Imaging of Pediatric Bone and Joint Trauma
The role of diagnostic imaging in the evaluation of fractures and soft-tissue injuries in skeletally immature patients continues to evolve as the techniques increasingly enable detection and characterization of abnormalities and provide results that affect decisions about patient care.

Written by the leaders in the field, *Imaging of Pediatric Bone and Joint Trauma* answers the questions arising in the diagnosis of these conditions, which are peculiar to patients who are still growing, and offers a valuable and comprehensive tool to all those called to prevent the often disabling deformities that are secondary to these conditions, and may be observed in adults.

The chapters are ideally divided into three parts, and offer an accurate, complete, and updated analysis of the different locations, multiple lesions, and dramatic consequences of these injuries on other parts of the body.

For its didactic value, the volume will certainly meet the requirements of the reader and will particularly appeal to radiologists who will turn to it during their daily work.

My warmest congratulations go to the authors and co-authors for a book that will certainly be a great success.

L’Aquila, October 2010

Carlo Masciocchi
Chief of the Department of Radiology
University of L'Aquila
Past-President of the European Society of Musculoskeletal Radiology (ESSR)
Acute and chronic orthopedic injuries in children are unique in terms of the mechanisms of injury, pathophysiology, and healing. In fact, because of the dynamic state of growth and development, patterns of skeletal injury in children are frequently different in type and presentation from those in adults, and so often require different diagnostic and treatment algorithms. The role of diagnostic imaging in the evaluation of fractures and soft-tissue injuries in skeletally immature patients continues to evolve, as the techniques increasingly enable detection and characterization of abnormalities and provide results that affect decisions about patient care.

The aim of this volume is to use a practical approach to provide an up-to-date and comprehensive text on the all important aspects of musculoskeletal trauma imaging in children and adolescents. Accidental trauma, chronic and sport-related injuries, birth fractures, and battered child are described and illustrated, highlighting corresponding features in imaging, and providing an overview of findings in the different anatomical sites of the body.

Rome, October 2010

Fabio Martino
Claudio Defilippi
Roberto Caudana
2.1.2 Osteochondrosis and Osteochondritis Dissecans .......................... 39
2.1.3 Osteochondritis ................................................................. 41
2.1.4 Chronic Lesions of the Physis ................................................ 43
2.2 The Upper Limb ................................................................. 43
2.2.1 Little League Shoulder ......................................................... 43
2.2.2 Osteochondrosis of the Humeral Condyle (Panner Disease) .......... 44
2.2.3 Osteochondritis Dissecans of the Humeral Condyle .................... 44
2.2.4 Little League Elbow Syndrome ............................................. 45
2.2.5 Osteochondritis of the Olecranon Apophysis ............................ 45
2.3 The Lower Limb ................................................................. 46
2.3.1 Osteochondrosis of the Epiphyseal Nucleus of the Femur
(Legg–Calvé–Perthes Disease) ....................................................... 46
2.3.2 Epiphysiolysis of the Epiphyseal Nucleus of the Femoral Head ..... 46
2.3.3 Osteochondritis Dissecans of the Femoral Condyle
(König Syndrome) ................................................................. 46
2.3.4 Osteochondritis of the Inferior Pole of the Patella
(Sinding–Larsen–Johansson Syndrome) ......................................... 46
2.3.5 Osteochondritis of the Anterior Tibial Apophysis
(Osgood–Schlatter Disease) ....................................................... 47
2.3.6 Shin Splints ........................................................................... 47
2.3.7 Osteochondritis Dissecans of the Talus ................................... 47
2.3.8 Osteochondritis of the Calcaneal Apophysis (Sever Disease) ........ 47
2.3.9 Osteochondritis of the Apophysis of the Base of the Fifth Metatarsal
(Iselin Disease) ........................................................................... 48
2.3.10 Osteochondrosis of the Head of the Second Metatarsal
(Freiberg or Koehler II Disease) ................................................... 48
Suggested Readings ........................................................................ 48

3 Osteoarticular Trauma in the Pediatric Age:
Overview – Apophyseal Injuries ....................................................... 49
M. Valle, A. Tagliafico, L. Oppezzi, N. Gandolfo, P. Tomà and C. Martinoli

3.1 Introduction ............................................................................. 49
3.2 Tendons .................................................................................. 50
3.2.1 Pathophysiology ................................................................. 50
3.2.2 Imaging ............................................................................... 52
3.2.3 Chronic Apophyseal Lesions Due to Tendon Traction ................. 53
3.2.4 Acute Apophyseal Lesions from Tendon Traction ....................... 56
3.3 Ligaments ............................................................................... 64
3.3.1 Apophyseal Injuries Due to Ligament Traction ......................... 65
Suggested Readings ........................................................................ 67
4 Major and Minor Pediatric Traumatic Muscolotendinous Injuries ........ 69
E. Genovese, A. Leonardi, L. Callegari, M.G. Angeretti,
M. Albrizio, E. Spanò and C. Fugazzola

4.1 Introduction ............................................. 69
4.2 The Role of Imaging in Detection ....................... 69
4.3 Muscolar Lesions ........................................ 71
4.3.1 Muscular Distractive Lesions ...................... 71
4.3.2 Muscolar Contusions ................................. 74
4.3.3 Complications and Follow-up ....................... 74
4.4 Tendon Lesions ........................................... 75
4.4.1 Tendinopathy .......................................... 75
4.4.2 Insertional Tendinopathies (Enthesopathies) ........ 76
4.4.3 Bursitis ................................................ 78
4.4.4 Tendinous Ruptures .................................. 78
4.5 Abnormalities of Ligaments ............................ 78
4.5.1 Extra-articular Ligaments ......................... 78
4.5.2 Intra-articular Ligaments ......................... 80
Suggested Readings ........................................... 81

5 Traumatic Lesions of the Peripheral Nerves ................. 83
E. Pacciani, F. Randisi, C. Orazi, M. Valle and C. Martinoli

5.1 Introduction ............................................. 83
5.2 Ultrasound Scanning .................................... 84
5.3 Magnetic Resonance Imaging ........................... 89
Suggested Readings ........................................... 95

6 Imaging of Regional Injuries: The Axial Skeleton – the Skull, Vertebral
Column, and Thoracic Cage .................................. 97
C. Fonda, M. Mortilla, C. Cesarini and M. Basile

6.1 The Skull .................................................. 97
6.1.1 Epidemiology ........................................... 97
6.1.2 Orbital and Nasoethmoid Fractures .................. 103
6.1.3 Maxillofacial Fractures ............................... 105
6.1.4 Mandibular Fractures ................................. 107
6.1.5 Zygomatic and Maxillary Fractures .................. 108
6.2 The Vertebral Column .................................... 108
6.2.1 Epidemiology ........................................... 108
6.2.2 Radiological Examination ........................... 109
6.2.3 Evaluation of Spinal Trauma ........................................ 110
6.2.4 Pathophysiology .................................................. 112
6.2.5 Superior Cervical Spine Injuries .............................. 114
6.2.6 Occipito-atlanto-axial Instability .......................... 114
6.2.7 Odontoid Process Fractures .................................. 115
6.2.8 Extension Fractures of the Atlas and Axis ................. 117
6.2.9 Flexion Trauma of the Inferior Cervical Spine .......... 117
6.2.10 Extension Trauma ................................................. 119
6.2.11 Fractures of the Thoracolumbar Spine ................... 119
6.3 The Thoracic Cage .................................................. 121
6.3.1 Chest Wall Injury .................................................. 121
Suggested Readings ..................................................... 123

7 The Upper Limbs ...................................................... 125
D. Barbuti, E. Pacciani, M. Cirillo, A. Magistrelli and L. Tanturri De Horatio

7.1 The Shoulder and Arm .............................................. 125
7.2 The Elbow and Forearm ............................................ 131
7.3 The Wrist and Hand ............................................... 146
Suggested Readings ..................................................... 150

8 The Pelvis and Lower Limbs ........................................ 151
D. Barbuti, E. Pacciani, A. Magistrelli, M. Cirillo, F. Fassari and L. Tanturri De Horatio

8.1 The Pelvis, Hip, and Femur ..................................... 151
8.1.1 Fractures of the Pelvis .......................................... 152
8.1.2 Sacro-coccygeal Fractures ................................... 158
8.1.3 Traumatic Luxation of the Hip in Children ............. 159
8.1.4 Fractures of the Femur .......................................... 160
8.2 The Knee and Leg .................................................. 164
8.2.1 Fractures of the Distal Epiphysis of the Femur ......... 164
8.2.2 Fractures of the Patella ......................................... 166
8.2.3 Fractures of the Tibia ........................................... 166
8.3 The Ankle and Foot ................................................. 169
8.3.1 Lesions of the Ankle Region ................................... 169
8.3.2 Fractures of the Foot ........................................... 173
8.3.3 Fractures of the Astragalus ................................... 174
8.3.4 Fractures of the Calcaneus ................................... 174
8.3.5 Fracture of the Scaphoid ....................................... 175
8.3.6 Lisfranc Fracture ................................................. 175
8.3.7 Fractures of the Metatarsals and Phalanges ............. 176
Suggested Readings ..................................................... 177
9 Birth Trauma ......................................................... 179
   C. Defilippi, B. Santoro and P. Pautasso

   9.1 Introduction ............................................. 179
   9.2 Obstetric Pseudo-paralysis ......................... 179
   9.3 “Birth Fractures” ...................................... 180
   Suggested Readings ...................................... 182

10 Toddlers’ Fractures ........................................... 183
   C. Defilippi, B. Santoro and P. Pautasso

   10.1 Introduction ........................................... 183
   10.2 The Concept of Toddlers’ Fractures ............. 183
   10.3 Imaging ................................................. 184
   Suggested Readings ...................................... 186

11 Bony Lesions from Non-accidental Trauma ................. 187
   C. Defilippi, B. Santoro and P. Pautasso

   11.1 Introduction ........................................... 187
   11.2 The “Battered Child”: Imaging ................. 187
   11.3 Fractures in Specific Anatomical Sites ........ 190
   11.4 Fractures in Non-specific Anatomical Sites, with Particular
       X-ray Characteristics for Dating of Fractures ...... 191
   11.5 Fractures with Particular Radiographic Characteristics ... 193
   11.6 Differential Diagnosis ................................ 196
   11.6.1 Defective Osteogenesis ......................... 197
   11.6.2 Infantile Cortical Hyperostosis (Illness of Roske–De Tone–
       Caffey–Silverman) ...................................... 198
   11.6.3 Dysmetabolic Bone Disease of Premature Infants .... 199
   11.6.4 Menkes Disease ...................................... 200
   11.6.5 Rickets .................................................. 200
   11.6.6 Congenital Syphilis .............................. 201
   11.6.7 Scurvy ............................................... 202
   Suggested Readings ...................................... 202

12 The Battered Child: Guidelines and Medical-legal Implications .... 203
   M. Solarino and B. Solarino

   12.1 Introduction ........................................... 203
   12.2 Current Regulations and Medical-legal Considerations ... 206
   12.3 Conclusions ............................................ 207
   References ................................................... 208
   Suggested Readings ...................................... 208
Contributors

Maria Gloria Angeretti
Department of Radiology
Circolo Hospital Macchi Foundation
Varese, Italy

Domenico Barbuti
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Rome, Italy

Massimo Basile
Department of Pediatric Radiology
Children’s Hospital Meyer
Florence, Italy

Leonardo Callegari
Department of Radiology
Circolo Hospital Macchi Foundation
Varese, Italy

Cecilia Cesarini
Department of Pediatric Radiology
Children’s Hospital Meyer
Florence, Italy

Marco Cirillo
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Rome, Italy

Claudio Defilippi
Pediatric Radiology Service
Regina Margherita Children’s Hospital
Turin, Italy

Lorenzo Falcone
Radiology Department
Policlinico - Giovanni XXIII Hospital
Bari, Italy

Carlo Faletti
Department of Radiology
AO CTO
Turin, Italy

Fausto Fassari
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Palidoro (RM), Italy

Claudio Fonda
Department of Pediatric Radiology
Children’s Hospital Meyer
Florence, Italy

Carlo Fugazzola
Department of Radiology
Circolo Hospital Macchi Foundation
Varese, Italy
Contributors

Nicola Gandolfo
IM2S - Institut Monegasque de Médecine & Chirurgie Sportive
Montecarlo, Monaco

Maurizio Matarazzo
Orthopedic Department
Policlinico - Giovanni XXIII Hospital
Bari, Italy

Eugenio Genovese
Department of Radiology
Circolo Hospital Macchi Foundation
Varese, Italy

Marzia Mortilla
Department of Pediatric Radiology
Children’s Hospital Meyer
Florence, Italy

Mariantonietta Indolfi
Complex Structure of Radiology
“Valle d’Itria” Hospital
Martina Franca (TA), Italy

Leila Oppezzi
Department of Radiology
University of Genoa
Genoa, Italy

Anna Leonardi
Department of Radiology
Circolo Hospital Macchi Foundation
Varese, Italy

Cinzia Orazi
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Palidoro (RM), Italy

Andrea Magistrelli
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Rome, Italy

Enzo Pacciani
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Palidoro (RM), Italy

Davide Mariani
Department of Radiology
Circolo Hospital Macchi Foundation
Varese, Italy

Patrick Pautasso
Department of Radiology
AO CTO
Turin, Italy

Fabio Martino
Radiology Department
Policlinico - Giovanni XXIII Hospital
Bari, Italy

Francesco Randisi
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Palidoro (RM), Italy

Gianluigi Martino
School of Medicine
University of Bari
Bari, Italy

Bianca Santoro
Pediatric Radiology Service
Regina Margherita Children’s Hospital
Turin, Italy

Carlo Martinoli
Radiology Department - DISC
University of Genoa
Genoa, Italy

Biagio Solarino
Section of Legal Medicine
University of Bari
Bari, Italy
Contributors

Michele Solarino
Section of Radiology
“Fallacara” Hospital
Triggiano – Bari, Italy

Alberto Tagliafico
Radiology Department – DISC
University of Genoa
Genoa, Italy

Laura Tanturri
Department of Diagnostic Imaging
Pediatric Hospital “Bambino Gesù”
Rome, Italy

Paolo Tomà
Department of Radiology
Pediatric Hospital “Bambino Gesù”
Rome, Italy

Maura Valle
Department of Radiology
Istituto Scientifico “Giannina Gaslini”
Genoa, Italy