

Urogenital Imaging

A Problem-Oriented Approach

Editors

Sameh K. Morcos

Northern General Hospital, Sheffield, UK

and

Henrik S. Thomsen

Copenhagen University Hospital at Herlev, Denmark

 **WILEY-BLACKWELL**

A John Wiley & Sons, Ltd., Publication

Urogenital Imaging

Urogenital Imaging

A Problem-Oriented Approach

Editors

Sameh K. Morcos

Northern General Hospital, Sheffield, UK

and

Henrik S. Thomsen

Copenhagen University Hospital at Herlev, Denmark

 **WILEY-BLACKWELL**

A John Wiley & Sons, Ltd., Publication

This edition first published 2009 © 2009, John Wiley & Sons Ltd

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered office: John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Other Editorial Offices:

9600 Garsington Road, Oxford, OX4 2DQ, UK

111 River Street, Hoboken, NJ 07030-5774, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting a specific method, diagnosis, or treatment by physicians for any particular patient. The publisher and the author make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of fitness for a particular purpose. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. Readers should consult with a specialist where appropriate. The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.

Library of Congress Cataloging-in-Publication Data

Urogenital imaging : a problem-oriented approach/edited by Sameh Morcos and Henrik Thomsen.

p. : cm.

Includes bibliographical references and index.

ISBN 978-0-470-51089-6 (cloth)

1. Genitourinary organs – Imaging. 2. Genitourinary organs – Diseases – Diagnosis. I. Morcos, Sameh K. II. Thomsen, Henrik Klem.

[DNLM: 1. Female Urogenital Diseases – diagnosis. 2. Male Urogenital Diseases – diagnosis. 3. Diagnostic Imaging – methods. WJ 141 U773 2009]

RC874.U72 2009

616.6'0754 – dc22

2008047080

ISBN 978-0-470-51089-6

A catalogue record for this book is available from the British Library.

Set in 10/12 Times New Roman by Laserwords Private Ltd, Chennai, India.

Printed and bound in Great Britain by Antony Rowe Ltd, Chippenham, Wiltshire

First Impression 2009

*To the memory of my late parents Kamel and Monira
who gave me so much unconditionally.*

*To my beloved wife and daughters Sandra, Sarah,
Hannah and Rebecca whose tremendous love and
support I will always cherish.*

Sameh K. Morcos, Sheffield, UK

Contents

Foreword	xiii
Preface	xv
Contributors	xvii
1 Adrenal Imaging	1
<i>Khaled M. Elsayes, Isaac R. Francis, Melvyn Korobkin and Gerard M. Doherty</i>	1
1.1 Introduction	1
1.2 Cushing's syndrome	2
1.3 Primary hyperaldosteronism	5
1.4 Pheochromocytoma	8
1.5 Adrenal cortical carcinoma	12
1.6 Adrenal incidentaloma	15
2 Retroperitoneal Masses	21
<i>Pietro Pavlica, Massimo Valentino and Libero Barozzi</i>	21
2.1 Introduction	21
2.2 Retroperitoneal anatomy	21
2.3 Pathological conditions	22
2.4 Primary solid retroperitoneal tumors	22
2.5 Retroperitoneal lymphoma	27
2.6 Cystic retroperitoneal masses	30
2.7 Retroperitoneal metastases	32
2.8 Retroperitoneal fibrosis (Ormond's disease)	33
2.9 Retroperitoneal fluid collections (traumatic and non-traumatic)	35
References	41
3 Imaging of Renal Artery Stenosis	43
<i>Robert Hartman</i>	43
3.1 Introduction	43
3.2 Clinical features	43
3.3 Pathology	45

3.4	Imaging of suspected renal artery stenosis	45
	References	51
4	Renal Masses	53
	<i>Philip J. Kenney</i>	53
4.1	Introduction	53
4.2	Symptomatic renal carcinoma	53
4.3	Incidental renal masses	55
4.4	Patients with a known cancer (other than RCC)	62
4.5	Renal mass in patients with symptoms	63
4.6	Vascular lesions presenting as a renal mass	68
4.7	Renal mass in patients with cystic disease	72
4.8	Treatment	73
	References	73
5	Non-neoplastic Renal Cystic Lesions	75
	<i>Sameh K. Marcos</i>	75
5.1	Introduction	75
5.2	Classification	75
5.3	Cystic lesions affecting renal cortex	76
5.4	Cystic lesions of renal medulla	80
5.5	Cystic diseases affecting both the cortex and medulla	86
	References	97
6	Urological and Vascular Complications Post-renal Transplantation	99
	<i>Tarek El-Diasty and Yasser Osman</i>	99
6.1	Introduction	99
6.2	Vascular complications	99
6.3	Urological complications	107
6.4	Ureteric strictures	110
6.5	Post-transplant lymphocele	113
6.6	Delayed graft function (DGF)	116
6.7	Post-transplant bladder malignancy	119
	References	120
7	Urinary Tract Injuries	121
	<i>Elliott R. Friedman, Stanford M. Goldman and Tung Shu</i>	121
7.1	Introduction	121
7.2	Renal trauma	121
7.3	Adrenal trauma	130
7.4	Ureteral trauma	131
7.5	Bladder trauma	133
7.6	Urethral trauma	136
7.7	Penile and scrotal trauma	142
	References	147

8 Urinary Tract Infections	149
<i>Mikael Hellström, Ulf Jodal, Rune Sixt and Eira Stokland</i>	149
8.1 Symptomatic urinary tract infection in children	149
8.2 Symptomatic upper urinary tract infection in adults	167
8.3 Emphysematous pyelonephritis	173
8.4 Xanthogranulomatous pyelonephritis	174
8.5 Urinary tract infection in the immunocompromised patient	177
8.6 Tuberculosis	179
8.7 Schistosomiasis	183
8.8 Hydatid disease (echinococcosis)	188
8.9 Urethritis	191
References	193
9 Imaging of the Genitourinary System – Urolithiasis	195
<i>Sami A Moussa and Paramanathan Mariappan</i>	195
9.1 Introduction	195
9.2 Pathology	195
9.3 Clinical features	197
9.4 Evaluation of patients with suspected urinary stones	198
9.5 Treatment	198
9.6 Imaging	199
References	218
10 Hematuria	219
<i>Thomas Bretlau, Kirstine L. Hermann, Jørgen Nordling and Henrik S. Thomsen</i>	219
10.1 Definition	219
10.2 Clinical considerations	219
10.3 Diagnosis of hematuria	220
10.4 Epidemiology	220
10.5 Distribution of malignancy in patients with hematuria	223
10.6 Imaging	223
10.7 Summary	230
References	234
11 Bladder Cancer	235
<i>G. Heinz-Peer and C. Kratzik</i>	235
11.1 Introduction	235
11.2 Clinical features	237
11.3 Pathology	239
11.4 Imaging findings	243
11.5 Treatment planning	253
11.6 Post-treatment Imaging	254

11.7	Summary	254
	References	255
12	Imaging of Urinary Diversion	257
	<i>Sameh Hanna and Hesham Badawy</i>	257
12.1	Introduction	257
12.2	Indications for urinary diversion	257
12.3	Types of urinary diversion	257
12.4	Non-continent cutaneous form of diversion	258
12.5	Continent cutaneous urinary diversion (<i>Continent Catheterizing Pouches</i>)	258
12.6	Non-orthotopic continent diversion, relying on the anal sphincter for continence	260
12.7	Orthotopic form of diversion to the native, intact urethra (neobladder)	261
12.8	Contraindications to urinary diversion	264
12.9	Complications of urinary diversions	264
12.10	The role of radiologist in urinary diversion includes	267
12.11	Imaging studies	268
12.12	Imaging of complications	269
12.13	Summary	271
	References	271
13	Imaging of the Prostate Gland	273
	<i>François Cornud</i>	273
13.1	Introduction	273
13.2	Zonal anatomy and benign prostatic hypertrophy	273
13.3	Diagnosis of prostate cancer: TRUS features	276
13.4	Diagnostic of prostate cancer: MRI	284
13.5	Contrast-enhanced (dynamic) MRI	285
13.6	Magnetic Resonance Spectroscopic Imaging (MRSI)	290
13.7	Diffusion-weighted imaging	292
13.8	Indications of functional MRI	295
13.9	Extension of prostate cancer	297
13.10	Local extension by TRUS and TRUS-guided biopsy	297
13.11	MRI and staging of prostate cancer	298
13.12	Local staging	299
13.13	Lymph node metastases: lympho-MRI	304
13.14	Bone metastases: whole marrow MRI	304
13.15	Benign disorders of the prostate (BPH excluded)	305
	References	321
14	Haemospermia	323
	<i>Drew A. Torigian, Keith N. Van Arsdalen and Parvati Ramchandani</i>	323
14.1	Introduction	323
14.2	Clinical features	323

14.3	Pathology	325
14.4	Imaging findings	325
14.5	Summary	337
	References	337
15	Scrotal Masses	339
	<i>Lorenzo E. Derchi and Alchiede Simonato</i>	339
15.1	Introduction	339
15.2	Clinical features	339
15.3	Pathology	340
15.4	Imaging	340
15.5	Important principles in assessment of scrotal masses	341
15.6	Important problems in differentiating benign from malignant lesions	345
	References	350
16	Gynaecological Adnexal Masses	351
	<i>John A. Spencer and Michael J. Weston</i>	351
16.1	Introduction	351
16.2	Clinical features	351
16.3	Pathology	352
16.4	Imaging	354
16.5	Standard radiographic techniques	355
16.6	Ultrasound (US)	355
16.7	MR Imaging (MRI)	366
16.8	Computed Tomography	373
	References	379
17	Imaging of Abnormal Uterine Bleeding	381
	<i>Patricia Noël, Evis Sala and Caroline Reinhold</i>	381
17.1	Abnormal uterine bleeding	381
17.2	Adenomyosis	382
17.3	Leiomyomas	385
17.4	Endometrial polyp	389
17.5	Endometrial hyperplasia	391
17.6	Endometrial carcinoma	394
17.7	Summary	396
	References	397
18	Female Pelvic Floor Dysfunction	399
	<i>Rania Farouk El Sayed</i>	399
18.1	Introduction	399
18.2	Anatomical considerations	399
18.3	Pathophysiology of pelvic floor dysfunction	401

18.4	Clinical features	401
18.5	Imaging of pelvic floor dysfunction	404
18.6	Magnetic resonance imaging (MRI)	407
	References	413
19	Imaging of female infertility	415
	<i>Ahmed-Emad Mahfouz and Hanan Sherif</i>	415
19.1	Introduction	415
19.2	Polycystic ovary syndrome	415
19.3	Abnormalities of the fallopian tubes (Hydrosalpinx/Hematosalpinx, tubal block)	418
19.4	Fibroids	421
19.5	Adenomyosis	423
19.6	Developmental anomalies of the uterus	424
19.7	Endometriosis	429
19.8	Imaging	430
	Index	431

Foreword

This book has the unique aim to provide the greatest utility to the modern radiologist practicing diagnostic imaging of the genitourinary system. In this time of great pressure within the medical environment, where time is always of the essence, one can even question the usefulness of any book. Many practitioners quickly go the internet for a “google search”. Unfortunately, although the internet can provide extremely valuable information quickly, it also can provide an enormous amount of misinformation quickly. Unless one knows and trusts the source, the internet although readily available may lead to uncertainty. In addition, the internet often provides “factoids” bereft of context.

This book is designed for the busy modern world, by providing key information representing a consensus of current practice in a very accessible fashion. The nineteen chapters cover, in moderate depth, all the most important topics relating to the male and female genital and urinary tracts. The forty three authors are truly an international group of experts in the field. Each chapter provides information on usual presentation of disorders, clinical, laboratory and pathologic features and the best current information on imaging features critical for diagnosis. A brief presentation on current therapy is also included.

A critical decision was made in the preparation of this book as to the style of presentation of the information. Elegant phraseology has been bypassed in favor of a “bullet point” approach, along with heavy use of tables and extensive illustration of typical features of common lesions. This results in an “information dense” text. Despite the relative brevity of the chapters, each is packed with useful information. That information can be accessed by the reader extremely quickly – whether searching for a single key point, such as how to calculate relative washout of an adrenal mass and the best diagnostic cutoffs, or whether desirous of a quick overview of a topic. This book in fact would be an excellent choice for someone reviewing for a radiology exam such as ABR MOC. The authors have concentrated in each chapter on accepted key diagnostic features; the character of the authors makes this truly an international consensus.

What one will not find in the book is extensive discussion of the history of imaging of any area. It does not include the initial description of some sign, or the early attempts for criteria that failed. There is not an extensive list of references, nor a discussion of controversial areas. Rare entities or extremely unusual presentations of common lesions are not included in general. Rather the focus is on well accepted key points on clinical aspects of the more common diseases and the accepted findings that allow one to make an imaging diagnosis. Some presentation, although limited, is given of imaging techniques. This is not meant to teach in detail how to perform exams correctly. The heavy emphasis in most chapters is on Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), as those methods currently are most useful for final diagnosis in most areas. However, in appropriate areas,

such as kidney transplant, prostate disease, female pelvis and male scrotum, ultrasound is well covered. As it has been largely superseded, little attention is paid to intravenous urography or to most radiologic methods. This is not a text that extensively reviews nuclear medicine techniques.

I am proud to have been a contributor to this text. I expect many radiologists will find it a most useful guide to the best of current practice of imaging diagnosis of the genitourinary tract. The size of the book is designed such that it can be kept close at hand for easy and frequent use.

Professor Philip J. Kenney

Preface

This book is designed to offer both radiologists and clinicians focused information about different important aspects of the urogenital system. Each chapter provides concise information about clinical features, pathology and imaging findings of the aspect under consideration.

The book does not follow the traditional style of scientific textbooks. The text is presented mainly in bullet format which the reader will find easy to follow and remember. Many images demonstrating important diagnostic features of different diseases are provided in each chapter. A list of key references is provided at the end of each chapter. A diagnostic algorithm is also provided whenever appropriate.

The book is aimed mainly at urologists, nephrologists, gynecologists, general radiologists and trainee radiologists. Specialized urogenital radiologists will also find the book a quick reminder of important features of different conditions in their field of interest.

We are most grateful to all the authors who covered their topics expertly and clearly. We are fortunate to have so many eminent colleagues contributing to this book.

We hope you will find the book informative and a good reference to refresh your knowledge in the field of urogenital imaging.

SK Morcos
Sheffield, UK

HS Thomsen
Copenhagen, Denmark

Contributors

Hesham Badawy

Urology Department,
Kasr El Aini Hospital – Faculty of Medicine,
Cairo University,
Egypt

Libero Barozzi,

Radiology Unit,
S. Orsola-Malpighi University Hospital,
Via Massarenti, 9,
40138 Bologna
Italy

Thomas Bretlau,

Departments of Diagnostic Radiology and
Urology,
Copenhagen University Hospital at Herlev,
Herlev Ringvej 75,
DK-2730 Herlev
Denmark

François Cornud,

Service de Radiologie B (Pr Chevrot),
Hôpital Cochin,
27 rue du Faubourg St Jacques,
75014 Paris,
France

Lorenzo E. Derchi,

DICMI-Radiologia,
Università di Genova,
I-16132 Genova,
Italy

Gerard M. Doherty

Department of Surgery,
University of Michigan,
Ann Arbor,
Michigan, 48109
USA

Tarek El-Diasty

Radiology Department,
Urology & Nephrology Center,
Mansoura University,
Mansoura,
Egypt.

Rania Farouk El Sayed

Radiology Department,
Cairo University Hospitals,
Cairo,
Egypt

Khaled M. Elsayes

Dept. of Radiology,
University of Michigan,
Ann Arbor,
Michigan 48109
USA

Isaac R. Francis

Department of Radiology,
University of Michigan,
Ann Arbor,
Michigan 48109
USA

Elliott R. Friedman

Diagnostic and Interventional Imaging,
University of Texas Health Science Center at
Houston,
Texas,
USA

Stanford M. Goldman

Diagnostic and Interventional Imaging and
Urology,
University of Texas Health Science Center at
Houston,
Texas,
USA

Sameh A.Z. Hanna

Radiology Department,
Kasr El Aini Hospital – Faculty of Medicine,
Cairo University,
Egypt

Robert Hartman,

Department of Diagnostic Radiology,
Mayo Clinic,
Rochester MN,
USA

Gertraud Heinz-Peer

Department of Radiology,
Medical University of Vienna,
Währinger Gürtel 18-20,
1090 Vienna,
Austria

Mikael Hellström,

Department of Radiology,
The Sahlgrenska University Hospital,
Göteborg,
Sweden

Kirstine L. Hermann,

Departments of Diagnostic Radiology and
Urology,
Copenhagen University Hospital at
Herlev,
Herlev Ringvej 75,
DK-2730 Herlev
Denmark

Ulf Jodal,

Department of Pediatric Nephrology,
The Queen Silvia Children's Hospital,
Göteborg,
Sweden

Philip J. Kenney

University of Arkansas for Medical
Science,
4301 W. Markham St.,
Little Rock, AR 72205
USA

Melvyn Korobkin

Department of Radiology,
University of Michigan,
Ann Arbor,
Michigan 48109
USA

C.Kratzik

Department of Urology,
Medical University of Vienna,
Währinger Gürtel 18-20,
1090 Vienna,
Austria

Ahmed-Emad Mahfouz

Radiology Departments,
Hamad Medical Corporation,
POB 3050, Doha
Qatar and
Cairo University, Cairo
Egypt

Mr Paramanathan Mariappan,

Department of Urology,
Western General Hospital,
Crewe Road South,
Edinburgh, EH4 2XU,
UK

Sameh K. Morcos

Sheffield Teaching Hospitals NHS Foundation
Trust,
Department of Diagnostic Imaging,
Northern General Hospital,
Herries Rd, Sheffield S5 7AU UK

Sami A. Moussa,

Department of Radiology,
Western General Hospital,
Crewe Road South,
Edinburgh, EH4 2XU,
UK

Patricia Noël

Department of Radiology
CHUQ Hôtel-Dieu de Québec
11, Côte du Palais Québec,
Québec, G1R 2J6
Canada

Jørgen Nordling

Departments of Diagnostic Radiology and
Urology,
Copenhagen University Hospital at Herlev,
Herlev Ringvej 75,
DK-2730 Herlev
Denmark

Yasser Osman

Urology and Nephrology Center,
Mansoura University,
Mansoura
Egypt

Pietro Pavlica,

Radiology Unit,
S. Orsola-Malpighi University Hospital,
Via Massarenti, 9
40138 Bologna
Italy

Parvati Ramchandani

University of Pennsylvania School of
Medicine,
Philadelphia, PA 19104,
USA

Caroline Reinhold

Department of Radiology,
McGill University Health Center,
1650 Cedar Ave.,
Montreal, Quebec, H3G 1A4
Canada

Evis Sala

University Department of Radiology,
5, Addenbrooke's Hospital,
Hills Road,
Cambridge CB2 0QQ,
UK

Hanan Sherif

Radiology Departments,
Hamad Medical Corporation,
POB 3050, Doha
Qatar and
Cairo University, Cairo
Egypt

Tung Shu

University of Texas Health Sciences Center at
Houston,
Houston,
Texas,
USA

Alchiede Simonato,

Clinica Urologica, Università di Genova,
Ospedale San Martino,
Largo R. Benzi, 10
I-16132 Genova
Italy

Rune Sixt,

Department of Clinical Physiology,
The Queen Silvia Children's Hospital,
Göteborg,
Sweden

Eira Stokland

Department of Radiology,
The Queen Silvia Children's Hospital,
Göteborg,
Sweden

John A. Spencer,

Department of Clinical Radiology,
St James's University Hospital,
Leeds LS9 7TF,
UK

Henrik S. Thomsen,

University of Copenhagen,
Department of Diagnostic Radiology,
Copenhagen University Hospital at Herlev,
Herlev Ringvej 75, DK-2730 Herlev,
Denmark

Drew A. Torigian

Department of Radiology,
Hospital of the University of Pennsylvania,
3400 Spruce Street,
Philadelphia, PA 19104,
USA

Massimo Valentino,

Radiology Unit,
S. Orsola-Malpighi University Hospital,
Via Massarenti, 9
I-40138 Bologna
Italy

Keith N. Van Arsdalen

University of Pennsylvania School of
Medicine,
Philadelphia, PA 19104,
USA

Michael J Weston

Department of Clinical Radiology
St James's University Hospital,
Leeds LS9 7TF,
UK

1

Adrenal Imaging

Khaled M. Elsayes¹, Isaac R. Francis¹, Melvyn Korobkin¹ and Gerard M. Doherty²

¹*Department of Radiology, University of Michigan*

²*Department of Radiology and Surgery, University of Michigan*

1.1 Introduction

Most adrenal adenomas are initially detected incidentally by computed tomography (CT), in patients who undergo the examination for other indications. But CT and magnetic resonance imaging (MRI) are also used in the investigation of adrenal hyperfunction.

Adrenal adenoma is the most common adrenal mass that is seen on cross-sectional imaging, usually CT and MRI. The majority of these lesions contain abundant lipid and can be seen on unenhanced CT as low density masses measuring less than 10 Hounsfield units [HU], and exhibit loss of signal intensity on out-of-phase (opposed phase) gradient-echo MR images. Adenomas also exhibit rapid intravenous iodinated contrast enhancement washout and therefore can be distinguished from malignant lesions which do not exhibit this feature.

CT and MRI can be used to stage adrenal cortical carcinomas and detect pheochromocytomas. FDG PET scans can help differentiate adrenal metastases from adenomas by their strong avidity for FDG, but some adenomas show mild tracer uptake.

There are several masses such as uncomplicated adrenal cysts, adrenal myelolipomas and acute adrenal hemorrhage which can be readily characterized on CT and MRI.

Utility of various imaging modalities in diagnosis of adrenal gland masses:

- Ultrasound: Ultrasound is sensitive but not specific for diagnosis adrenal masses
- Computed Tomography (CT):
 - Most commonly used modality for detection and characterization of adrenal masses
 - Measuring the unenhanced attenuation value of adrenal mass is important for diagnosing lipid rich adenoma

- Use of contrast enhancement washout values are also useful in distinguishing between adenomas and malignant lesions
- The absolute per cent enhancement washout can be calculated by measuring the enhanced attenuation, the delayed enhanced, the unenhanced values and using the following formula:

$$\begin{aligned} &\text{Absolute enhancement Washout} \\ &= \frac{\text{Enhanced attenuation value} - \text{Delayed attenuation value}}{\text{Enhanced attenuation value} - \text{Unenhanced attenuation value}} \end{aligned}$$

- When non-contrast scans have not been obtained, and only contrast enhanced scans have been obtained, delayed images of the adrenal mass can be performed at 15 min following initial injection of intravenous contrast, and relative enhancement washout calculated as follows:

$$\begin{aligned} &\text{Relative enhancement Washout} \\ &= \frac{\text{Enhanced attenuation value} - \text{Delayed attenuation value}}{\text{Enhanced attenuation value}} \end{aligned}$$

- Threshold values of greater 60% for absolute and 40% for relative enhancement washout have been found to be over 90% specific for adenoma diagnosis.
- Magnetic Resonance Imaging (MRI):
 - Qualitative analysis: The most important sequence of the adrenal MR imaging protocol is chemical shift imaging sequence. Chemical shift imaging is performed with in-phase and out-of-phase sequences. Loss of signal intensity of the adrenal mass using the spleen as reference organ, on out-of-phase, compared with in-phase pulse sequence is diagnostic for the presence of intracellular lipid
 - Quantitative Analysis:

$$\text{Percentage loss of signal} = \frac{*SI \text{ on in-phase} - SI \text{ on opposed-phase}}{SI \text{ on in-phase}} \times 100$$

*SI: Signal Intensity

>16.5% loss of SI on out-of-phase images as compared with in-phase images has >90% specificity for adenoma diagnosis.

1.2 Cushing's syndrome

The most common cause of adrenocortical steroid hormone excess is Cushing's disease due to pituitary hypersecretion of ACTH. However, primary adrenal causes are an important part of the differential diagnosis, and diagnostic plan.

Clinical features

- Facial plethora, dorsocervical fat pad, supraclavicular fat pad, truncal obesity, easy bruisability, purple striae, hirsutism, impotence or amenorrhea, muscle weakness, and psychosis.

- Hypertension.
- Hyperglycemia.
- Includes Cushing's disease (excess adrenocorticotropic hormone [ACTH] produced by pituitary adenomas) and Cushing's syndrome (ectopic ACTH syndrome or primary adrenal disease resulting in glucocorticoid secretion independent of ACTH stimulation).
- Symptoms and Signs
 - Truncal obesity, hirsutism, moon facies, acne, buffalo hump, purple striae
 - Hypertension
 - Hyperglycemia
 - Weakness
 - Depression
 - Growth retardation or arrest in children.
- Laboratory Findings
 - Overnight, low-dose dexamethasone suppression test and measurement of urinary free cortisol establishes diagnosis
 - No suppression and elevated urinary cortisol suggest Cushing's syndrome.
 - Detection of elevated midnight cortisol level suggests Cushing's syndrome (midnight plasma level or late-night salivary cortisol sampling).
 - Once Cushing's syndrome established, measure plasma ACTH level
 - A normal or elevated ACTH level suggests pituitary adenoma or ectopic ACTH secretion.
 - Suppressed ACTH is diagnostic of hyperadrenocorticism due to primary adrenal disease.
 - If ACTH-dependent Cushing's disease and no clear pituitary lesion on MRI, may proceed to petrosal sinus sampling with corticotropin-releasing hormone (CRH) stimulation: a central to peripheral ACTH gradient suggests Cushing's disease, while no gradient suggests ectopic ACTH secretion.

Pathophysiology

- Rare forms of ACTH-independent Cushing's syndrome include macronodular hyperplasia.
- Pigmented micronodular hyperplasia is associated with the syndrome of Carney complex (also includes cardiac myxomas and lentiginos).
- Rarely, ectopic adrenal tissue can be the source for excess cortisol secretion; most common location is along the abdominal aorta.
- Ectopic ACTH syndrome usually caused by small-cell lung cancers or carcinoids but can result from tumors of the pancreas, thyroid, thymus, prostate, esophagus, colon, ovaries, pheochromocytoma, and malignant melanoma.

Treatment

- Resection is best treatment for cortisol-producing adrenal tumors or ACTH-producing tumors.
- Pituitary irradiation may be necessary if pituitary surgery fails.
- Medical treatment may be indicated to control hypercortisolism, or when patients not cured by resection or when complete resection is impossible.

Imaging findings

Adrenal hyperplasia

- Often seen in patients with Cushing's syndrome and less commonly in Conn's syndrome.
- May be diffuse or nodular and is typically bilateral (Figs 1.1 and 1.2).

Adrenal adenoma

- Most are less than 3 cm in size.
- Can be of varying density on CT and MRI.
- Lipid-rich adenoma. Attenuation value of 10 HU or less at unenhanced CT (Fig. 1.3).
- Adenomas usually have absolute enhancement washout of >60% (Fig. 1.4) and relative enhancement washout of >40%.
- Greater than 16.5% loss of signal intensity on out-of-phase, compared with in-phase MRI pulse sequences (Fig. 1.5).

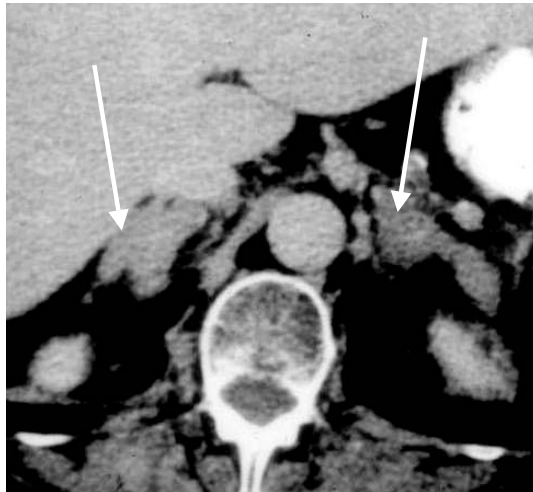


Figure 1.1 Bilateral adrenal cortical hyperplasia. Axial contrast-enhanced CT image shows nodular thickening of adrenal glands bilaterally in patient with Cushing's syndrome.

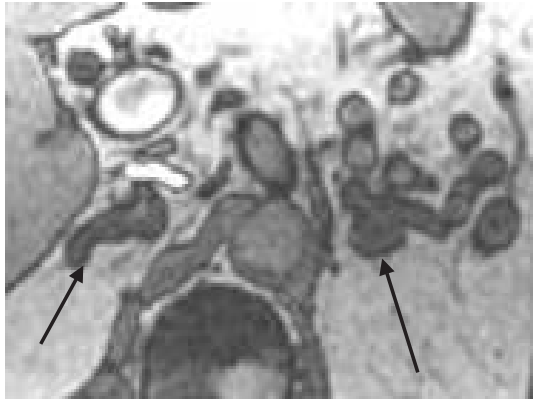


Figure 1.2 Bilateral adrenal cortical hyperplasia. Axial out-of-phase MR image shows nodular thickening of adrenal glands bilaterally in patient with Cushing's syndrome.



Figure 1.3 Lipid-rich adenoma. Axial unenhanced CT shows a right adrenal mass measuring 8 HU.

- Functioning and non-functioning adenomas, appear similar based on imaging as do Cushing's and Conn's adenomas.

Adrenal cortical carcinomas can also cause Cushing's syndrome (see below for imaging appearances of adrenal cortical carcinoma).

1.3 Primary hyperaldosteronism

Introduction

Primary hyperaldosteronism is a relatively common and underdiagnosed condition that contributes to hypertension in about 1% of hypertensive people. The condition is very effectively treated, and so screening programs have become routine in some places.

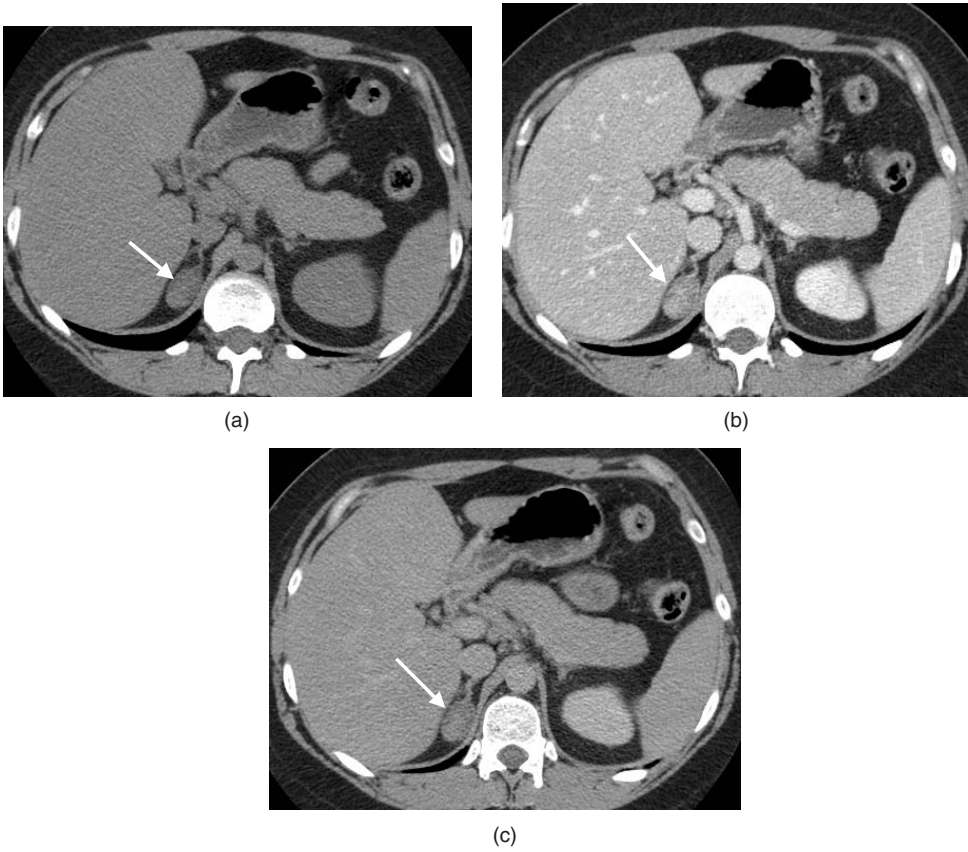


Figure 1.4 Lipid-poor adenoma. Axial unenhanced CT shows a right adrenal mass measuring 27 HU (arrow) (a). Following intravenous contrast enhancement the mass measures 96 HU (arrow) (b) and 50 HU (arrow) on delayed images (c), respectively. This mass had an absolute enhancement washout of 67%. Absolute Washout = $96 - 50 / 96 - 27 \times 100 = 67\%$.

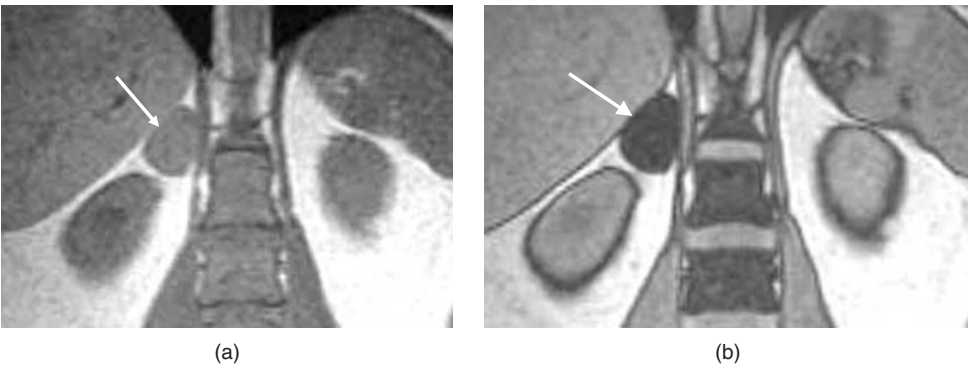


Figure 1.5 Adrenal adenoma. Coronal in-phase (a) and out-of-phase (b) MR images show an adrenal mass (arrow) which exhibits a typical decrease in signal intensity on the out-of-phase image.

Clinical features

- Hypertension with or without hypokalemia.
- Elevated aldosterone secretion and suppressed plasma renin activity.
- Metabolic alkalosis, relative hypernatremia.
- Weakness, polyuria, paresthesias, tetany, cramps due to hypokalemia.
- Common subtypes of primary hyperaldosteronism: aldosteronoma (75%) and bilateral adrenal hyperplasia (25%).
- Rare subtypes of primary hyperaldosteronism: unilateral primary adrenal hyperplasia, aldosterone-producing adrenocortical carcinoma, glucocorticoid-remediable hyperaldosteronism (familial hyperaldosteronism type 1).
- Symptoms and signs
 - Hypertension
 - Headaches
 - Malaise
 - Muscle weakness
 - Polyuria
 - Polydipsia
 - Cramps
 - Paresthesias
 - Hypokalemic paralysis (rare).
- Laboratory findings
 - Hypokalemia
 - Hypernatremia
 - Metabolic alkalosis
 - Elevated plasma aldosterone to renin ratio (\gg 20)
 - Elevated plasma aldosterone concentration (\gg 15 ng/dL)
 - Elevated urine/serum aldosterone level with PO or IV sodium challenge.

Treatment

- Surgical therapy for patients with aldosteronoma and unilateral primary adrenal hyperplasia.
- Medical therapy for bilateral adrenal hyperplasia, or poor surgical candidates.
- Surgery
 - Nearly always laparoscopic approach.
 - Unilaterality best defined by adrenal vein sampling for aldosterone and cortisol

- Indications
 - Unilateral aldosteronoma
 - Unilateral primary adrenal hyperplasia.
- Contraindications
 - Bilateral adrenal hyperplasia.
- Removal of aldosteronoma normalizes potassium, but hypertension is not always cured.
- 33% of patients have persistent, mild hypertension (easier to control than before operation).
- Medications
 - Spironolactone: competitive aldosterone antagonist.
 - Amiloride: potassium-sparing diuretic.
 - Other antihypertensive agents such as ACE inhibitors and calcium channel blockers.

Imaging findings

Adrenal hyperplasia

- May be diffuse or nodular and is typically bilateral (Figs 1.1 and 1.2).

Adrenal adenoma

- Most are small and less than 2 cm in size.
- Usually much smaller than Cushing's adenoma.
- Can have varying appearances of CT and MRI.
- Lipid-rich adenoma- Attenuation value of 10 HU or less at unenhanced CT (Fig. 1.3).
- Absolute enhancement washout >60% (Fig. 1.4) and relative enhancement washout >40%.
- Greater than 16.5% loss of signal intensity on out-of-phase, compared with in-phase MRI pulse sequences (Fig. 1.5).
- Functioning and non-functioning adenomas, appear similar based on imaging as do Cushing's and Conn's adenomas.

Adrenal cortical carcinomas rarely cause Conn's syndrome.

1.4 Pheochromocytoma

Introduction

Pheochromocytomas are tumors that develop from the adrenal medulla. The hormonal function typically includes production of catecholamines, and the characteristic syndrome that follows. These tumors can be benign or malignant.