ
RANKL	RANK ligand
RBC	Red blood cell
RCT	Randomized controlled trial
RF	Radio-frequency
RH	Retinal hemorrhage
RMRP	RNA component of mitochondrial RNA processing endoribonuclease
RPO	Right posterior oblique
rZPC	Radiologic ZPC
SAH	Subarachnoid hemorrhage
SAS	Subarachnoid space
SBS	Shaken baby syndrome
SCALP	Skin, Connective subcutaneous tissue, Aponeurotica, Loose avascular connective tissue between the aponeurotica and the pericranium, Pericranium
SCIWORA	Spinal cord injury without radiographic abnormality
SD	Subdural
SD	Standard deviation
SDH	Subdural hematoma
SDH	Subdural hemorrhage
SDHy	Subdural hygroma
SE	Spin echo
SH	Salter–Harris
SH	Subperiosteal hemorrhage
SID	Source-to-image distance
SIDS	Sudden infant death syndrome
SIS	Second impact syndrome
SMD	Spondylometaphyseal dysplasias
SMPTE	Society for Motion Picture and Television Engineers
SNR	Signal-to-noise ratio
SPACE	3D T2 turbo spin echo with variable flip angle (Sampling Perfection with Application optimized Contrasts)
SPBC	Subperiosteal bone collar
SPECT	Single photon emission CT
SPGR	Spoiled gradient recalled echo
SPGR FS	Spoiled gradient recalled echo fat-saturated
SPGR MR	Spoiled gradient recalled echo MR
SPNB	Subperiostial new bone
SPNBF	Subperiosteal new bone formation
SPR	Society for Pediatric Radiology
SPR	Superior pubic ramus
SS	Skeletal survey
SSDE	Size-Specific Dose Estimates
SSDHI	Spontaneous subdural hemorrhage in infants
SSFSE	Single-shot fast spin echo
STIR	Short tau inversion recovery
SUID	Sudden unexpected infant death
Sv	Sieverts, a unit designating the equivalent dose
SWI	Susceptibility-weighted imaging
T1WI	T1-weighted image

T2WI	T2-weighted image
"TBBD"	"Temporary brittle bone disease"
TBI	Traumatic brain injury
TE	Echo time
TFT	Thin-film transistor
TI	Inversion time
TNF	Tumor necrosis factor
TOF	Time of flight
TR	Repetition time
TrueFISP	True fast imaging with steady state free precession
TSE	Turbo spin echo
UGI	Upper gastrointestinal
US	Ultrasound
VDR	Vitamin D receptor
VKDB	Vitamin K deficient bleeding
VL	Ventral lateral
VSD	Ventricular septal defect
VWD	Von Willebrand disease
WB-MRI	Whole-body MRI
WI	Weighted image
ZPC	Zone of provisional calcification