

Acknowledgements xv

Foreword xvi

Preface xviii

Personal Prefaces xx

List of Abbreviations xxiii

Contributors xxiv

Section I: Lymphology and Clinical Presentation

Edited by Yves Harder and Katrin Seidenstücker

1	Lymphatic System	3		
1.1	Embryology of the Lymphatic System	3	1.3.2	The Lymphatic System and Its Immunological Function
	<i>Florian Fröh, Patrick A. Will, and Epameinondas Gousopoulos</i>			9
1.2	Anatomy of the Lymphatic System	4	1.4	Lymphangiogenesis
	<i>Hiroo Suami</i>			<i>Patrick A. Will</i>
1.3	Physiology of the Lymphatic System	7	1.4.1	Potential Therapeutic Approaches and Future Perspectives
	<i>Florian Fröh, Patrick A. Will, and Epameinondas Gousopoulos</i>			12
1.3.1	The Lymphatic System to Transport Lymph Fluid (Circulating System)	8		References
				12
2	Epidemiological, Clinical, and Pathophysiological Aspects	14		
2.1	Etiology including Lymphatic Malformations	14	2.4	Pathophysiology
	<i>Stephan Wagner and Jörg Wilting</i>			<i>Katja Kilian</i>
2.2	Prevalence	15	2.5	Stages and Classification of Lymphedema
	<i>Katja Kilian</i>			<i>Stephan Wagner and Katja Kilian</i>
2.3	Incidence	16		References
	<i>Katja Kilian</i>			19
3	Lymphatic Filariasis	21		
	<i>Gurusamy Manokaran and Leela Praveen Kumar</i>			
3.1	Prevalence	21	3.2.1	Pathology
				22
3.2	Pathophysiology	21	3.3	Clinical Manifestations
				22

Contents

3.3.1	Diagnosis	22	3.4.3	Management of Stage III and IV.....	24
3.3.2	Clinical Classification of Filarial Lymphedema	23	3.4.4	Management of Stage V, VI, and VII	24
3.4	Management	23	3.5	Clinical Case	24
3.4.1	Management of Filarial Lymphedema	23	3.6	Conclusions	24
3.4.2	Management of Stage I and II	23	References	25	

Section II: Diagnostic Evaluation

Edited by Christoph Hirche

4	Diagnostics and Stage-Dependent Preoperative Evaluation	29			
4.1	Medical History	29	4.6.2	Lymphangiography	39
	<i>Tomke Cordts</i>		4.6.3	Reversed Lymphatic Mapping	41
4.2	Clinical Examination	29	4.6.4	Conclusions	42
	<i>Tomke Cordts</i>		4.7	Magnetic Resonance Imaging	43
4.2.1	Tissue Resistance	30		<i>Carola Brussaard</i>	
4.3	Nonapparative Volume Measurement	30	4.7.1	Conventional Magnetic Resonance Imaging: Detection of Free Movable Fluid, Fat Deposition as Stage Parameter, and Volumetry	43
	<i>Tomke Cordts</i>		4.7.2	Magnetic Resonance Imaging of Lymphatic Vessels	44
4.3.1	Circumference	31	4.7.3	Tips and Tricks	48
4.3.2	Water Displacement	32	4.8	Functional Magnetic Resonance Lymphangiography	48
4.4	Ultrasound Imaging	33		<i>Carola Brussaard, Hans Schild, and Claus Christian Pieper</i>	
	<i>Giuseppe Visconti, Alessendro Bianchi, Marzia Salgarello, and Akitatsu Hayashi</i>		4.8.1	Technique	48
4.4.1	Advantages of Technology in Preoperative Planning of Lymphovenous Anastomoses	35	4.8.2	Diagnosis of Peripheral Lymphatic Leakage	50
4.4.2	Advantages of Ultrasound in Preoperative Planning of Vascularized Lymph Node Transfer	36	4.9	Pearls and Pitfalls	51
4.5	Scintigraphic Lymphangiography	36		<i>Tomke Cordts</i>	
	<i>Pierre Bourgeois</i>		References	52	
4.6	Indocyanine Green Near-Infrared Imaging	38			
	<i>Emre Gazyakan</i>				
4.6.1	Indocyanine Green	38			

Section III: Modern Management of Chronic Lymphedema

Edited by Yves Harder

5	Establishment of an Interprofessional and Multidisciplinary Lymphedema Network.	57
	<i>Holger Engel</i>	
5.1	Presentation of the Concept	57
5.2	Goals	57
5.3	Organizational Structure and Involved Personnel	58
5.4	Funding	58
5.5	Marketing	58
5.6	Expert Group/Lymphedema Board and Patient Advocacy	58
5.7	Evidence-Based Medical Care	59
5.8	Future of Lymphedema Networks and Data-Driven Medicine	59
5.9	Pearls and Pitfalls	59
	References	59

Section IV: Non-Surgical Treatment and Techniques

Edited by Christoph Hirche

6	Integrative, Multiprofessional Conservative Treatment.	63
	<i>Joachim E. Zuther</i>	
6.1	Background	63
6.2	Complete Decongestive Therapy	63
6.2.1	Goals of Complete Decongestive Therapy.	63
6.2.2	Components of Complete Decongestive Therapy.	64
6.3	The Two-Phase Approach in Lymphedema Management.	79
6.3.1	Intensive Phase	79
6.3.2	Self-Management Phase.	81
6.3.3	Patient Education	81
6.4	Limitations of Complete Decongestive Therapy in Lymphedema Management	81
6.5	Additional Treatment Modalities	83
6.5.1	Sequential Intermittent Pneumatic Compression	83
6.5.2	Elastic Taping.	84
6.6	Documentation and Screening Modalities for Conservative Lymphedema Management.	85
6.7	Role of Weight Management, Nutrition, and Supplements	86
6.8	Outpatient versus Inpatient Treatment	86
6.9	Wound Management in Lymphedema Patients	86
6.9.1	Types of Lymphedema-Related Wounds	86
6.9.2	Modification of Lymphedema Bandaging in the Presence of Wounds	88
	References	88

Section V: Surgical Treatment and Techniques

Edited by Yves Harder

7	Basic Principles of Surgical Treatment and Accompanying Complete Decongestive Therapy	91
7.1	Lymphatic Surgery	91
	<i>Jaume Masià and Cristhian D. Pomata</i>	
7.1.1	Introduction	91
7.1.2	Pathophysiological Aspects and Clinical Considerations	91
7.1.3	Diagnostic Imaging Techniques	92
7.1.4	Surgical Procedures	92
7.1.5	Conclusions	93
7.2	Complete Decongestive Therapy in the Pre- and Postoperative Setting	93
	<i>Nele Adriaenssens, Ellen Vandyck, and Sarah Harnie</i>	
7.2.1	Introduction	93
7.2.2	Background	94
7.2.3	Evidence-Based Practice for Perioperative Complete Decongestive Therapy	96
7.2.4	Best Practices—the Expert’s Opinion	99
7.2.5	Discussion	100
7.2.6	Conclusions	102
	References	102

Section VI: Lymphoreconstructive Procedures

Edited by Yves Harder, Christoph Hirche, Katrin Seidenstücker, and Moustapha Hamdi

8	Lymphovenous Anastomosis	107
	<i>Johnson Chia-Shen Yang and Christoph Hirche</i>	
8.1	Introduction	107
8.1.1	Definition	107
8.1.2	Key Concepts of Supermicrosurgical Lymphovenous Anastomosis	108
8.2	Indications and Contraindications for Lymphovenous Anastomosis	110
8.2.1	Current Consensus Regarding Surgical Treatment for Lymphedema with Lymphovenous Anastomosis	110
8.2.2	Indications	111
8.2.3	Contraindications	111
8.3	Preoperative Evaluation and Planning	111
8.3.1	Medical History	111
8.3.2	Preoperative Evaluation for Lymphovenous Anastomosis	112
8.3.3	Identifying Functional Lymphatic Vessels	112
8.3.4	Timing for the Indocyanine Green Injection for the Identification of Functional Lymphatic Vessels	112
8.3.5	Identifying Reflux-Free Veins with a Vein Finder (Vein Viewer)	112
8.3.6	Other Imaging Studies for Preoperative Evaluation and Planning of Lymphovenous Anastomosis	113
8.4	Surgical Setting and Technique	113
8.4.1	Anesthesia: Local, Regional, or General	113
8.4.2	Intraoperative Position	114
8.4.3	Technique of Supermicrosurgical Lymphovenous Anastomosis	115
8.4.4	Which Suture Technique Is Best Suited for Supermicrosurgery?	116
8.4.5	Documentation	117
8.4.6	Dressing	117

8.5	Type and Configuration of Lymphovenous Anastomosis	117	8.6.2	Mobile Indocyanine Green Near-Infrared Systems (Selection)	122
8.5.1	Key Factors to a Successful Lymphovenous Anastomosis.	117	8.6.3	Supermicrosurgical Instruments (Selection)	123
8.5.2	End-to-End Lymphovenous Anastomosis.	118	8.7	Additional Intraoperative Tools	123
8.5.3	End-to-Side Lymphovenous Anastomosis.	118	8.7.1	Indocyanine Green Lymphangiography	123
8.5.4	Side-to-End Lymphovenous Anastomosis.	119	8.7.2	Blue Dye	123
8.5.5	End-to-End Lymphovenous Anastomosis in Conjunction with End-to-Side Lymphovenous Anastomosis: The Lambda-Shaped Lymphovenous Anastomosis.	119	8.8	Patient Education	123
8.5.6	Side-to-Side Lymphovenous Anastomosis.	120	8.8.1	Before Lymphovenous Anastomosis	123
8.5.7	End-to-Side Lympholymphatic Anastomosis.	120	8.8.2	After Lymphovenous Anastomosis	123
8.5.8	Comparison among Different Lymphovenous Anastomosis Types	120	8.9	Robotic Lymphovenous Anastomosis Microsurgery	124
8.5.9	Lymphovenous Anastomosis for Single Recipient Vein and Multiple Lymphatic Vessels.	121	8.10	How to Advance Your Supermicrosurgical Skills for Lymphovenous Anastomosis	124
8.5.10	Lymphovenous Implantation or “Octopus” Anastomosis.	121	8.11	Perspective	124
8.6	Surgical Equipment	121	8.12	Clinical Cases	124
8.6.1	Surgical Microscopes (Selection)	121	8.13	Pearls and Pitfalls	124
				References	125
9	Autologous Lymph Vessel Transfer	127			
	<i>Ruediger Baumeister, Andreas Frick, and Christiane G. Stäuble</i>				
9.1	Indications and Contraindications	127	9.6	Number of Used Lymphatic Collectors	130
9.2	Preoperative Considerations	127	9.7	Surgical Equipment	130
9.3	Operative Technique	127	9.8	Postoperative Management	130
9.3.1	Harvesting the Lymphatic Graft	128	9.9	Pearls and Pitfalls	130
9.3.2	Autologous Lymph Vessel Transfer to the Axilla Region	128	9.10	Clinical Cases	131
9.3.3	Autologous Lymph Vessel Transfer in the Groin Region	129		References	132
9.4	Type of Vessel Transfer	130			
9.5	Interpositional Graft	130			

10	Vascularized Lymph Node Transfer	133
10.1	Donor Sites: Anatomical Basics and Clinical Reality	133
	<i>Moustapha Hamdi, Chieh-Han Tzou, and Julia Roka-Palkovitz</i>	
10.1.1	Inguinal Lymph Node Transfer	133
10.1.2	Supraclavicular Lymph Node Transfer	134
10.1.3	Lateral Thoracic/Thoracodorsal Lymph Node Transfer	136
10.1.4	Submental Lymph Node Transfer	137
10.1.5	Omental Lymph Node Transfer	138
10.1.6	Gastroepiploic Lymph Node Transfer	138
10.1.7	Jejunal Mesenteric Lymph Node Transfer	138
10.2	Indications and Contraindications	139
	<i>Holger Engel</i>	
10.3	Preoperative Evaluation and Planning	140
	<i>Holger Engel</i>	
10.4	Choice and Management of Donor and Recipient Sites	140
	<i>Holger Engel and Katrin Seidenstücker</i>	
10.4.1	Proximal versus Distal Recipient Area, Scar Management, and Flap Types	140
10.4.2	Inguinal Vascularized Lymph Node Transfer to Distal Recipient (Wrist)	141
10.5	Surgical Technique	143
	<i>Moustapha Hamdi, Holger Engel, and Katrin Seidenstücker</i>	
10.5.1	Vascularized Inguinal Lymph Node Transfer	143
10.5.2	Vascularized Supraclavicular Lymph Node Transfer	143
10.5.3	Vascularized Lateral Thoracic Lymph Node Transfer	144
10.5.4	Vascularized Submental Lymph Nodes Transfer	145
10.5.5	Vascularized Jejunal Mesenteric Lymph Node Transfer	145
10.6	Robotic-Assisted Omental Lymph Node Harvest for Lymphedema Treatment	145
	<i>Moustapha Hamdi, Assaf Zeltzer, and Karl Waked</i>	
10.7	Surgical Equipment and Intraoperative Tools	146
	<i>Holger Engel</i>	
10.8	Postoperative Management	147
	<i>Katrin Seidenstücker</i>	
10.9	Patient Education	148
	<i>Katrin Seidenstücker</i>	
10.10	Pearls and Pitfalls	148
	<i>Katrin Seidenstücker</i>	
	References	148
11	Autologous Breast Reconstruction in Conjunction with Lymphatic Surgery	150
	<i>Randy De Baerdemaeker, Assaf Zeltzer, and Moustapha Hamdi</i>	
11.1	Indications and Contraindications	150
11.2	Surgical Technique	151
11.2.1	Lymphatic Anatomy of the Recipient Site	151
11.2.2	Lymphatic Anatomy of the Donor Site	151
11.2.3	Value and Extent of Scar Release of Axillar Recipient Site	152
11.2.4	Breast Reconstruction in Conjunction with Vascularized Lymph Node Flap	152
11.2.5	Breast Reconstruction in Conjunction with Lymphovenous Anastomosis	155
11.2.6	Breast Reconstruction in Conjunction with Lymph Node Flap and Lymphovenous Anastomosis ("Barcelona Cocktail" or Total Breast Anatomy Restoration)	156
11.3	Intraoperative Position	156
11.4	Postoperative Management	156
11.4.1	Complete Decongestive Therapy	156
11.4.2	Follow-ups	157
11.5	Patient Education	157

11.6	Clinical Cases	157	11.7	Pearls and Pitfalls	161
11.6.1	Case 1	157		References	161
11.6.2	Case 2	159			
12	Nodo-Venal Shunt Microsurgery	163			
	<i>Gurusamy Manokaran and Leela Praveen Kumar</i>				
12.1	General Considerations	163	12.6	Postoperative Care	165
12.2	Indications and Contraindications	163	12.7	Patient Education	165
12.3	Preoperative Assessment	163	12.8	Complications	165
12.4	Preoperative Preparation	164		References	168
12.5	Surgical Technique	164			

Section VII: Lymphoreductive Procedures, Secondary Procedures, and Tips and Tricks

Edited by Christoph Hirche, Katrin Seidenstücker, and Moustapha Hamdi

13	Suction-Assisted Lipectomy	171			
	<i>Arin K. Greene, Jeremy A. Goss, and Håkan Brorson</i>				
13.1	Indications and Contraindications	171	13.7	Clinical Cases	174
13.2	Preoperative Evaluation and Planning	171	13.7.1	Lymphedema of the Lower Extremity	174
13.3	Surgical Technique	172	13.7.2	Lymphedema of the Lower Extremity Preceded by Conservative Treatment	174
13.4	Intraoperative Position	172	13.7.3	Lymphedema of the Upper Extremity	174
13.5	Postoperative Management	172	13.8	Pearls and Pitfalls	175
13.6	Patient Education	173		References	175
14	Excisional Procedures	177			
	<i>Vincenzo Penna and Nestor Torio</i>				
14.1	Lymphoreductive Surgery	177	14.5	Intraoperative Position	181
14.2	Indications and Contraindications	177	14.6	Additional Intraoperative Tools	181
14.3	Preoperative Evaluation and Planning	178	14.7	Surgical Equipment	181
14.4	Surgical Technique	179	14.8	Postoperative Management	183
14.4.1	General Remarks	179	14.9	Patient Education	183
14.4.2	Dermolipectomies in Extremities	179	14.10	Pearls and Pitfalls	183
14.4.3	Scrotal Dermolipectomies	180		References	183
14.4.4	Vulvar Dermolipectomies	180			

15	Secondary Procedures after Reconstructive Microsurgery	184
15.1	Suction-Assisted Lipectomy	184
	<i>Amir K. Bigdeli, Andreas Frick, and Christiane G. Stäuble</i>	
15.2	Secondary Lymph Node Transfer	185
	<i>Katrin Seidenstücker</i>	
15.3	Lymphovenous Anastomosis for Chronic Lymphocele After Lymph Node Excision and/or Vascularized Lymph Node Transfer	187
	<i>Nicole Lindenblatt and Semra Uyulmaz</i>	
15.4	One Stage versus Staged-Combined Surgical Procedures to Treat Lymphedema	188
	<i>Holger Engel</i>	
15.5	Pearls and Pitfalls	190
	<i>Holger Engel</i>	
	References	191
16	Tips and Tricks for Modern Surgical Management of Chronic Lymphedema	193
16.1	How to Avoid the Wrong Surgical Technique in the Wrong Patient for the Wrong Lymphedema Stage	193
	<i>Christoph Hirche and Yves Harder</i>	
16.2	Local Dermolipectomy and Lymphoreductive Surgery	194
	<i>Vincenzo Penna and Nestor Torio</i>	
16.3	Suction-Assisted Lipectomy	194
	<i>Håkan Brorson, Arin Greene, and Jeremy Goss</i>	
16.3.1	Preoperative	194
16.3.2	Intraoperative	195
16.3.3	Postoperative	195
16.4	Lymphovenous Anastomosis	195
	<i>Johnson Chia-Shen Yang and Christoph Hirche</i>	
16.4.1	For the Surgeon	195
16.4.2	During Surgery	196
16.4.3	Regarding the Patient	196
16.5	Vascularized Lymph Node Transfer	196
	<i>Holger Engel</i>	
16.6	Autologous Breast Reconstruction in Conjunction with Vascularized Lymph Node Transfer	197
	<i>Moustapha Hamdi, Elena Rodríguez-Bauza, and Jaume Masià</i>	
16.7	Dealing with Therapeutic Failure	197
	<i>Holger Engel</i>	
16.7.1	Analysis of Causes	198
16.7.2	Secondary Procedures	198
	References	199

Section VIII: Training, Treatment Algorithm, Outcomes, and Further Developments

Edited by Christoph Hirche, Yves Harder, and Moustapha Hamdi

17	Teaching and Training in Lymphoreconstructive Surgery	203
	<i>Amir Bigdeli and Christoph Hirche</i>	
17.1	Introduction	203
17.2	Supermicrosurgical Training Models without the Use of Lymphatic Vessels ..	203
17.3	Supermicrosurgical Training Models with the Use of Lymphatic Vessels	204
17.4	Supermicrosurgical Training Models with the Use of Lymphatic Vessels for Different Types of Lymphovenous Anastomosis and for Vascularized Lymph Node Transfer	204
17.5	Robotic-Assisted Lymphedema Surgery	205
	References	206

18	Treatment Algorithm for the Surgical Management of Lymphedema	207		
	<i>Christoph Hirche, Moustapha Hamdi, Katrin Seidenstücker, and Yves Harder</i>			
18.1	Introduction.....	207	18.3.4	Surgery for Upper Extremity Lymphedema.....
18.2	Diagnostics.....	208	18.3.5	Surgery for Lower Extremity Lymphedema.....
18.3	Modern Surgical Management of Chronic Lymphedema	208	18.3.6	Surgery for Lymphedema with Fat Hypertrophy and/or Tissue Fibrosis
18.3.1	Surgery for Lymphedema Presenting with Functional Lymphatic Collectors.....	208	18.4	Conclusions
18.3.2	Surgery for Lymphedema Lacking Functional Lymphatic Collectors.....	208		References
18.3.3	Surgery for Breast Cancer-Related Lymphedema.....	209		
19	Review of the Current Literature	213		
	<i>Mario F. Scaglioni and Matteo Meroni</i>			
19.1	Introduction.....	213	19.6	Prophylactic Surgery
19.2	Lymphoreductive Surgery	213	19.7	Consensus for Treatment Indication ...
19.3	New Tools to be Used for Pre-, Intra-, and Postoperative Visualization of Lymphatic Structures	214	19.8	Conclusions
				References
19.4	Lymphoreconstructive Surgery	214		
19.5	Combined Surgical Approaches	221		
20	Experimental Research and Future Directions	227		
20.1	Animal Models.....	227	20.2.5	Conclusions
	<i>Florian Fröh</i>			
20.1.1	Introduction.....	227	20.3	Tissue Engineering for the Replacement of Lymph Nodes.....
20.1.2	Lymphedema Models in Large Animal....	227		<i>Min-Seok Kwak and Hans-Günther Machens</i>
20.1.3	Lymphedema Models in Rodents	229	20.3.1	Introduction.....
20.1.4	Challenges of Small Animal Models	230	20.3.2	The Lymphatic System
20.1.5	Conclusions	232	20.3.3	Regeneration of Lymphatic Tissue
20.2	Tissue Engineering and Replacement of Lymphatic Vascular Network	233	20.3.4	Biomaterials.....
	<i>Andreas Spörlein, Patrick A. Will, and Anja M. Boos</i>		20.3.5	Lymph Node Tissue Engineering.....
20.2.1	Introduction.....	233	20.3.6	Conclusions
20.2.2	Cells and Growth Factors for Lymphatic Tissue Engineering	233	20.4	Vascularized Lymph Node Transfer and Growth Factors
20.2.3	Scaffolds for Lymphatic Tissue Engineering—Translational Concepts	235		<i>Mikko Visuri, Pauliina Hartiala, and Anne Saaristo</i>
20.2.4	Current Achievements and Limitations ...	235	20.4.1	Introduction.....

Contents

20.4.2	Application and Delivery of Growth Factors.....	242	20.4.5	Conclusions	244
20.4.3	Experimental Background.....	242		References	245
20.4.4	Clinical Application.....	244			
	Glossary				249
	Index				251