# Contents

## Spinal Infections

### Section 1: Fundamental Concepts


**1. Bacteriology of Spinal Infections ..... 5**
*GD Sundararaj, K Venkatesh, Joy Sarojini Michael*
- Pathogenesis 5
- Microbial Agents 5
- Types of Spinal Infections 7
- Diagnosis of Infection 13
- Histology 14

**2. Biomechanical Aspects of Spinal Infections..... 16**
*Vijay K Goel, Hiroshi Kuroki, S Rajasekaran*
- Anatomical Concepts 16
- Effects of Infectious Diseases on the Anatomical Structures 17
- Biomechanical Features in Infectious Diseases of the Spine 18
- Effect of Biomechanical Forces on Vertebral Endplates (VEP) 20

**3. Imaging in Spinal Infections ..... 25**
*Ketan S Khurjekar, Devarati K Khurjekar, Vilas P Kanikdaley, Ashok K Shyam*
- Various Modalities of Imaging 25
- Spinal Osteomyelitis 29
- Spondylodiscitis 29
- Intraspinal Infections 38

**4. Management Principles of Spinal Infections ..... 43**
*Dilip K Sengupta*
- Bacteriology 43
- Management Plan 43


### Section 2: Tuberculosis of Spine

#### A. General Principle


**5. Tuberculosis of the Spine: A Historical Perspective and Evolution of Treatment ..... 55**
*SM Tuli*
- Historical Perspective 55
- Evolution of Treatment of Spinal Tuberculosis 56
- Evolution of Surgical Treatment of Spinal Tuberculosis 57
- Drug Resistance, Relapse, or Recurrence 59
- New Imaging Modalities 60
- Immunodeficiency and Tuberculosis 61
- The Challenges for Future 61

**6. Spinal Tuberculosis—Microbiology and Pathology ..... 64**
*Premik Nagad, Abhay Nene*
- Types of Mycobacterium Organisms 64
- Microbiological Diagnostic Methods for MTB 65
- Pathology of Spinal Tuberculosis 66
- Atypical Tuberculosis 69
- Histopathology 70

**7. Clinical Features and Physical Assessment of Tuberculosis of Spine ..... 73**
*VT Ingalhalikar*
- Clinical Presentation 73
- Tuberculous Cold Abscess 74
- Tubercular Spinal Deformity 76
- Neurological Deficits 77
- Tuberculosis of Specific Regions 78
- Differential Diagnosis 81

**8. Investigations for Spinal Tuberculosis ..... 83**
*Yogesh K Pithwa*
- Blood Investigations 83
- Tuberculin Skin Test 83
- Serological Tests 84
- Tissue Diagnosis 84
- Other Investigations 87

**9. Neurological Deficit ..... 90**
*Anil K Jain, Saurabh Jain*
- Pathology of Neurological Deficits 90
- Staging of Neural Deficit 92
- Clinical Presentations 93
- Treatment 93
- Indications of Surgery 95
- Surgical Decompression (Anterior or Posterior) 96
- Surgical Approaches to Tubercular Spine 98
- Instrumented Stabilization 99
- Neurological Complications in Healed Disease 100

**10. Deformity in Spinal Tuberculosis ..... 103**
*S Rajasekaran*
- Natural History of Progress of Deformity 103
- Other Factors Influencing Deformity 105
- Patterns of Healing 108
- Buckling Collapse 109
- Surgery for Prevention of Deformity 110
- Surgery for Established Deformity 110

**11. Spinal Intradural and Meningeal Tuberculosis ..... 114**
*Gomatam R Vijay Kumar*
- Definition 114
- Incidence 114
- Etiology and Pathogenesis 114
- Clinical Presentation 115
- Imaging Studies 115
- Management 116
- Outcome 117

## B. Management

**12. Management Principles—An Overview ..... 120**
*K Sriram*
- Historical Review 120
- Chemotherapy 120
- Surgery 121
- Tuberculosis of Cervical Spine 126
- Tuberculosis of the Lumbar Spine 127

**13. Drug Therapy for Spinal Tuberculosis ..... 133**
*Mathew Varghese, Shwetabh, Pranay Bhushan*
- Rationale of Chemotherapy 133
- Essential Drugs/First-Line Drugs 133
- Reserve Drugs/Second-Line Drugs 134
- Differential Action of Antitubercular Drugs in Bacterial Population 135
- Scientific Basis for Intermittent Therapy: The "Lag Period" Factor 136
- Case Definitions 136
- Multidrug Regimens for Chemotherapy 136
- Management of Common Adverse Effects of Chemotherapy 139

**14. Multidrug-resistant Tuberculosis of the Spine ..... 141**
*Uday Pawar, Abhay Nene*
- Definitions 141
- Causes of Drug Resistance 141
- Laboratory Diagnosis of Resistance 141
- Management Principles 142

**15. Upper Cervical Tuberculosis ..... 145**
*S Govender*
- Pathology 145
- Presentation 145
- Imaging 145
- Treatment 148

**16. Tuberculosis of the Lower Cervical Spine ..... 151**
*Ram Chaddha, Swapnil Keny*
- Cervical Spine Infections 151
- Peculiarities of Cervical Spine Tuberculosis 151
- Classification 151
- Clinical Features 154
- Management 157
- The Role of Surgery 157

**17. Thoracic and Thoracolumbar Tuberculosis ..... 167**
*Shekhar Bhojraj, Sameer Kalkotwar, Tarak Patel, Gautam Prasad*
- Anatomical Peculiarities 167
- Clinical Presentation 167
- Diagnosis 167
- Differential Diagnosis 170
- Treatment 170
- Complications 172
- Special Situations 173
- Authors' Recommendations 174

**18. Lumbosacral Tuberculosis ..... 177**
*Shankar Acharya, Abhishek Srivastava*
- Clinical Presentation 179
- Investigations 179
- Management 181
- Special Considerations in Lumbosacral Tuberculosis 183

## C. Surgical Techniques

**19. Tuberculosis of Spine: Biopsy Techniques ..... 190**
*Bharat R Dave, Ajay Krishnan*
- Techniques 190
- Approach and Technique 191
- Types of Needles Used 191
- Difficult Areas 192
- Complications 192
- Examination of Specimen 192
- Authors' Preferred Technique (For Thoracic and Lumbar Spine) 192

**20. Cold Abscess in Spinal Tuberculosis ..... 195**
*Surya Prakash Rao V, Gopala Krishnaiah T*
- Pathogenesis 195
- Craniovertebral Junction 195
- Midcervical Spine (C3-C6) 196
- Cervico-Dorsal Junction and Upper Dorsal Spine (C7-D4) 196
- Thoracic Spine 196
- Lumbar and Lumbosacral Spine 197
- Prognostic Signs in Plain Radiograph 198
- Principles of Management 199
- Types of Treatment 199

**21. Minimally Invasive Spine Surgery in Spinal Infections ..... 201**
*Upendra BN, Abhishek Srivastava, Kamran Farooque, Arvind Jayaswal*
- History of Minimally Invasive Spine Surgery (MISS) 201
- Advantages of MISS 201
- Thoracic-Lumbar Spine 202
- Cervical Spine 207

**22. Anterior Approaches in Spinal Tuberculosis ..... 209**
*Mallikarjun, Sajan K Hegde*
- Evolution of the Anterior Approach of the Spine 209
- Subaxial Cervical Spine TB 210
- Cervicodorsal TB 210
- Thoracic TB 213
- Thoracolumbar Junction 213
- Lumbar Spine 213

**23. Anterior Procedures in the Management of Tuberculosis of Thoracic, Thoracolumbar and Lumbar Spine ..... 217**
*Subbiah M, Ajoy P Shetty, S Rajasekaran*
- Evolution of Anterior Surgeries in TB Spine 217
- Anterior Surgical Options 218

**24. Posterior Approaches for Management of Spinal Tuberculosis ..... 225**
*Gautam Zaveri*
- Posterior Approaches to the Thoracic Spine 225
- Posterior Approach to the Lumbar Spine 232
- Posterior Approach to the Cervical Spine 234

**25. Surgeries in Healed Tuberculosis of Spine ..... 237**
*Ajoy P Shetty, Rishi M Kanna, Subbiah M*
- Natural Healing in Spinal Tuberculosis 237
- Posterior Approaches 241

## Section 3: Pyogenic Infections of the Spine

**26. Pyogenic Vertebral Osteomyelitis..... 251**
*GD Sundararaj, R Amritanand*
- Epidemiology 251
- Pathogenesis 251
- Bacteriology 252
- Clinical Presentation 252
- Diagnosis 254
- Management 255
- Facet Joint Septic Arthritis 257

**27. Spinal Epidural Abscess ..... 260**
*Rushama Tandon*
- Incidence 260
- Pathophysiology and Pathogenesis 261
- Clinical Features 263
- Diagnosis 263
- Management of Sea 264
- Outcome 264
- Tubercular Spinal Epidural Abscess 264
- Epidural Granuloma 265

## Section 4: Miscellaneous Spinal Infections

**28. Fungal Infections..... 271**
*S Govender*
- Pathoanatomy 271
- Clinical Features 271
- Radiological Features 272
- Diagnostic Tests 272
- Treatment 272
- Prevention of Invasive Aspergillosis in the Immunocompromised Patient 273
- Epidemiology 274
- Diagnostic Tests 274
- Surgical Treatment 275
- Medical Treatment 275

**29. Unusual Bacterial Infections ..... 278**
*S Govender*
- Salmonella Spondylitis 278
- Epidemiology 278
- Etiology 278
- Clinical Features 278
- Imaging 278
- Diagnostic Studies 279
- Treatment 279
- Preventative Measures 279
- Introduction 280
- Epidemiology 280
- Etiology 280
- Clinical Manifestations 280

- Imaging Studies 280
- Diagnostic Studies 280
- Treatment 281
- Prognosis 281

**30. Parasitic Infestations ..... 284**
*S Govender*
- Epidemiology 284
- Parasitology 284
- Pathology 285
- Clinical Features 285
- Laboratory Findings 285
- Imaging Features 285
- Differential Diagnosis 286
- Natural History 286
- Treatment 286
- Introduction 289
- Life Cycle 289
- Presentation 289
- Investigations 289
- Treatment 290

**31. Spinal Infections in the Immunocompromised Patients ..... 293**
*S Govender, S Danaviah*
- HIV and Host Interactions 295
- Opportunistic Spinal Infections 299
- Antiretroviral Therapy 301
- Malignancy and HIV/Aids 302

**32. Postoperative Spondylodiscitis ..... 307**
*Raghava D Mulukutla*
- Incidence 307
- Etiopathology 307
- The Source 308
- Clinical Presentation and Diagnosis 308
- Investigations 309
- Radiology 310
- MRI 311
- Management 311
- Prevention 311
- Treatment 312
- Surgery 313
- Instrumentation 314
- Prognosis 315

**33. Peri-implant Spinal Infections ..... 318**
*Uday Pawar, Samir Dalvie*
- Risk Factors for Wound Infection 318
- Anterior Versus Posterior Instrumentation 318
- Clinical Presentation 318
- Investigations 318
- Microbiology of Infection 319

# Spinal Trauma

## Section 5: Basic Concepts in Spinal Injury

**34. Epidemiology of Traumatic Spinal Cord Injuries ..... 327**
*Harvinder Singh Chhabra, Mohit Arora*
- Incidence Rate 327
- Prevalence of SCI 327
- Survival Time 329
- Age 329
- Gender 329
- Marital Status 329
- Educational Level 329
- Primary Occupational Status at the Time of Injury 329
- Mode of Injury 331
- Neurological Level and Category of Injury 332
- Time and Place of Injury 334
- Associated Injuries 334

**35. Prehospital Care in Spinal Injury Patients ..... 338**
*Sudhir K Srivastava, Sunil K Bhosale, Kshitij Kumar M Agrawal, Pradip S Nemade*
- Principles of Prehospital Care 338
- Prehospital Care System 339
- Initial Evaluation 339
- Protection of Spine 340
- Cervical Collars 341
- Transfer to Tertiary Units 342
- Consideration in Special Circumstances 343
- Pitfalls of Spinal Immobilization 344
- Future Trends 344

**36. Initial Evaluation of Patients with Spinal Injuries ..... 347**
*SS Patil, Samir Dalvie*
- General Evaluation 347
- Local Examination 347
- Neurological Examination 347
- Classification and Scoring of the Spinal Injuries 351

**37. Radiology of Spinal Trauma ..... 355**
*Ashutosh Sabnis, Kapil Mohan, Abhay Nene*
- Plain Radiograph 355
- Cervical Spine Radiograph 355
- Thoracolumbar Spine Radiograph 363
- Plain Radiographs for Sacrum 364
- Spinal Cord Injuries without Radiographic Abnormalities (SCIWORA) 364
- Computed Tomography in Spinal Trauma 366
- Magnetic Resonance Imaging in Spinal Trauma 370
- Conventional Angiography for Spinal Trauma 373
- Radionuclide Bone Imaging for Spinal Trauma 374

**38. Surgical Decision Making in Spinal Cord Injuries ..... 377**
*Harvinder Singh Chhabra, Ankur Nanda, Vikas Tandon*
- Surgical or Conservative Management 377
- The Context of Developing Countries 380
- SCI—When to Operate 380

## Section 6: Spinal Cord Injury

**39. Pathophysiology of Spinal Cord Injury ..... 389**
*Uday M Pawar, Dilip K Sengupta*
- Epidemiology 389
- Pathophysiology of Spinal Cord Injury 389

**40. Current Status of Pharmacological Agents in Acute Spinal Cord Injury ..... 395**
*Amol Rege*
- Pathophysiology of SCI 395
- Mechanism of Action of Pharmacological Agents 396

**41. Regenerative Strategies in Spinal Cord Injury ..... 402**
*Vijay Kamath, S Rajasekaran*
- Pathophysiology of the SCI and Obstacles to Regeneration in the Injured Spinal Cord 403
- Approaches to Treatment 403
- Challenges in Developing Cellular Therapies to Treat Spinal Cord Injury 405
- What are Stem Cells? 406
- Olfactory Ensheathing Cells (OECS) 406
- Schwann Cells 408
- Macrophages 408
- Bone Marrow Stromal Stem Cells 408
- Neural Stem Cells and Glial Progenitors 409
- Embryonic Stem Cell-Derived NSCS, NPCS and OPCS 410
- Adult-Derived NSCS 410
- Delivery Methods 411

## Section 7: Cervical Spine Trauma

**42. Upper Cervical Spine Injuries ..... 421**
*Saumyajit Basu*
- Anatomical Considerations 421
- Atlanto-occipital Injuries 422
- Atlas Fractures 422
- Atlantoaxial Dislocations 423
- Axis Fractures 424

**43. Missed Spinal Injuries ..... 431**
*Gautam Zaveri*
- Epidemiology 431
- Consequences of Missed Spinal Injuries 433
- Etiology of Missed Injuries 434
- Prevention 435
- Thoracolumbar Trauma 439

## Section 8: Thoracolumbar Spine Trauma

**44. Biomechanics and Classification of Thoracolumbar Spinal Injuries ..... 449**
*Uday M Pawar, Swapnil Keny, Ram Chaddha*
- Thoracolumbar Spine 449
- Concept of Instability and Surgical Indication 452

**45. Vertebral Compression Fractures ..... 457**
*Arvind G Kulkarni, Siddharth M Shah*
- Etiology 457
- Epidemiology 457
- Classification 457
- Biomechanics 458
- Clinical Features 458
- Differential Diagnosis 458
- Investigations 458
- Treatment 459

**46. Burst Fractures of the Thoracolumbar Spine ..... 462**
*KV Menon, Ramesh Dalwai*
- Definition 462
- Epidemiology 462
- Classification 463
- Pathological Anatomy 464
- Management 465
- Management Algorithm According to the AO Classification 468

**47. Flexion-distraction Injuries and Fracture Dislocations of the Thoracic and Lumbar Spine ..... 471**
*Harsh Priyadarshi, Thomas J Kishen, Greg Etherington, Ashish D Diwan*
- Incidence 471
- Anatomy and Biomechanical Considerations 471
- Assessment 472
- Mechanism of Injury: Flexion-Distraction Injury of the Thoracic and Lumbar Spine 472
- Mechanism of Injury: Fracture Dislocations of the Thoracic and Lumbar Spine 475
- Management of Flexion-Distraction Injuries and Fracture Dislocations of the Thoracic and Lumbar Spine 476

**48. Fractures of the Sacrum ..... 481**
*J Naresh Babu*
- Sacral Anatomy 481
- Etiology and Incidence 482
- Evaluation of Sacral Fractures 482
- Classification 484
- Treatment 486

**49. Pediatric Spinal Injuries ..... 492**
*Saumyajit Basu*
- Epidemiology 493
- Related Anatomy 493
- Biomechanics 494
- SCIWORA 494
- Clinical Presentation 495
- Imaging Studies 495
- Management Strategies 497
- Late Complications of Pediatric Spinal Injuries 498

**50. Gunshot Injuries to the Spine ..... 500**
*S Govender*
- Ballistics of Gunshot Injuries 500
- Assessment 500
- Role of Steroids 501
- Investigations 501
- Antibiotic Treatment 501

- Indicatons for Surgery 502
- Lead Toxicity 502
- Migrating Bullets 502
- Case Review 502
- Results of Treatment 503

**51. Nonoperative Management of Spinal Injuries ..... 506**
*Rajagopalan, Rishi M Kanna*
- Medical Management of Acute Spinal Cord Injury 506
- Conservative Management of Upper Cervical Spine Injuries 507
- Conservative Management of Lower Cervical Spine Injuries 510
- Conservative Management of Thoracic Spine Injuries 511
- Conservative Management of Thoracolumbar Fractures 511
- Nonoperative Management of Thoracolumbar Fractures with Normal Neurology 514

**52. Iatrogenic Spinal Cord Injury—Incidence, Prevention and Management ..... 518**
*Bibhudendu Mohapatra, Thomas J Kishen, Sonia Sandhu, Greg Etherington, Ashish D Diwan*
- Iatrogenic Spinal Cord Injury 518
- Incidence of Iatrogenic Spinal Cord Injury 518
- Etiopathogenesis of ISCI 520
- Management of Iatrogenic Spinal Cord Injury 524

**53. SCI Rehabilitation ..... 531**
*Gabriel David Sundararaj, Henry Prakash, E Subbian*
- Acute Phase Rehabilitation 531
- Post-Acute Management of Conservatively and Surgically Managed Patients 531
- Mobility 532
- Neurogenic Bladder Management after SCI 533
- Neurogenic Bowel 535
- Sexual Rehabilitation 535
- Functional Outcomes in SCI Rehabilitation 538

**54. Complications of Spinal Cord Injury ..... 541**
*Harvinder Singh Chhabra, Gururaj Sangondimath, Darshan Gautam, Nishit Patel*
- Respiratory Complications in Spinal Cord Injury 541
- ARDS 543
- Cardiovascular Complications after SCI 544
- Deep Vein Thrombosis in Spinal Cord Injury 550
- Gastrointestinal (GI) Complications in Spinal Cord Injury Patients 552
- Hemorrhoids 556
- Pressure Ulcer (PrU) 556
- Heterotopic Ossification (HO) 559
- Spasticity 561
- Genitourinary Tract Complications 562
- Osteoporosis in Spinal Cord Injured Patient 566
- Post-traumatic Pain Syndromes 567
- Syringomyelia 569
- Mortality in Spinal Cord Injury 571

## Section 9: Special Situations

**55. Management of Subaxial Cervical Spine Injuries ..... 587**
*Gautam Zaveri*
- Emergency In-Hospital Care 587
- Definitive Treatment 590
- Indications for Surgery 590

- Selection of Surgical Approach 592
- Complications 600

**56. Osteoporosis and Spinal Trauma ..... 604**
*Raghava Dutt*
- Incidence 604
- Clinical Features 604
- Classification 604
- Pathology 604
- Risk Factors 605
- Diagnosis 605
- Fractures in Osteoporotic Spine 607
- Management 608
- Prevention and Medical Management 608
- Management of Vertebral Compression Fractures 609
- Nonoperative Management 609
- Surgical Management 610
- Minimally Invasive Techniques 610
- Open Surgical Procedures 610
- Methods of Fixation 611

**57. Special Considerations for Geriatric Spinal Injuries ..... 614**
*Harvinder Singh Chhabra, Vivek Mittal*
- Predisposing Factor 614
- Etiology 614
- Level of Injury 615
- Type of Injury 615
- Symptoms 617
- Diagnosis 617
- Complications 618
- Mortality 618
- Outcomes 621

**58. Vertebroplasty for Osteoporotic Vertebral Fractures ..... 623**
*Arvind Bhave*
- Consequence of Vertebral Compression Fractures 623
- Indications for Vertebroplasty 623
- Contraindications 623
- Timing of Vertebroplasty 623
- Preoperative Evaluation 623
- Materials Used for Augmentation 624
- Vertebroplasty—How Does It Work? 624
- Devices for Performing Vertebroplasty 625
- Surgical Technique 625
- Postoperative Management 626
- Complications 627
- Current Opinion on Vertebroplasty 628
- Future of Vertebroplasty 628

**59. Kyphoplasty of Symptomatic Vertebral Body Compression Fractures ..... 630**
*Anand Agarwal, John Yeh, Robert Pflugmacher*
- Surgical Management 630
- Indications 630
- Diagnosis and Imaging 631
- Kyphoplasty 631

**60. Spinal Injuries in Ankylosing Spinal Disorders ..... 638**
*Kshitij Chaudhary, Mihir Bapat, Vinod Laheri*
- Clinical Presentation 638
- Investigations 638
- General Principles 639
- Spinal Fractures in Ankylosing Spondylitis 639
- Diffuse Idiopathic Skeletal Hyperostosis 641
- Complications 642

***Index*** ..... ***645***