## Contents

### Section 1: Introduction

1. **Prelude** .......................................................... 3  
   Harikrishnan S

2. **Rheumatic Heart Disease—an Epidemiological Mystery** ................................................. 7  
   Biju Soman
   Magnitude 7  
   Contextual Determinants 8  
   Control Strategies 10

3. **Anatomy of the Mitral Valve**................................. 13  
   Yoav Turgeman, Hosam Hasan-Ali, Syamkumar Menon, Raghuram A Krishnan  
   Mitral Annulus 13  
   Left Atrium 13  
   Mitral Valve Leaflets 15  
   Microscopic Structure of the Valve Leaflets 15  
   Mitral Subvalvar Apparatus 16  
   Papillary Muscles 16  
   Chordae Tendineae 17  
   Function of the SVA 20  
   Left Ventricle 20  
   Mitral Valve Orifice 20  
   Pathological Anatomy in Rheumatic Mitral Stenosis 21

4. **Pathological Aspects of Rheumatic Mitral Stenosis** ........ 24  
   Ruma Ray, Prasenjit Das  
   Normal Mitral Valve 24  
   Rheumatic Mitral Stenosis 25  
   Pathogenesis 26  
   Gross Pathology 26  
   Mitral Valve with Previous Mitral Valveplasty/Valve Replacement 32  
   Pathology of Complications of Rheumatic Mitral Valve Stenosis 32

5. **Pathophysiology, Natural History and Hemodynamics of Mitral Stenosis** ...................... 34  
   Krishnakumar M, Mahesh Kumar S, Arun SR  
   Natural History of Mitral Stenosis 34
Section 2: Evaluation Prior to Percutaneous Mitral Valvotomy (PMV)

6. Mitral Stenosis—Management ............................................. 47
   Harikrishnan S, Stigimon Joseph
   Medical Management 47
      Control of Symptoms 47
      Rheumatic Fever Prophylaxis 48
      Anticoagulation 48
   Intervention 48
   Mechanism of Percutaneous Balloon Mitral Valvotomy 48
   Indications and Contraindications for PMV 50
      Indications for PMV 51
      Contraindications for PMV 51
   PMV—Special Considerations 51
      When to Perform PMV? Earlier the Better? 51
      Planning Pregnancy 51
      Left Atrial Thrombus 51
      Mitral Regurgitation 52
      Calcification of the Valve 52

7. Clinical Assessment and Stress Testing Prior to
   Percutaneous Mitral Valvotomy ......................................... 54
   P Shanmugha Sundaram
   History 54
      Physical Examination 55
         Stress Testing in the Assessment of Patients with Mitral Stenosis 55
   Treadmill Exercise Testing in Patients with Mitral Stenosis 56
   Dobutamine Stress Echocardiography 57
      DSE Protocol 58

8. Electrocardiogram in Mitral Stenosis ............................. 60
   Krishnakumar Nair, Diego Chemello, Raja Selvaraj
   Terminology 60
   Left Atrial Abnormality 61

Percutaneous Mitral Valvotomy

Pathophysiology of Mitral Stenosis 35
   Severity of Mitral Stenosis (ACC-AHA) 36
Obstructive Physiology of Mitral Stenosis 37
   Influence of Heart Rate 38
Chamber Dynamics in Mitral Stenosis 38
   Left Atrium and Left Ventricle 38
   Atrial Fibrillation 39
Pulmonary Circulation 40
   Right Ventricle 40
   Cardiac Catheterization in Mitral Stenosis 41
   Left Atrial Pressure Waveform 41
Right Atrial Abnormality 62
    Electrocardiographic Criteria 62
Combined Atrial Abnormality 62
Right Ventricular Hypertrophy 63
Atrial Arrhythmias 64
Mitral Stenosis Severity and the ECG 65
Effects of Mitral Valvotomy on Electrocardiographic Changes of Mitral Stenosis 65
Clinical Significance 65

9. Radiological Evaluation in Mitral Stenosis.................69
    Bhavesh Harivadan, Harikrishnan S
    Chest Roentgenography 69
        Left Atrial Enlargement 69
        Calcification 70
        Pulmonary Hypertension 70
        Pulmonary Congestion 70
        Miscellaneous Findings 71
    Left Ventricular Angiography in Mitral Stenosis 71
        Fulcrum and Fornix 73
        Assessment of Subvalvar Pathology 74
        Assessment of Mitral Regurgitation 75

10. Balloon Mitral Valvotomy—Role of Echocardiography..........................76
    Hosam Hasan-Ali, Harikrishnan S
    Anatomical Background 76
        Pathological Anatomy in Mitral Stenosis 76
    Pathophysiology of Mitral Stenosis 76
    Echocardiographic Assessment in MS Prior to Percutaneous Mitral Valvotomy (PMV) 77
        What are the Parameters we Assess for PMV? 77
        M-mode Echocardiography 78
        Two-dimensional Echocardiography 80
        MVA Assessment by Planimetry 83
        Mitral Leaflet Separation Index 84
        Mitral Valve Morphology 85
        Valve Thickening 86
        Valve Calcification 86
    Subvalvar Pathology 87
        Chambers, Septum and Thrombi 89
    Left Atrium 90
        Left Ventricle 90
        Interatrial Septum 92
    Assessment of Lesions in Other Valves 93
    Transesophageal Echocardiography in PMV 93
    Doppler Assessment of Mitral Valve 95
    Pressure Half-time 100
        Advantages of PHT 101
        Disadvantages of PHT 101
11. **Subvalvular Apparatus in Rheumatic Mitral Stenosis—Methods of Assessment and Therapeutic Implications** ............................................... 119

Yoav Turgeman

Anatomy and Function of Subvalvar Apparatus 120

*SVAp Involvement in Rheumatic Heart Disease* 120

Methods of Assessment of the SVA 121

*Noninvasive Methods* 121

*Invasive Methods* 123

*During PBMV* 124

The Impact of SVA Deformity on the Results of PBMV 126

Clinical Implications and Conclusion 126

12. **Atrial Function in Mitral Stenosis—Effect of Percutaneous Mitral Valvuloplasty** ................................................................. 130

Tomás F Cianciulli, María C Saccheri

*Echocardiographic Assessment of the Left Atrial Size and Function* 131

*Percutaneous Mitral Valvuloplasty and Atrial Function* 133

---

**Section 3: Pmv—Procedure, Technical Considerations and Peri-procedural Monitoring**

13. **Trans-septal Puncture** ................................................................. 141

Harikrishnan S, Krishnakumar Nair

Anatomy of the Atrial Septum 141

How to Perform Trans-septal Puncture 144

*Catheters/Instruments Needed* 144

*Steps in Trans-septal Puncture* 147

Landmarks for Septal Puncture 152

*Needle Orientation* 153
Contents

14. Use of Safe-Sept Guidewire in Trans-septal Access ..... 160
Carlo de Asmundis, Jayakeerthi Yoganarasimha Rao, Gian Battista Chierchia, Andrea Sarkozy, Pedro Brugada
Indications 160
Technical Aspects 160
Advantages of Safe-Sept Guidewire 163
Limitations 163
Our Suggestions 163

15. Percutaneous Mitral Valvotomy (PMV)—Procedure .... 165
Harikrishnan S, Sanjay G, Rajesh Muralidharan
Preparation of the Patient (SCTIMST Protocol) 165
Obtaining the Vascular Access 165
Preparation of the Septal Puncture System and the Balloon 166
Steps of Percutaneous Mitral Valvotomy (PMV) 167
Assessing Hemodynamics 167
Septal Puncture 167
Entering the Left Atrium and Balloon Inflation 167
Increase in Mitral Regurgitation (MR) 173

16. Peri-procedural Monitoring during PMV .................. 175
S Venkiteshwaran, Suchith Majumdar
What We do in Our Cathlab in SCTIMST 176
Pitfalls in Gorlin Equation 177
Other Formulas to Calculate Mitral Valve Area (MVA) 179
Hakki’s Formula 179
Cui’s Method 179

17. Anesthetic Management during Percutaneous Mitral Valvuloplasty ............................................. 182
Thomas Koshy
Patient Evaluation Prior to PMV 182
Precatheterization Preparation 183
Premedication 184
Monitoring during PMV 184
Sedation 184
General Anesthesia 185
Management of Complications 185
PMV and the Anesthesiologist 186

18. Intracardiac Echocardiography Imaging in Percutaneous Balloon Mitral Valvuloplasty .......... 188
Santhosh KG Koshy, Antwon Robinson
History and Evolution 188
Advantages and Limitations 189
Percutaneous Balloon Mitral Valvuloplasty 190
Section 4: PMV—Techniques and Gadgets

19. Comparison of Different Techniques and Devices for Percutaneous Mitral Valvuloplasty—Introduction ...... 201
Mohammad A Sherif
Historical Background 201
Techniques Available for Percutaneous Mitral Valvotomy 202

20. Double Balloon Technique............................................. 204
Mohammad A Sherif
DBT-Technique 204
Balloon Sizing 205
  Sizing Based on Annulus Diameter 205
  Sizing Based on Body Surface Area 205

21. Mitral Valvotomy by Metallic Commissurotome ....... 208
Mohammad A Sherif, Harikrishnan S
Description of the Device 208
Mechanism of Valvotomy with Metallic Commissurotome 210
Technique 210
Technical Considerations 212
  Crossing the Septum and the Mitral Orifice 212
  Positioning the Device Across the Mitral Valve 212
  Extent of Bar Opening 212
Complications 213
Initial and Long-term Results 213

22. Inoue and Accura Balloons—The Single Balloon Mitral Valvotomy Catheters............................................ 215
Harikrishnan S, Krishnakumar M, Suji K
Anatomy of Inoue and Accura Balloons 216
Pressure Volume Relationship 219
Inoue Balloon PMV System—Description and Specifications 221
Accura Balloon—Description 221
Balloon Selection 223
Advantages of the Single Balloon Technique 225

23. JOMIVA Balloon........................................................... 227
Sajy Kuruttukulam
Technique 227
  Femoral Approach 227
  Jugular Approach 229
24. Other Gadgets for Percutaneous Mitral Valvotomy ..... 230
Mohammad A Sherif, Harikrishnan S

Multi-Track System 230
Description of the Device 230
Selection of the Size of the Balloon Catheters 230
Technique 230
Nucleus™ Balloon 232

25. Percutaneous Mitral Valvuloplasty—Comparative Analysis of Different Gadgets 234
Mohammad A Sherif

Inoue Versus Double Balloon 235
Inoue Balloon Technique Versus Percutaneous Metallic Commissurotomy 237

26. Re-use and Re-sterilization of PMV Hardware 241
Suji K, Sethu Parvathy VK

Methods of Sterilization 242
Ethylene Oxide 242
Glutaraldehyde Sterilization 242
Re-sterilization Process of the PMV Hardware 243
Re-sterilization of Inoue Balloon 243
Quality Control 244
Economic Aspects of Re-use 244

Section 5: Complications Following PMV

27. Device Related Complications during PMV 249
Harikrishnan S

Breakage of Coiled LA Wire 249
Entrapment of the Pigtai1 Guidewire 251
Balloon Rupture during PMV 253
Balloon Impasse 255

28. Complications of Trans-septal Puncture and Management 257
Harikrishnan S, Meera R

Suspected Pericardial Tamponade 257
Management 258
Reversal of Heparin—Protamine 259
Autotransfusion 260

29. Neurological Complications Related to Percutaneous Mitral Valvotomy 262
Sajith Sukumaran

Systemic Embolism in Patients with Mitral Stenosis 262
Factors Associated with Systemic Embolization in Patients with Mitral Stenosis 263
Percutaneous Mitral Valvotomy

Percutaneous Balloon Mitral Commissurotomy and Systemic Embolism 263
Prevention of Cardioembolic Stroke in Rheumatic Mitral Stenosis during Percutaneous Mitral Interventions 264
Treatment Options 264

30. **Arrhythmias and its Management during PMV** .......... 268
   **Shomu R Bohora**
   Arrhythmias during PMV 268
   Pre-procedure Management of Atrial Fibrillation 270
   Post-procedure Management of Atrial Fibrillation 271
   Atrial Flutter 274

31. **Emergency Surgery after Percutaneous Mitral Valvotomy** .............................................. 277
   **Praveen Reddy Bayya, Praveen Kumar Neema,**
   **Praveen Kerala Varma**
   Incidence 277
   Hemopericardium and Cardiac Tamponade 277
   Mechanism of Hemopericardium 278
   Management of Hemopericardium and Cardiac Tamponade 279
   Acute Mitral Regurgitation 279
   Presentation 279
   Mechanism of Mitral Insufficiency 280
   Management of Mitral Insufficiency 281
   Mortality and Morbidity 282

32. **Deflation Failure of Mitral Valvuloplasty Balloon** ...... 283
   **Pranav Bansal, Mamtesh Gupta, RD Yadave**
   Deflation Failure of Mitral Valvuloplasty Balloon 283
   Possible Mechanisms of Deflation Failure of Inoue Balloon Assembly 283

33. **Troubleshooting of Single Balloon Catheters—**
    **Inoue and Accura Balloon** ........................................... 290
    **Harikrishnan S**
    Kinking of the Balloon 290
    Loss of Balloon Volume 292
    Twisting of the Inner Tube of the Balloon 293
    Tear in the Balloon 294
    Troubleshooting in the Event of a Tear 295

Section 6: PMV in Special Situations

34. **Percutaneous Mitral Valvotomy in Pregnancy** .......... 299
    **Shyam Sundar Reddy**
    Mitral Stenosis and Pregnancy 299
    Medical Therapy 300
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interventions in Mitral Stenosis in Pregnancy</td>
<td>301</td>
</tr>
<tr>
<td>Percutaneous Mitral Valvotomy (PMV) in Pregnancy</td>
<td>301</td>
</tr>
<tr>
<td>PMV in Pregnancy—Procedural Details</td>
<td>302</td>
</tr>
<tr>
<td>Short and Long-term Outcomes Following PMV in Pregnancy</td>
<td>304</td>
</tr>
<tr>
<td><strong>35. Percutaneous Mitral Valvotomy</strong></td>
<td>308</td>
</tr>
<tr>
<td>in Juvenile Mitral Stenosis</td>
<td></td>
</tr>
<tr>
<td>Randeep Singla</td>
<td></td>
</tr>
<tr>
<td>Indications for Balloon Mitral Valvotomy (BMV) in Juvenile Mitral Stenosis</td>
<td>308</td>
</tr>
<tr>
<td>Valve Morphology</td>
<td>308</td>
</tr>
<tr>
<td>BMV Procedure in Juvenile MS</td>
<td>308</td>
</tr>
<tr>
<td>Vascular Access</td>
<td>309</td>
</tr>
<tr>
<td>Balloon Selection and Dilatation</td>
<td>309</td>
</tr>
<tr>
<td>Immediate Hemodynamic Results</td>
<td>309</td>
</tr>
<tr>
<td>Complications</td>
<td>310</td>
</tr>
<tr>
<td>Long-term Outcome</td>
<td>310</td>
</tr>
<tr>
<td>Restenosis</td>
<td>310</td>
</tr>
<tr>
<td>Repeat PMV in Juvenile MS</td>
<td>310</td>
</tr>
<tr>
<td><strong>36. Percutaneous Mitral Valvotomy in Mitral Restenosis</strong></td>
<td>312</td>
</tr>
<tr>
<td>Krishnakumar Nair, Harikrishnan S</td>
<td></td>
</tr>
<tr>
<td>Prevalence</td>
<td>313</td>
</tr>
<tr>
<td>Predictors of Restenosis</td>
<td>313</td>
</tr>
<tr>
<td>Pathology</td>
<td>314</td>
</tr>
<tr>
<td>Management</td>
<td>315</td>
</tr>
<tr>
<td>PMV for Restenosis Versus PMV for de novo Mitral Stenosis</td>
<td>315</td>
</tr>
<tr>
<td>Predictors of Success of PMV for Mitral Restenosis</td>
<td>316</td>
</tr>
<tr>
<td>Repeat Surgical Commissurotomy Versus PMV for Mitral Restenosis</td>
<td>316</td>
</tr>
<tr>
<td>Do Patients with Prior PMV Fare Better than Patients with Prior CMV at the time of the Second Procedure?</td>
<td>317</td>
</tr>
<tr>
<td>Late Results and Event-free Survival after PMV for Mitral Restenosis</td>
<td>317</td>
</tr>
<tr>
<td>Technical Considerations during PMV for Mitral Restenosis</td>
<td>317</td>
</tr>
<tr>
<td><strong>37. PMV in Patients with Atrial Fibrillation</strong></td>
<td>323</td>
</tr>
<tr>
<td>Krishnakumar M</td>
<td></td>
</tr>
<tr>
<td>Mechanism of Atrial Fibrillation in Mitral Stenosis</td>
<td>323</td>
</tr>
<tr>
<td>Problems</td>
<td>325</td>
</tr>
<tr>
<td>Medical Management</td>
<td>326</td>
</tr>
<tr>
<td>Technical Difficulties in PMV</td>
<td>327</td>
</tr>
<tr>
<td>Long-term Outcome</td>
<td>327</td>
</tr>
<tr>
<td>Restoration and Maintenance of Sinus Rhythm in Mitral Stenosis</td>
<td>328</td>
</tr>
<tr>
<td><strong>38. Transjugular Percutaneous Mitral Valvotomy</strong></td>
<td>333</td>
</tr>
<tr>
<td>Boonjong Saejueng, Sudaratana Tansuphasawadikul</td>
<td></td>
</tr>
<tr>
<td>Transjugular Interatrial Septal Puncture</td>
<td>333</td>
</tr>
<tr>
<td>Landmark for Optimal Puncture</td>
<td>333</td>
</tr>
<tr>
<td>Procedure of Septal Puncture</td>
<td>335</td>
</tr>
</tbody>
</table>
Percutaneous Mitral Valvotomy

39. Balloon Mitral Valvotomy—Left Femoral Vein Approach .......................................................... 340
   Rajesh Muralidharan

40. Percutaneous Mitral Valvotomy in Dextrocardia .......... 344
    Harikrishnan S, Krishnakumar Nair

41. PMV Performed with Other Percutaneous Interventions .............................................................. 349
    Harikrishnan S, Dinesh Choudhary
    PMV and Percutaneous Valvotomy of Other Valves 349
    Which Valve to Tackle First? 349
    PMV and Percutaneous Aortic Valvotomy 350
    PAV Along with PMV—Techniques 351
       Retrograde Technique 351
       Antegrade Technique 351
    PMV and Balloon Pulmonary Valvotomy 352
    Triple Valve Intervention 355
    Percutaneous Coronary Intervention and PMV 355

42. Balloon Tricuspid Valvotomy Along with PMV ........... 358
    Harikrishnan S, Chaurasia Amit Kumar
       Technique 359
       Inoue Balloon 361
       Bhargava Algorithm for BTV Using Inoue Balloon 361
       ‘Over the Wire’ Technique 362
       Complications Related to BTV 363

43. PMV in Technically Challenging Situations ............... 364
    Harikrishnan S, Rohan Vijay Ainchwar
    Calcification of the Valve 364
    Left Atrial Thrombi 365
    Difficulty at the Groin Puncture Site 365
    Difficulty in Septal Puncture, Dilatation and Balloon Entry 367
       Large Left Atrium 367
       Problems in Needle Entry into LA—Needle “Jerk” 368
    Difficulty in Negotiating the Atrial Septum 369
    Balloon Catheter Stuck at Septum—“Septal Catch” 369
       “Hairpin Loop” Entry 370
       Reverse Loop Entry 370
       Difficulty in Crossing the Valve 371
    Techniques Facilitating Entry of Balloon Across Mitral Valve 372
       Changing the Shape of the Stylet 372
       “Over-the-Wire” LV Entry 372
       Catheter Sliding Method 376
    Entry of Balloon Through the Secondary Orifices 377
Failure to Dilate the Valve 377
Popping of the Balloon Back to Left Atrium 378
Small Left Atrium 379
PMV in Small Children 381

44. Left Atrial Thrombosis in Rheumatic Mitral Stenosis 385
Sonney P Jacob
Left Atrial Thrombus—Types 387
Balloon Valvotomy in Patients with LA Thrombus 388

Section 7: Long-term Outcome Following PMV

45. Comparison of Percutaneous Mitral Valvotomy and Surgical Mitral Commissurotomy 395
Sanjay G
Introduction 395
Studies Comparing the Techniques of Surgical Mitral Commissurotomy 395
Studies Comparing PMV and Surgical Commissurotomy 396
PMV vs Surgical Commissurotomy in Special Situations 397
Pregnancy 397
Calcific Mitral Valve 398
Mitral Restenosis 398

46. Mitral Regurgitation Following Percutaneous Mitral Valvotomy 401
Rachel Daniel, Anees Thajudeen, Harikrishnan S
Mechanism of Mitral Regurgitation Following PMV 401
Incidence 402
Clinical Course of MR 404
Mechanisms of Reduction in MR 405
Surgical Management of MR Following PMV 406

47. Atrial Septal Defects Following Percutaneous Mitral Valvotomy 409
Harikrishnan S, Kiron Sukulal

48. Pulmonary Hypertension in Rheumatic Mitral Stenosis—Influence of Balloon Mitral Valvotomy 412
Harikrishnan S, Chandrasekharan C Kartha
Pathogenesis of PH in RHD 412
Evaluation of PH in RHD 412
PH in Rheumatic Mitral Valve Disease 415
Pathological Findings 416
Treatment Options and Effect of Treatments 418
Effect of Balloon Mitral Valvotomy on PH 418
Juvenile Mitral Stenosis 420
49. Long-term Follow-up of Patients Undergoing Percutaneous Mitral Valvotomy

Rachel Daniel

Factors Affecting Long-term Prognosis after PMV 424
Symptom Benefit Following PMV 424
Effect of Atrial Fibrillation 425
Effect of Mitral Regurgitation 425
Clinical Course of Tricuspid Regurgitation Following PMV 425
Mitral Restenosis and Long-term Outcome 426
Follow-up and Management of Patients after BMV 426
MS and Sinus Rhythm 426
MS and AF 426
Infective Endocarditis Prophylaxis 427
Rheumatic Fever Prophylaxis 427

50. Setting Up a PMV Program

Harikrishnan S, SJ Arulkumar Ajeet

Personnel 431
Physicians with Adequate Training 431
Nursing Staff 431
Cath Lab Technicians 432
Equipments 432
Cath Lab 432
Echocardiographic Monitoring 433
Re-sterilization Facility 433
Supporting Team 433
Surgical Standby 433
Anesthesiologists 433

Index 435