MRI of the Liver - 2nd Edition

Imaging Techniques, Contrast Enhancement, Differential Diagnosis

Günther Schneider • Luigi Grazioli • Sanjay Saini (Eds.)

MRI of the Liver

2nd Edition

Imaging Techniques, Contrast Enhancement,
Differential Diagnosis

EDITORS

Günther Schneider, M.D.
Clinic for Diagnostic and Interventional
Radiology
University Hospital of Saarland
66421 Homburg/Saar, Germany

Luigi Grazioli, M.D.
Department of Radiology
University of Brescia
Piazzale Spedali Civili 1
25023 Brescia, Italy

Sanjay Saini, M.D.
Emory University School of Medicine
Department of Radiology
1364 Clifton Road, NE
Atlanta GA 30322, USA

CONTRIBUTORS

M.A. Kirchin
P. Fries
M.P. Bondioni
A. Massmann
K. Altmeyer
L. Olivetti
L. Romanini
R. Seidel
D.R. Martin
A. Luca
M. Harisinghani
R.V. D'Souza
D. Sahani

Library of Congress Control Number: 2005937525

ISBN 88-470-0209-5 (1st ed.) Springer Milan Berlin Heidelberg New York

ISBN-10 88-470-0335-0 (2nd ed.) Springer Milan Berlin Heidelberg New York

ISBN-13 978-88-470-0335-4 (2nd ed.) Springer Milan Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the Italian Copyright Law in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the Italian Copyright Law.

Springer is a part of Springer Science+Business Media
springer.com
© Springer-Verlag Italia 2003, 2006
Printed in Italy

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product liability: The publishers cannot guarantee the accuracy of any information about dosage and application contained in this book. In every individual case the user must check such information by consulting the relevant literature.

Cover design: Simona Colombo, Milan
Typesetting: Compostudio, Cernusco s/N (Milan)
Printing and binding: Arti Grafiche Nidasio, Assago (Milan)

Preface to the Second Edition

The practicing radiologist is continually challenged to update his/her competencies so as to deliver state-of-the-art radiological care. Nowhere is this truer than in the rapidly evolving world of magnetic resonance imaging, where innovations in both technology and diagnostic pharmaceuticals have dramatically altered the landscape of practice.

MR imaging plays an important role in the management of patients with liver disease, permitting not only the detection of benign and malignant hepatic masses but also the characterization of focal and diffuse liver lesions in a single non-invasive examination. The excellent soft tissue contrast achievable on MR imaging permits accurate assessment of both the full extent of tumor infiltration and of the relationship of tumors to adjacent vascular structures. This information is vital for decisions as to the appropriate course of treatment for a given patient. With this in mind, this book is aimed at assisting busy radiologists to incorporate the experience of experts in MR imaging of the liver into their daily practice. The contributors to this book are highly acclaimed radiologists with extensive personal experience in abdominal imaging in general and liver MR imaging in particular. The product of their efforts is a book that comprehensively reviews the many diseases that affect the liver, and describes in detail the typical enhancement features of these diseases on MR imaging. Because a number of very different MR contrast agents are now available for use in MR imaging of the liver, a feature of this book is the comparative enhancement behavior of lesions on post-contrast imaging after administration of these agents. For completion, comparison is also made with the typical enhancement behavior of lesions on alternative diagnostic imaging modalities, namely ultrasound and computed tomography.

This second edition of "MRI of the Liver" is a revised and extensively updated version of the first edition published in 2003. The chapters included in the first edition have been enriched with the most recent information available in the literature, and by the inclusion of many additional images; the opportunity to directly observe the characteristic features of the lesions under discussion represents a very efficient learning tool for practicing radiologists.

Additional chapters included in the second edition are dedicated to MR imaging of hepatic pseudolesions (Chapter 5), MR imaging of the biliary tree and gallbladder (Chapter 7), MR imaging of the liver in pediatric patients (Chapter 10) and MR angiography in liver disease (Chapter 12). Finally, an entire chapter is dedicated to comparing the available contrast agents for imaging of specific liver lesions (Chapter 8).

Much of the additional information available in this edition highlights the potential of MR imaging to be a "one-stop shop" procedure for the comprehensive evaluation of the liver, hepatic vasculature, and biliary tract. This information is essential in transplant patients and can also contribute to reducing overall health-care costs by reducing the number of imaging studies and avoiding unnecessary surgery.

The editors owe a debt of gratitude to the contributors to this book for sharing their extensive knowledge with the wider radiology community. We are also grateful to Bracco for supporting this educational endeavor. Indeed, this kind of academic-industrial partnership is what helps us provide the best care for our patients. We hope readers find the contents of this book beneficial, and we welcome feedback on how we might continue to facilitate the transfer of essential knowledge in the radiological community.

Foreword to the First Edition

It is with pleasure that I am writing the foreword for this textbook entitled “MRI of the Liver: Imaging Techniques, Contrast Enhancement, Differential Diagnosis” by Drs. Schneider, Grazioli and Saini.

If the liver has become the key organ to image in the abdomen, magnetic resonance (MR) imaging has become an indispensable modality for its evaluation. The absence of ionizing radiation, unparalleled soft tissue contrast, inherent multiplanar capability and high temporal resolution in dynamic gadolinium-enhanced imaging are major advantages over other imaging techniques. Furthermore, the introduction of contrast agents with liver specific properties has increased the usefulness of MRI for the detection and characterization of liver lesions.

This book fills a void in the current literature, giving radiologists and other physicians (primarily hepatologists and liver surgeons) interested in liver diseases the opportunity to have an up-to-date, single source of knowledge on MRI applied to the liver. This book is a combination of a manual, a reference textbook and an atlas. The first chapter constitutes a manual of liver MRI including modern imaging techniques and sequences. By including common imaging protocols tailored for the main manufacturers, it offers to practicing radiologists cookbook recipes to obtain superb liver MRI studies like the ones obtained by experts such as the authors. Current approaches to MRI of the liver using phased-array multicoils, enhanced gradients and motion reduction techniques allow us to have images with superb contrast resolution and acceptable spatial and temporal resolution. In chapter two, the authors cover the contrast administration strategy for MRI of the liver, detailing the use of both extracellular and liver specific contrast agents. The reasoning for the intravenous administration of extracellular gadolinium contrast agents as a useful adjunct in liver MRI is discussed. The increase in differences in signal intensity between normal hepatic parenchyma and hypo- or hypervascular neoplastic tissues is discussed, as are the specific enhancement patterns observed in different phases of perfusion following gadolinium administration. In addition, the rationale for using liver specific MR contrast agents is presented, with examples given for both manganese and iron oxide-based agents.

Chapter three presents a detailed overview of the histological classification of focal and diffuse liver pathologies, focusing on the essential needs of radiologists. In addition, possible classifications of focal liver lesions are presented based on their appearance on both unenhanced and contrast-enhanced MRI. Specifically, flow charts and tables for the differential diagnoses of liver lesions are presented, thereby consolidating in a single source the charts and tables found in a multiplicity of books and articles on abdominal and hepatobiliary imaging.

Chapters four and five constitute a reference on liver MRI of focal liver disease, discussing the radiological features of benign and malignant focal lesions in a systematic fashion. All benign and malignant primary liver lesions are presented from the most common such as hemangioma or hepatocellular carcinoma to the rarest such as nodular regenerative hyperplasia or epithelial hemangioendothelioma. Both pediatric and adult liver tumors are included. The sections on secondary liver lesions cover not only metastases and lymphoma, but also inflammatory and parasitic lesions. Where appropriate, the imaging features observed with other techniques (computed tomography and ultrasound) are presented for comparison.

The role of MRI in the characterization and monitoring of diffuse liver disease is recognized with a whole chapter dedicated to cirrhosis, iron overload and vascular pathol-

ogy. For completion a chapter is included on MRI of the liver post-surgery/post-ablation, an increasing challenge for abdominal radiologists given the increased frequency with which these techniques are performed.

This textbook is very well illustrated with more than 600 figures of high quality, which allow it to be seen as an atlas on liver MRI.

This textbook on MRI of the liver taps on the expertise of three obvious leaders in liver imaging, namely Drs. Günther Schneider, Luigi Grazioli and Sanjay Saini. Their respective institutions, the University Clinic of Homburg-Saar, Germany, the University Hospital of Brescia, Italy, and the Mass. General Hospital in Boston, USA, are well-known for their interest in liver radiology and, specifically, liver MRI. This truly international effort has produced a fully-encompassing source for radiologists anywhere with current and practical information. I predict that this book will influence the way we practice liver imaging: the protocols will be improved, the differential diagnosis charts will be copied and pinned up in reading rooms in many departments and overall it will have a beneficial impact.

I invite you to read the work of Drs. Schneider, Grazioli and Saini with the certainty that you will enjoy their material and information.

November, 2002

Pablo R. Ros, MD, MPH

Contents

1	Techniques for Liver MR Imaging	1
1.1	Introduction	1
1.2	MR Imaging Techniques and Concepts	2
1.2.1	T1-Weighted Sequences	5
1.2.1.1	Spoiled Gradient-Echo (SGE) Sequences	6
1.2.1.2	Out-of-Phase SGE Sequences	7
1.2.1.3	Fat Suppressed SGE Sequences	7
1.2.1.4	3D SGE Sequences	7
1.2.1.5	Motion-Insensitive SGE	9
1.2.1.6	Contrast-Enhanced SGE	9
1.2.2	T2-Weighted Sequences	11
1.2.2.1	Standard Spin-Echo and Fast Spin-Echo Sequences	11
1.2.2.2	Echo-Train Spin-Echo Sequences	11
1.2.3	The Uncooperative Patient Examination	13
1.3	Technical Factors	13
1.3.1	Surface Coils	13
1.3.2	Magnetic Field Strength	13
1.3.2.1	SAR and RF Power Deposition	14
1.3.2.2	Magnetic Field Distortions	14
1.3.2.3	Field-of-View	14
1.3.2.4	Motion	14
1.3.2.5	Contrast	14
1.3.2.6	Signal-to-Noise Ratio	14
1.3.2.7	Dielectric Effect	14
1.4	Summary	14
	References	15
2	Histopathologic Classification of Liver Pathologies	17
2.1	Benign and Malignant Nodular Hepatocellular Lesions	18
2.1.1	Regenerative Lesions	18
2.1.1.1	Monoacinar Regenerative Nodule	18
2.1.1.2	Multiacinar Regenerative Nodule	19
2.1.1.3	Lobar or Segmental Hyperplasia	19
2.1.1.4	Cirrhotic Nodule (Monoacinar Cirrhotic Nodule / Multiacinar Cirrhotic Nodule)	19
2.1.1.5	Focal Nodular Hyperplasia (FNH)	19
2.1.2	Dysplastic or Neoplastic Lesions	21
2.1.2.1	Hepatocellular Adenoma	21
2.1.2.2	Dysplastic Focus	22
2.1.2.3	Dysplastic Nodule	22

2.1.2.4	Hepatocellular Carcinoma (HCC)	23
2.1.2.5	Fibrolamellar Carcinoma (FLC)	25
2.2	Benign and Malignant Tumors of the Biliary Tract	26
2.2.1	Bile Duct Adenoma	26
2.2.2	Bile Duct Cystadenoma	26
2.2.3	Biliary Papillomatosis	26
2.2.4	Bile Duct Carcinoma (Cholangiocarcinoma, CCC)	26
2.2.5	Bile Duct Cystadenocarcinoma	27
2.2.6	Gallbladder Carcinoma	28
2.3	Benign Non-Epithelial Tumors	28
2.3.1	Hemangioma	28
2.3.2	Infantile Hemangioendothelioma (IHE)	28
2.3.3	Lymphangioma	29
2.3.4	Angiomyolipoma	29
2.4	Malignant Non-Epithelial Tumors	29
2.4.1	Angiosarcoma	29
2.4.2	Malignant Epithelioid Hemangioendothelioma (EHE)	29
2.4.3	Undifferentiated (Embryonal) Sarcoma	30
2.4.4	Rhabdomyosarcoma (Sarcoma Botryoides)	30
2.4.5	Other Primary Sarcomas	30
2.4.6	Primary Lymphoma of the Liver	30
2.5	Hepatoblastoma	31
2.6	Tumor-like Lesions	31
2.6.1	Cysts	31
2.6.1.1	Non-Parasitic Cysts	31
2.6.2	Mesenchymal Hamartoma	32
2.6.3	Biliary Hamartoma	32
2.6.4	Inflammatory Pseudotumor (IPT)	32
2.6.5	Other Tumor-like Lesions: Peliosis Hepatis	32
2.7	Infectious Diseases of the Liver	33
2.7.1	Liver Abscess	33
2.7.1.1	Abscess Formation in Bile Ducts	34
2.7.2	Helminthic Infections	34
2.7.2.1	Nematodes (Ascariasis)	34
2.7.2.2	Cestodes (<i>Echinococcus</i>)	34
2.7.2.3	Trematodes (Schistosomiasis)	34
2.8	Parenchymal Disease	34
2.8.1	Hemochromatosis	34
2.8.2	Transfusional Iron Overload (Hemosiderosis)	35
2.8.3	Fatty Liver	35
2.8.4	Wilson's Disease	35
2.8.5	Primary Sclerosing Cholangitis	36
2.8.6	Cirrhosis	36
2.8.7	Primary Biliary Cirrhosis	37
2.8.8	Secondary Biliary Cirrhosis	37
2.8.9	Reye's Syndrome	38
2.8.10	Caroli's Syndrome	38
2.8.11	Liver Disease in Patients with Cystic Kidneys	38
2.8.11.1	Cystic Liver Disease in Combination with Cystic Kidney Disease	38
2.8.11.2	Congenital Hepatic Fibrosis and Cystic Kidneys	38
2.8.12	Langerhans' Cell Histiocytosis	39
2.8.13	Storage Diseases	39
2.8.13.1	Glycogen Storage Disease	39

2.8.13.2	Galactosemia	39
2.8.13.3	Hereditary Intolerance of Fructose	40
2.8.13.4	Mucopolysaccharidosis	40
2.8.14	Viral Hepatitis	40
2.8.14.1	Acute Hepatitis	40
2.8.14.2	Chronic Hepatitis	40
2.8.15	Liver Disease in Congestive Heart Disease	40
2.9	Vascular Changes.	41
2.9.1	Thrombosis of the Portal Vein	41
2.9.2	Obstruction of Smaller Portal Branches	41
2.9.3	Budd-Chiari Syndrome	41
2.9.4	Veno-Occlusive Disease (VOD)	42
2.9.5	Lobular or Segmental Atrophy	42
2.9.6	Infarction / Ischemia	42
2.10	HIV-associated Liver Diseases	43
2.10.1	Kaposi's Sarcoma	43
2.10.2	Primary Lymphoma of the Liver	43
2.10.3	Cholangitis	43
2.10.4	Fungal Infections	43
2.10.5	Protozoal Infections	43
2.10.6	Bacterial Infections	43
2.11	Hepatic Trauma	44
2.12	Metastases	44
2.12.1	Metastases of Colorectal Adenocarcinoma	45
2.12.2	Liver Metastases of Breast Carcinoma	45
2.12.3	Carcinoid Metastases	45
2.13	Infiltration of the Liver in Hematologic Diseases	46
2.13.1	Non-Hodgkin's Lymphoma (NHL)	46
2.13.2	Hepatic Hodgkin's Lymphoma	46
	References	46
3	Contrast Agents for Liver MR Imaging	53
3.1	Introduction	53
3.1.1	Non-Specific Gadolinium Chelates	54
3.1.2	Hepatocyte-Targeted Contrast Agents	58
3.1.3	Agents with Combined Extracellular and Hepatocyte-Specific Distribution	60
3.1.4	RES-Specific Contrast Agents	62
3.2	Injection Schemes for Liver MRI with Different Contrast Agents.	72
3.3	Radiologic Classification of Focal Liver Lesions on Unenhanced and Contrast-Enhanced MRI	73
3.4	Summary	74
	References	82
4	Imaging of Benign Focal Liver Lesions	89
4.1	Primary Benign Liver Lesions	89
4.1.1	Hemangioma	89
4.1.2	Focal Nodular Hyperplasia	97
4.1.3	Hepatocellular Adenoma	113
4.1.4	Nodular Regenerative Hyperplasia	123

4.1.5	Cysts	130
4.1.6	Miscellaneous Tumors.....	135
4.1.6.1	Lipomatous Tumors.....	135
4.1.6.2	Leiomyoma	137
4.2	Secondary Benign Liver Lesions	137
4.2.1	Pyogenic Abscess	137
4.2.2	Amebic Abscess.....	141
4.2.3	Candidiasis Infection	143
4.2.4	Echinococcal Cyst.....	143
	References	146
5	Hepatic Pseudolesions	151
5.1	Pathophysiologic Background	151
5.1.1	Anatomic Variants of the Hepatic Circulation.....	152
5.1.2	Vascular Abnormalities.....	152
5.1.2.1	Portal Vein Compromise.....	152
5.1.2.2	Hepatic Artery Compromise.....	153
5.1.2.3	Hepatic Vein Compromise	153
5.2	Parenchymal Pseudolesions	153
5.2.1	Focal Fatty Liver	153
5.2.2	Focal Spared Areas in Fatty Liver.....	161
5.2.3	Inflammatory Pseudotumors	161
5.2.4	Peliosis Hepatis	168
5.2.5	Confluent Hepatic Fibrosis	170
5.2.6	Segmental Hypertrophy.....	172
5.2.7	Parenchymal Compression.....	172
5.3	Vascular Pseudolesions	174
5.3.1	Transient Hepatic Attenuation Differences (THAD)	174
5.3.2	Vascular Malformations	174
5.3.2.1	Arteriovenous Malformations (AVMs).....	174
5.3.2.2	Arterioportal Fistulas.....	181
5.3.2.3	Hereditary Hemorrhagic Teleangiectasia (HHT)	181
	References	185
6	Imaging of Malignant Focal Liver Lesions	187
6.1	Primary Malignant Liver Lesions	187
6.1.1	Hepatocellular Carcinoma.....	187
6.1.2	Fibrolamellar Hepatocellular Carcinoma	206
6.1.3	Epithelioid Hemangioendothelioma	211
6.1.4	Hepatic Sarcomas	214
6.1.4.1	Angiosarcoma	214
6.1.4.2	Undifferentiated Embryonal Sarcoma.....	215
6.1.4.3	Hepatobiliary Rhabdomyosarcoma.....	215
6.1.4.4	Leiomyosarcoma, Malignant Fibrous Histiocytoma and Fibrosarcoma	215
6.2	Secondary Malignant Liver Lesions	217
6.2.1	Non-Hodgkin's Lymphoma and Hodgkin's Disease.....	217
6.2.2	Metastases	218
	References	233

7	Imaging of the Biliary Tree and Gallbladder Diseases	237
7.1	Introduction - Imaging Technique	237
7.2	Anatomy	238
7.2.1	Normal Anatomy	238
7.2.2	Biliary Tree and Gallbladder Anomalies	239
7.2.2.1	Choledochal Cyst and Cystic Dilatation of the Bile Duct	239
7.2.2.2	Caroli's Disease	241
7.2.2.3	Biliary Atresia	245
7.2.2.4	Agenesis of the Gallbladder	248
7.2.2.5	Duplication of the Gallbladder	248
7.2.2.6	Anomalies of Gallbladder Shape	248
7.3	Benign Biliary Neoplasms	249
7.3.1	Biliary Cystadenoma	249
7.3.2	Bile Duct Adenoma	252
7.3.3	Biliary Hamartoma	252
7.3.4	Biliary Papillomatosis	252
7.4	Malignant Biliary Neoplasms	253
7.4.1	Cholangiocellular Carcinoma	253
7.4.2	Biliary Cystadenocarcinoma	256
7.5	Benign Neoplasms of the Gallbladder	261
7.5.1	Gallbladder Adenoma	261
7.6	Malignant Neoplasms of the Gallbladder	261
7.6.1	Gallbladder Carcinoma	261
7.6.2	Gallbladder Carcinoid	263
	References	264
8	Comparison of Available Contrast Agents for the Imaging of Specific Liver Lesions	267
8.1	Introduction	267
8.2	Benign Focal Liver Lesions of Hepatocellular Origin	268
8.2.1	Focal Nodular Hyperplasia (FNH)	268
8.2.2	Nodular Regenerative Hyperplasia (NRH)	271
8.2.3	Hepatocellular Adenoma (HA)	271
8.3	Malignant Focal Liver Lesions of Hepatocellular Origin	282
8.3.1	From Regenerative Nodules to Hepatocellular Carcinoma (HCC)	282
8.4	Benign Focal Liver Lesions of non-Hepatocellular Origin	293
8.4.1	Cavernous and Capillary Hemangioma	293
8.5	Malignant Focal Liver Lesions of non-Hepatocellular Origin	295
8.5.1	Hypervascular Metastases	295
8.5.2	Hypovascular Metastases	295
8.5.3	Cholangiocellular Carcinoma (CCC)	300
8.6	Summary	303
	References	303

9	Imaging of Diffuse Liver Disease	305
9.1	Steatosis Hepatis	305
9.2	Inflammatory Disease	308
9.2.1	Viral Hepatitis	308
9.2.2	Sclerosing Cholangitis	308
9.2.3	Radiation-Induced Hepatitis	308
9.3	Cirrhosis	311
9.3.1	Regenerative Nodules	311
9.3.2	Portal Hypertension	312
9.4	Iron Overload	313
9.4.1	Hemochromatosis	313
9.4.2	Siderosis	315
9.4.3	Iron Overload in Liver Cirrhosis	317
9.4.4	Hemolysis	317
9.5	Vascular Pathologies	318
9.5.1	Portal Vein Thrombosis	318
9.5.2	Budd-Chiari Syndrome (Acute, Chronic)	318
9.5.3	Arteriovenous Malformations	328
	References	332
10	MR Imaging of the Liver in Pediatric Patients	335
10.1	Introduction	335
10.2	Techniques in Pediatric Liver Imaging	336
10.3	Benign Liver Lesions in Pediatric Patients	337
10.3.1	Infantile Hemangioendothelioma (IHE)	337
10.3.2	Focal Nodular Hyperplasia (FNH)	338
10.3.3	Hepatocellular Adenoma (HA)	338
10.3.4	Hemangioma	338
10.3.5	Mesenchymal Hamartoma	338
10.3.6	Choledochal Cyst and Cystic Dilatation of the Bile Duct	343
10.3.7	Inflammatory Pseudotumor	343
10.4	Malignant Liver Lesions in Pediatric Patients	346
10.4.1	Hepatoblastoma (HB)	346
10.4.2	Hepatocellular Carcinoma (HCC)	349
10.4.3	Fibrolamellar Carcinoma (FLC)	352
10.4.4	Undifferentiated Embryonal Sarcoma (UES)	352
10.4.5	Hepatobiliary Rhabdomyosarcoma (RMS)	353
10.4.6	Hepatic Angiosarcoma (HAS)	355
10.4.7	Hodgkin' and Non-Hodgkin's Lymphoma (NHL), Burkitt Lymphoma	357
10.4.8	Metastases	357
10.5	Diffuse Liver Disease in Pediatric Patients	362
10.5.1	Steatosis	362
10.5.2	Biliary Atresia	362
10.5.3	Liver Fibrosis	365
10.5.4	Storage Disease, Metabolic Diseases	365
	References	366

11	Imaging of the Liver Post-Surgery and/or Post-Ablative Therapy	371
11.1	Introduction	371
11.2	Surgical Resection	371
11.3	Radio-Frequency (RF) Ablation	373
11.4	Laser-Induced Interstitial Therapy (LITT)	376
11.5	Cryotherapy	378
11.6	Loco-Regional Drug Application	378
11.6.1	Percutaneous Ethanol Injection (PEI)	378
11.6.2	Regional Transarterial Chemoembolization (TACE)	379
11.7	Multimodality Treatment of Hepatic Lesions	385
	References	387
12	MR Angiography in Liver Disease	389
12.1	Introduction	389
12.2	Technique	389
12.2.1	Time-of-Flight MRA	390
12.2.2	Phase-Contrast MRA	390
12.2.3	Contrast-Enhanced MRA	390
12.3	Imaging of the Arterial System	391
12.3.1	Normal Anatomy and Variants	391
12.3.1.1	Celiac Artery (CA)	391
12.3.1.2	Superior Mesenteric Artery (SMA)	391
12.3.1.3	Inferior Mesenteric Artery (IMA)	391
12.4	Imaging of the Portal-Venous System	397
12.4.1	Normal Anatomy and Variants	397
12.4.2	Clinical Implications	397
12.4.3	Evaluation in Liver Transplantation	399
12.4.4	Portal Vein Thrombosis and Cavernous Transformation	399
12.4.5	Tumor Encasement	399
12.5	Imaging of the Venous System	403
12.5.1	Normal Anatomy and Variants	403
12.5.2	Budd-Chiari Syndrome / Veno-Occlusive Disease	403
12.6	Evaluation of Living Donors in Liver Transplantation	403
12.7	Segmental Anatomy of the Liver	403
	References	405
	Subject Index	407

Contributors

Günther Schneider, M.D.

Clinic for Diagnostic and Interventional
Radiology
University Hospital of Saarland
66421 Homburg/Saar, Germany

Luigi Grazioli, M.D.

Department of Radiology
University of Brescia
Piazzale Spedali Civili 1
25023 Brescia, Italy

Sanjay Saini, M.D.

Emory University School of Medicine
Department of Radiology
1364 Clifton Road, NE
Atlanta GA 30322, USA

Miles A. Kirchin, Ph.D.

World Wide Medical Affairs
Bracco Imaging SpA
Via E. Folli 50
Milan, Italy

Peter Fries, M.D.

Clinic for Diagnostic and Interventional
Radiology
University Hospital of Saarland
66421 Homburg/Saar, Germany

Maria Pia Bondioni, M.D.

Department of Radiology
University of Brescia
Piazzale Spedali Civili 1
25030 Brescia, Italy

Alexander Massmann, M.D.

Clinic for Diagnostic and Interventional
Radiology
University Hospital of Saarland
66421 Homburg/Saar, Germany

Katrin Altmeyer, M.D.

Clinic for Diagnostic and Interventional
Radiology
University Hospital of Saarland
66421 Homburg/Saar, Germany

Lucio Olivetti, M.D.

Department of Radiology
Istituti Ospedalieri di Cremona
Viale Concordia 1
26100 Cremona, Italy

Laura Romanini, M.D.

Department of Radiology
University of Brescia
Piazzale Spedali Civili 1
25023 Brescia, Italy

Roland Seidel, M.D.

Clinic for Diagnostic and Interventional
Radiology
University Hospital of Saarland
66421 Homburg/Saar, Germany

Diego R. Martin, M.D.

Emory Healthcare
The Emory Clinic, Inc.
Department of Radiology
1364 Clifton Road, NE
Atlanta, GA 30322, USA

Angelo Luca, M.D.

Department of Radiology
ISMETT - Mediterranean Institute
for Transplantation and Advanced
Specialized Therapies
Via Tricomi 1
90127 Palermo, Italy

Mukesh Harisinghani, M.D.

Division of Abdominal Imaging
Department of Radiology
Massachusetts General Hospital
and Harvard Medical School
White 270, 55 Fruit Street
Boston, MA 02114, USA

Roy V. D'Souza, M.D.

Division of Abdominal Imaging
Department of Radiology
Massachusetts General Hospital
and Harvard Medical School
White 270, 55 Fruit Street
Boston, MA 02114, USA

Dushyant Sahani, M.D.

Clinical Instructor
Harvard Medical School
Assistant Radiologist in Abdominal
and Interventional Radiology
Massachusetts General Hospital
White 270, 55 Fruit Street
Boston, MA 02114, USA

Acknowledgements

We are indebted to Diane Wagner-Jochem (University Hospital Homburg/Saar, Germany) and Antonella Cerri (Springer-Verlag Italia, Milan) for their beyond-the-call-of-duty efforts to get this book published in a timely manner.

Our sincere thanks go also to Anne M. Johnston, Gianni Chiappella and Patrizia Andreoni for their precious support in the preprint processes of copyediting and typesetting, respectively, and Alexandra Davies and John R. Parker for their contributions to proofreading.

November, 2005

The Editors