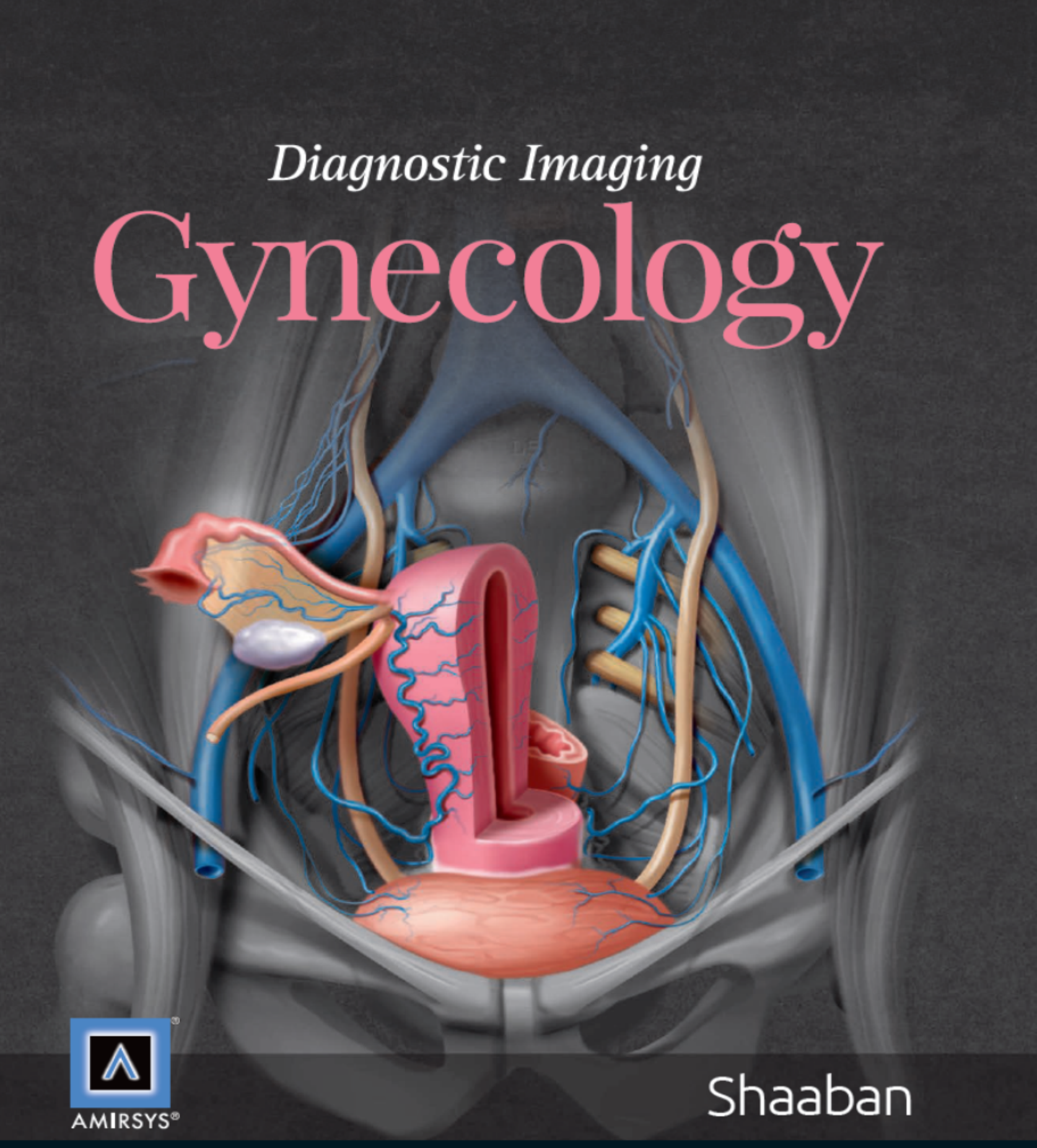
Diagnostic Imaging

Gynecology



AMIRSYS®

Shaaban

MENIAS • REZVANI • TUBAY
EL SAYED • WOODWARD

ELSEVIER

Diagnostic Imaging

Gynecology

Akram M. Shaaban, MBBCh
Associate Professor (Clinical)
Department of Radiology
University of Utah School of Medicine
Salt Lake City, Utah

Christine O. Menias, MD
Professor of Radiology
Mayo Clinic School of Medicine
Scottsdale, Arizona
Adjunct Professor of Radiology
Washington University School of Medicine
St. Louis, Missouri

Marc S. Tubay, MD
Chief of Cross Sectional Imaging
Department of Radiology
United States Air Force Academy Medical Clinic
Colorado Springs, Colorado

Maryam Rezvani, MD
Associate Professor of Radiology
Department of Radiology
University of Utah School of Medicine
Salt Lake City, Utah

Rania Farouk El Sayed, MD, PhD
Lecturer of Radiodiagnosis
Department of Radiology
University of Cairo
Faculty of Medicine
Cairo, Egypt

Paula J. Woodward, MD
David G. Bragg, MD and Marcia R. Bragg Presidential
Endowed Chair in Oncologic Imaging
Department of Radiology
Department of Obstetrics and Gynecology
University of Utah School of Medicine
Salt Lake City, Utah

ELSEVIER

1600 John F. Kennedy Blvd.
Ste 1800
Philadelphia, PA 19103-2899

DIAGNOSTIC IMAGING: GYNECOLOGY, SECOND EDITION ISBN: 978-1-931884-77-8

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

With respect to any drug or pharmaceutical products identified, readers are advised to check the most current information provided (i) on procedures featured or (ii) by the manufacturer of each product to be administered, to verify the recommended dose or formula, the method and duration of administration, and contraindications. It is the responsibility of practitioners, relying on their own experience and knowledge of their patients, to make diagnoses, to determine dosages and the best treatment for each individual patient, and to take all appropriate safety precautions.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Publisher Cataloging-in-Publication Data

Diagnostic imaging. Gynecology / [edited by] Akram M. Shaaban.
2nd edition.
pages ; cm
Gynecology
Includes bibliographical references and index.
ISBN 978-1-931884-77-8 (hardback)
1. Generative organs, Female--Imaging--Handbooks, manuals, etc.
I. Shaaban, Akram M. IV. Title: Gynecology.
[DNLM: 1. Genital Diseases, Female--diagnosis--Handbooks.
2. Diagnostic Imaging--Handbooks. 3. Genitalia, Female--patholgoy--Handbooks.
WP 39]
RG107.5.I4 D53 2014
618.1075--dc23

International Standard Book Number: 978-1-931884-77-8

Cover Designer: Tom M. Olson, BA
Cover Art: Lane R. Bennion, MS

Printed in Canada by Friesens, Altona, Manitoba, Canada

Last digit is the print number: 9 8 7 6 5 4 3 2 1

Dedications

To my parents, who taught me the value of perseverance & hard work. To my wife Inji, my son Karim, and my daughters May and Jena, the jewels of my life, thanks for your understanding & tremendous support. To all my residents and fellows, whose challenging questions made me a better radiologist.

AMS

I'd like to dedicate this book to all my former residents, fellows, colleagues, and teachers, who continue to donate to the "Cooky Jar," and continue to teach me. It has truly been a privilege. This work could not have been completed without them.

COM

To my parents, Houshmand & Shahla, and my sister, Sara, who humble me with their patience and selfless support of all my endeavors. To my aunt, Laghaieh, whose generous spirit and devotion to radiology have always served as an example for which I continue to strive.

MR

I wish to dedicate this to my teachers and mentors, for their generosity and dedication; to Roman and Ivy, for their endless energy and love; and most of all to Amy, for her guidance, patience, and devotion.

MST

Thanks to my professors and colleagues in radiology and the ESUR Society, for their inestimable support. A special dedication to my passed Prof. Hazem Moharram & my doctoral students for their extensive effort. A special thanks to these stars who have lit my life path—my wonderful parents, loving sisters and brothers, children, Omar and Mariam Emad, and my kind husband, for their endless love and support; and to Professors Suaad Moussa & Tahany El Zainy, and Katharine O'Moore-Klopf; my friends Dr. Karen Kinkel, Tarek ElShayal & Inas Aref. And sincere appreciation to the Amirsys team for their guidance & making my chapters come to life.

RFES

To the awesome Amirsys pub team (Andrea, Angie, Arthur, Ashley, Chuck, Dave, Jeff, Katherine, Kellie, Lane, Laura, Lisa, Nina, Rebecca, Rich, Sarah, Tricia), your standard of excellence is unparalleled. I get to be the person out front, but we all know who does the heavy lifting. You guys rock!

PJW

Contributing Authors Continued

Oguz Akin, MD
Associate Professor of Radiology
Department of Radiology
Memorial Sloan-Ketteting Cancer Center
New York, New York

Sandra J. Allison, MD
Washington Radiology Associates, P.C.
Associate Professor of Radiology
Georgetown University School of Medicine
Washington, District of Columbia

Susan M. Ascher, MD, FISMRM, FSCBT/MR
Professor of Radiology and Co-Director of Abdominal Imaging
Georgetown University School of Medicine
Washington, District of Columbia

Mostafa Atri, MD, FRCPC, Dipl. Epid.
Director of Ultrasound, Joint Department of Medical Imaging (UHN, MSH, WCH)

Professor of Radiology
University of Toronto
Toronto, Ontario, Canada

Ilse Castro-Aragon, MD
Assistant Professor of Radiology
Boston University School of Medicine
Boston, Massachusetts

Nyree Griffin, MD, FRCR
Consultant Radiologist
Guy's and St. Thomas' NHS Foundation Trust
London, United Kingdom

Winnie Hahn, MD
Staff Radiologist
Department of Radiology
Washington, DC Veterans Administration Medical Center
Washington, District of Columbia

Olga Hatsiopoulou, MD, FRCR
Consultant Radiologist
Royal Hallamshire Hospital
Sheffield Teaching Hospitals NHS Foundation Trust
Sheffield, United Kingdom

Marcia C. Javitt, MD, FACR
Director of Medical Imaging
Rambam Healthcare Campus

Professor of Radiology
Technion Faculty of Medicine
Haifa, Israel

Deborah Levine, MD, FACR
Professor of Radiology
Vice-Chair of Academic Affairs
Department of Radiology

Director of Ob/Gyn Ultrasound
Department of Radiology
Beth Israel Deaconess Medical Center
Boston, Massachusetts

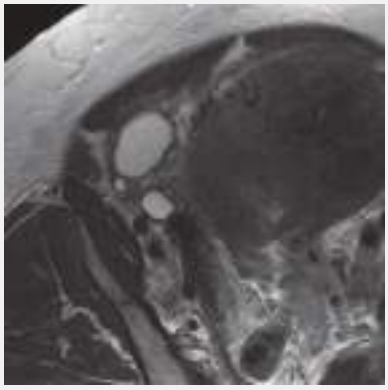
Patricia Noël, MD, FRCPC
Professor of Radiology, Laval University
Department of Medical Imaging
CHU de Québec, l'Hôtel-Dieu de Québec
Québec, Québec, Canada

Khashayar Rafatzand, MD, FRCPC
Assistant Professor of Radiology
Department of Radiology
University of Massachusetts Medical School
Worcester, Massachusetts

Caroline Reinhold, MD, MSc
Professor of Radiology, Gynecology and Internal Medicine (Gastroenterology)

Vice-Chair of Research
McGill University Health Center
Montreal, Québec, Canada

Evis Sala, MD, PhD
Chief of Body Imaging Service
Memorial Sloan-Kettering Cancer Center
New York, New York



Preface

We are pleased to present *Diagnostic Imaging: Gynecology*, second edition, the most extensive book of imaging in gynecologic diseases. More than 2,500 carefully annotated images illustrate pertinent pathologic entities and demonstrate the correlation between ultrasound (including 3D), sonohysterography, hysterosalpingography, MR, PET/CT, and gross pathology. For ease of reference and learning, diagnoses are grouped according to the organ involved—uterus, cervix, vagina and vulva, ovary, fallopian tubes, multiple organs, and the pelvic floor—and include all pertinent pathologic entities, including congenital anomalies, infectious/inflammatory diseases, and benign and malignant neoplasms.

This reference builds upon the success of the first edition with new image galleries, completely revised text, and updated references. In addition, we include a dedicated section on techniques, designed to help optimize imaging protocols and enhance diagnostic specificity. Each section now begins with a review of normal anatomy and variants, including extensive illustrations. As applicable, we have added modules on tumor staging that feature quick-reference tables, illustrations, and case examples of TNM classification, FIGO staging, and AJCC prognostic groups. The book closes with a section devoted to the pelvic floor, the evaluation of which has become an integral part of our clinical practice in the last decade.

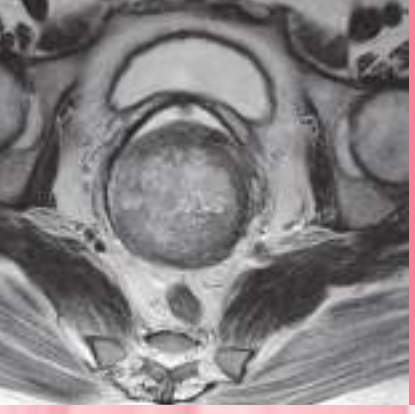
Diagnostic Imaging: Gynecology, second edition maintains the signature Amirsys format of concise bulleted text, Key Facts boxes, and plentiful, high-quality images. The online version includes another 900 images, plus additional diagnostic tips and references. In all, the book remains extremely useful for radiologists and gynecologists alike, both those practicing and those still in training.

I would like to thank all the editors and contributing authors from the bottom of my heart for their effort and dedication. We are extremely proud of the final product and hope that readers will appreciate the effort required to produce such an amazing reference.

I also want to acknowledge the sonographers and the CT and MR technologists for their fine work, which is used extensively throughout this text. Thanks also to the amazing Amirsys staff, especially Angie, Katherine, Kellie, and Jeff—whose attention to detail makes everything we do better—and to the illustrators—Lane, Rich, and Laura—who have helped make this book truly special.

We think you'll find this new volume a wonderfully rich resource that will enhance your practice and find a welcome place on your bookshelf.

Akram M. Shaaban, MBBCh
Associate Professor (Clinical)
Department of Radiology
University of Utah School of Medicine
Salt Lake City, Utah



Acknowledgements

Text Editing

Dave L. Chance, MA, ELS
Arthur G. Gelsinger, MA
Sarah J. Connor, BA
Tricia L. Cannon, BA

Image Editing

Jeffrey J. Marmorstone, BS
Lisa A. M. Steadman, BS

Medical Editing

Jaclyn Taylor, MD
Marc S. Tubay, MD

Illustrations

Lane R. Bennion, MS
Laura C. Sesto, MA
Richard Coombs, MS

Art Direction and Design

Laura C. Sesto, MA
Tom M. Olson, BA

Lead Editor

Angela M. Green Terry, BA

Publishing Leads

Katherine L. Riser, MA
Rebecca L. Hutchinson, BA

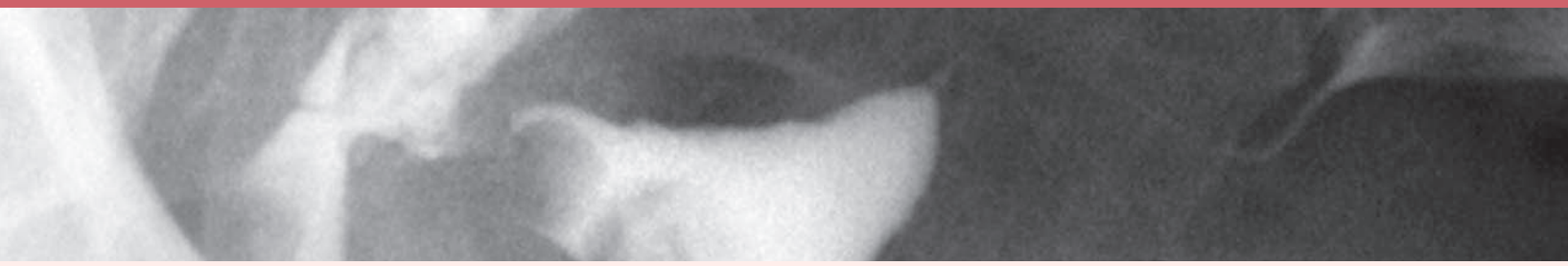
Names you know. Content you trust.®

Sections

TABLE OF CONTENTS

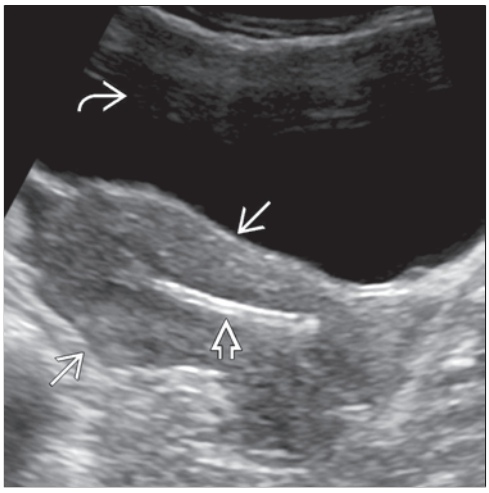
SECTION 1

Techniques

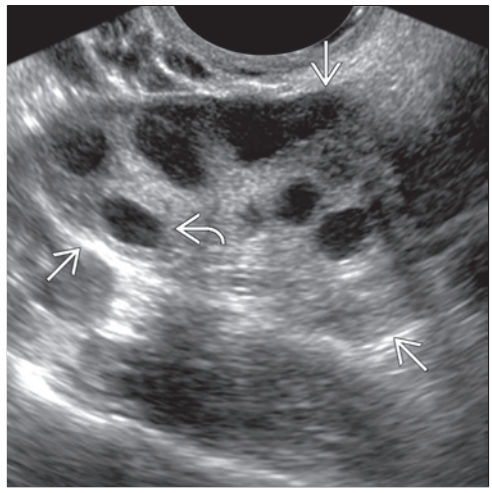


Pelvis

ULTRASOUND TECHNIQUE AND ANATOMY



Longitudinal transabdominal US image shows an IUD within an otherwise normal-appearing uterus. Transabdominal US should be performed with a full bladder to provide an adequate imaging window.



Longitudinal transvaginal ultrasound shows a normal ovary with a few follicles. The ovaries should be measured in 3 orthogonal planes and carefully evaluated for suspicious masses.

TERMINOLOGY

Abbreviations

- Transabdominal sonography (TAS)
- Transvaginal ultrasound (TVUS)
- Endovaginal (EV)
- Saline-infused sonohysterogram (SIS)
- Peak systolic velocity (PSV)
- End diastolic velocity (EDV)

Definitions

- Ultrasound is an imaging modality that transmits high frequency sound waves into tissues and generates images from reflected waves
  - TAS provides a large field of view
    - Lower frequencies are used to allow for a greater depth of view
      - Results in lower resolution images
    - Useful for large masses
    - Use for superficial lesions and lesions out of range of vaginal probe
    - Mid to late gestations are generally better evaluated with TAS
  - TVUS gives higher resolution images of uterus, cervix, and adnexa
    - Higher frequencies allow for higher resolution images at expense of decreased depth of view
    - Field of view is more constrained
    - Key technique in evaluation of uterine, cervical, and adnexal pathology
    - Useful in evaluation of early pregnancy
- B-mode (grayscale, 2D mode) ultrasound
  - Reflected sound wave data is reconstructed to produce 2D grayscale image of a plane of tissue
  - Majority of ultrasound examinations are performed using B-mode
- M-mode ultrasound
  - Column of tissue perpendicular to probe is interrogated to evaluate for motion/velocity
  - In pelvic sonography, used almost exclusively to demonstrate embryonic/fetal cardiac activity and obtain heart rate
- Doppler ultrasound uses frequency shifts of reflected sound waves to detect flowing blood
  - Blood flow can be evaluated with
    - Color Doppler: Flow is assigned a color based on direction of flow and overlaid on B-mode images
    - Power Doppler: Measures intensity of Doppler shift overlaid on a grayscale image; more sensitive for detection of slow flow
    - Pulsed-wave (spectral) Doppler: Velocity tracing is generated, allowing for velocity and waveform analysis
      - Duplex Doppler: Pulsed-wave Doppler displayed with grayscale anatomic images
      - Triplex Doppler: Pulsed-wave Doppler displayed with grayscale images overlaid with color Doppler
  - Presence of central blood flow can help distinguish a solid mass from a complicated cystic lesion
  - Vascularized nodules or thickened septations may increase suspicion of malignancy for a particular lesion
  - Resistive index: (PSV-EDV)/PSV
    - Low resistive index (< 0.4) is associated with malignancy but can also be seen in benign lesions with high flow (corpus luteum, metabolically active benign mass, inflammation)
    - High resistive index (> 0.7) associated with benign lesions, though not diagnostic
    - Thoroughly evaluate entirety of mass, as velocities can differ between solid components
- 3D ultrasound
  - Acquires a volume of ultrasound data
  - Volume can be manipulated at US machine or at dedicated workstation to produce multiplanar images or 3D reconstructions
  - Can provide images of similar orientation and quality to MR
- 4D ultrasound: 3D US data is acquired continuously over time
  - Allows generation of 3D sonographic movies

ULTRASOUND TECHNIQUE AND ANATOMY

Key Facts

Terminology
- Ultrasound is an imaging modality that transmits high frequency sound waves into tissues and generates images from reflected waves
- Pelvic sonography can be performed using a number of techniques (M-mode, 2D, Doppler, 3D, 4D)

Pre-Procedure
- Transabdominal US is usually performed with a full bladder
- Transvaginal pelvic US is performed with an empty bladder

Procedure
- Most pelvic sonographic examinations are performed with a combined transabdominal and transvaginal technique
  - Transperineal, translabial, and transrectal approaches are less frequently used
- TVUS gives higher resolution images of uterus, cervix, and adnexa
- Pelvic ultrasound requires dedicated evaluation and reporting of
  - Uterus: Size, contour, positioning, myometrial echotexture/masses
  - Endometrium: Thickness, appearance, presence/positioning of IUD
  - Adnexa: Ovarian size, presence of cystic/solid mass, ovarian vascular flow, tubal abnormalities
  - Cul-de-sac: Presence of fluid or mass
- Probes must be thoroughly cleansed according to manufacturer's and local institution's guidelines

PRE-PROCEDURE

Indications
· Common indications for pelvic sonography include pelvic pain, mass, abnormal/dysfunctional vaginal bleeding, staging for cancer

Contraindications
· TAS can be uncomfortable due to full bladder
· TVUS should be avoided in patients with an intact hymen or prior to having had intercourse
  - Transperineal/translabial sonography can be performed when needed
  - Patients may decline study due to being uncomfortable with procedure

Getting Started
· Things to check
  - Full bladder for TAS
    - Full bladder acts as an acoustic window and helps to better evaluate uterus/adnexa
    - Pushes small bowel from field of view
    - Overfilled bladder may push uterus and ovaries away from probe, making evaluation more difficult
  - Empty bladder for TVUS
    - Describe use of transvaginal probe to patient
    - Many sonographers prefer to have patient insert EV probe herself
    - Only a portion of probe is inserted
    - Exam should be relatively painless
    - If bladder is too distended, it may push uterus and ovaries out of field of view
  - In women of childbearing age, knowledge of serum β-hCG levels may be useful
· Equipment list
  - Ultrasound machine
  - Appropriate transducers
    - 3.5-7 MHz for transabdominal scans (curved or sector)
    - 5-12 MHz for EV scans (dedicated EV probe)
    - 7-15 MHz for superficial translabial/transperineal scans (linear probe)
  - Safety issues
    - 100 mW/cm² is intensity below which no significant biologic effects in mammalian tissues in vivo
    - Thermal index < 2 and mechanical index < 0.3 are safe levels for routine use
  - Commercial probe cover or condom to cover EV probe for TVUS
    - If latex allergy, do not use latex probe covers
  - Dedicated EV probe cleaning system and solution
  - US gel

PROCEDURE

Patient Position/Location
· Best procedure approach
  - Positioning for TAS
    - Patient comfortably positioned in supine position
  - Positioning for TVUS
    - Patient in lithotomy position, feet in stirrups if bed is so equipped
    - Pillow under buttocks can be utilized if needed, especially if bed does not have stirrups
    - Similar positioning for translabial or transperineal examinations
· In many centers, routine pelvic ultrasound examinations include both TAS and TVUS
  - Patient undergoes TAS with full bladder
  - After voiding, patient undergoes TVUS
· Some centers may not routinely perform both TAS and TVUS for each patient
  - Perform EV examination initially, and only perform TAS if TVUS is insufficient
  - Some centers begin with TAS but do not make patient fill bladder
    - Limited TAS to assess uterine size, large masses
    - Proceed to TVUS
    - Repeat TAS with full bladder only in cases when TVUS insufficient
· Transperineal/translabial evaluations
  - Utilized for visualization of labial/vulvar, distal urethral, and vaginal anomalies
  - Use a sector or linear transducer covered with condom or commercially available probe cover

- Utilized for assessment of primary amenorrhea in patients with intact hymen
- Useful in evaluation of cervix and lower uterus in late-term pregnant patients for whom TVUS is contraindicated

· Transrectal US may be useful to evaluate anal sphincter in setting of pelvic floor dysfunction

Equipment Preparation

· Probes need to be meticulously cleansed according to manufacturer's and local institutional guidelines
· Rinse probes prior to use to avoid chemical irritation from disinfectants
· US gel is better tolerated by patient if warmed

Procedure Steps

· TAS and TVUS examinations should include
- Uterine imaging
  - Uterine length measurements
    - Measure uterine length in sagittal midline image (long axis of uterus) from fundus to external cervical os
    - Uterine depth/AP measurement is measured on same sagittal long axis image of uterus, perpendicular to length measurement
    - Uterine width is measured on axial/coronal image of uterus
  - Cervical images
    - Transverse and longitudinal images through cervix
  - Representative images of myometrium
    - Several long (parasagittal) and transverse images through entire uterus
  - Myometrial masses should be documented
    - Measure 2 largest leiomyomas/masses in 3 planes
    - Measure exophytic masses in 3 planes
    - Usually not necessary to measure all masses
  - In setting of prior hysterectomy, evaluation of vaginal cuff should be performed
- Endometrial evaluation
  - Measure endometrial thickness perpendicular to long axis of uterus on midline sagittal image
  - Include both layers of endometrium
    - If there is fluid within endometrial cavity, it should be excluded by measuring each endometrial layer separately
  - Exclude hypoechoic subendometrial zone in endometrial measurement
  - Document and measure focal endometrial thickening or masses
    - If focal endometrial lesion, color and pulsed Doppler may be helpful to help evaluate for a vascular stalk
    - Any endometrial cystic change should be imaged
  - If an IUD is present, dedicated imaging in longitudinal and transverse planes should be obtained
    - Acquisition of a 3D volume, with coronal reformatted image, is very useful in evaluation of IUD embedment or expulsion
- Adnexal imaging
  - If ovaries are difficult to find, obtain a coronal view of uterine fundus and angle laterally to region of broad ligament
    - Alternatively, locate iliac vasculature in longitudinal plane and slowly image toward midline
  - Gentle pressure on anterior abdominal wall can move bowel gas out of the way to improve ovarian visualization
  - Ovaries should be measured in 3 orthogonal planes
  - Obtain color and duplex Doppler images of ovaries, documenting arterial and venous waveforms
  - Measure largest cyst/follicle &/or any atypical appearing adnexal lesion in 3 planes
  - Determine if cyst/mass arises from ovary or is separate from ovary
    - Gently press with EV probe; adnexal mass arising from ovary will move with ovary whereas paraovarian mass will move independent from ovary with pressure
    - Imaging as pressure is applied to anterior abdominal wall may also help distinguish exophytic ovarian mass from paraovarian mass
  - Doppler can be helpful to distinguish between parametrial vessel and adnexal cyst
  - Doppler can be helpful to determine if lesion is solid (increasing likelihood of malignancy) or is a complicated cyst (hemorrhagic)
  - Bladder filling &/or emptying can help determine etiology and location of a pelvic cyst in cases where large cyst is mistaken for urinary bladder
- Scan between uterus and ovaries to assess for other adnexal masses
  - May identify paraovarian cysts/masses or dilated fallopian tube
  - 3D US can help confirm tubular nature of suspected hydrosalpinx
  - Of particular importance in cases of suspected ectopic pregnancy
- Evaluate for fluid or mass in cul-de-sac
- In patients with focal tenderness or pain, area of maximal pain should be thoroughly evaluated

· In cases of pelvic masses, TAS may also include evaluation of kidneys for hydronephrosis/hydroureter
· For TVUS evaluation, EV probe should be slowly and gently inserted
- As probe is being inserted, images should be assessed for vaginal wall masses
- Scan generally performed through anterior vaginal wall, with probe positioned in anterior fornix
- If uterus is retroverted or retroflexed, scan may be performed through posterior vaginal wall
- Angle probe gently to avoid pain
- Some patients have pain when cervix is manipulated, so avoid excess probe pressure on cervix
- In patients with bowel gas obscuring visualization of ovary, gentle abdominal pressure can displace bowel loops and allow for visualization of ovary

· Transperineal evaluation
- Sagittal midline views of vagina, cervix, and lower uterus are obtained
- Parasagittal views as indicated
- If performed during pregnancy
  - Relationship between internal cervical os and placental margin should be evaluated
  - Measure cervix and assess for funneling

- Transrectal pelvic sonography is occasionally helpful, though rarely performed
- Saline-infused sonohysterography
  - Sterile saline is injected into endometrial cavity via balloon-tipped catheter
  - TVUS is performed simultaneously
  - Saline separates coapted endometrial layers, allowing for visualization of polyps or focal endometrial masses

Findings and Reporting

- Uterine size
- Uterine contour
  - In cases of suspected müllerian duct anomalies, 3D US can depict external uterine contour to help characterize anomaly
- Uterine positioning
  - Version: Positioning of uterus with relation to vagina
  - Flexion: Positioning of uterine fundus in relation to cervix
- Description of myometrial echotexture
- Presence of myometrial masses location and largest size
  - Including location, size, and position within uterine wall
- Appearance of cervix
- Endometrial thickness
- Presence of endometrial masses, fluid, cystic change, IUD, abnormal thickening, or areas that are ill defined or not well imaged
- Ovarian size
- Presence of suspicious adnexal masses
  - Ovarian cysts/follicles out of physiologic range
  - Complicated/complex or solid adnexal masses
  - Tubal abnormalities
- Ovarian arterial and venous waveforms detected on duplex Doppler evaluation
- Free fluid

Alternative Procedures/Therapies

- Radiologic
  - MR
    - Provides comprehensive evaluation of pelvic anatomy
    - Better soft tissue characterization
    - Multiplanar capabilities
  - CT
    - Not indicated for uterine or adnexal screening
    - Useful in staging of pelvic malignancies
  - Hysterosalpingography
    - Primarily used in evaluation of tubal patency
- Surgical
  - Blind endometrial biopsy for abnormal bleeding
  - Hysteroscopic biopsy for focal endometrial lesions
  - Laparoscopy

POST-PROCEDURE

Expected Outcome

- No harmful effects from pelvic sonography
- TAS and TVUS are generally well tolerated

Things to Do

- Cleanse probes according to manufacturer's and institution's guidelines
- Must have gel both inside and outside probe cover to prevent artifact from interposed air
- If scanning is performed for infertility, water or saline may be used as a lubricant to avoid adverse effect on sperm motility

Things to Avoid

- Male sonographers/sonologist should always have a female chaperone for TVUS

OUTCOMES

Problems

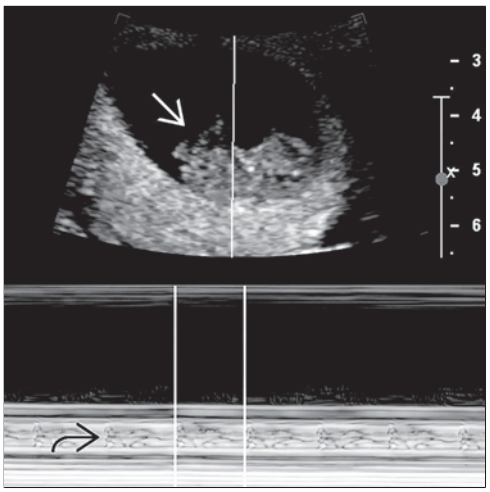
- Postmenopausal women with atrophic vaginitis may not tolerate TVUS
  - Use small probe
  - Use extra lubricating gel
  - Allow patient to insert probe herself

SELECTED REFERENCES

1. Armstrong L et al: Three-dimensional volumetric sonography in gynecology: an overview of clinical applications. Radiol Clin North Am. 51(6):1035-47, 2013
2. Sakhel K et al: Begin with the basics: role of 3-dimensional sonography as a first-line imaging technique in the cost-effective evaluation of gynecologic pelvic disease. J Ultrasound Med. 32(3):381-8, 2013
3. Andreotti RF et al: Sonographic evaluation of acute pelvic pain. J Ultrasound Med. 31(11):1713-8, 2012
4. Langer JE et al: Imaging of the female pelvis through the life cycle. Radiographics. 32(6):1575-97, 2012
5. American Institute of Ultrasound in Medicine: AIUM practice guideline for the performance of pelvic ultrasound examinations. J Ultrasound Med. 29(1):166-72, 2010
6. Dietz HP: Pelvic floor ultrasound: a review. Am J Obstet Gynecol. 202(4):321-34, 2010
7. Forsberg F et al: Comparing image processing techniques for improved 3-dimensional ultrasound imaging. J Ultrasound Med. 29(4):615-9, 2010
8. Valsky DV et al: Three-dimensional transperineal ultrasonography of the pelvic floor: improving visualization for new clinical applications and better functional assessment. J Ultrasound Med. 26(10):1373-87, 2007
9. Timor-Tritsch IE et al: Three-dimensional inversion rendering: a new sonographic technique and its use in gynecology. J Ultrasound Med. 24(5):681-8, 2005
10. Bega G et al: Three-dimensional ultrasonography in gynecology: technical aspects and clinical applications. J Ultrasound Med. 22(11):1249-69, 2003
11. Lev-Toaff AS: Sonohysterography: evaluation of endometrial and myometrial abnormalities. Semin Roentgenol. 31(4):288-98, 1996
12. Freimanis MG et al: Transvaginal ultrasonography. Radiol Clin North Am. 30(5):955-76, 1992

ULTRASOUND TECHNIQUE AND ANATOMY

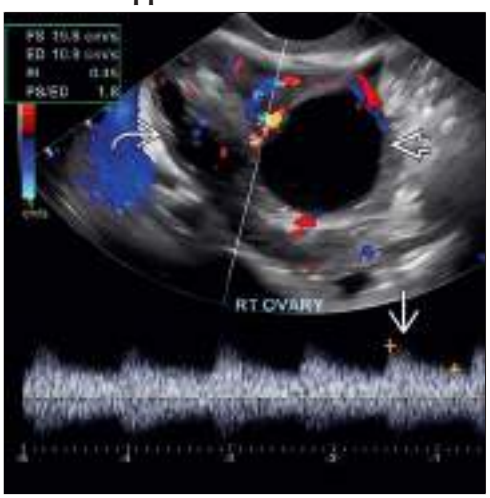
M-Mode US: Embryonic Cardiac Activity



Power Doppler: Ovarian Mass

(Left) *Longitudinal M-mode US in a 1st trimester pregnancy shows embryonic cardiac activity, confirming viability of the gestation. M-mode is typically used in obstetric US imaging.* ***(Right)*** *Longitudinal transabdominal ultrasound shows a large complex cystic adnexal mass. Power Doppler evaluation demonstrates blood flow within a heterogeneous mural nodule. Color and power Doppler can confirm flow within internal septations and mural nodules.*

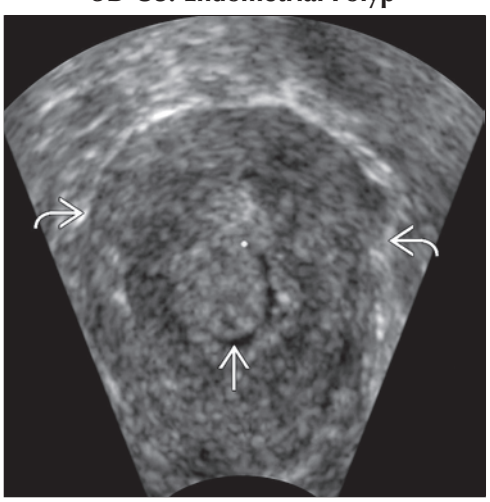
Color Doppler: Ovarian Arterial Flow



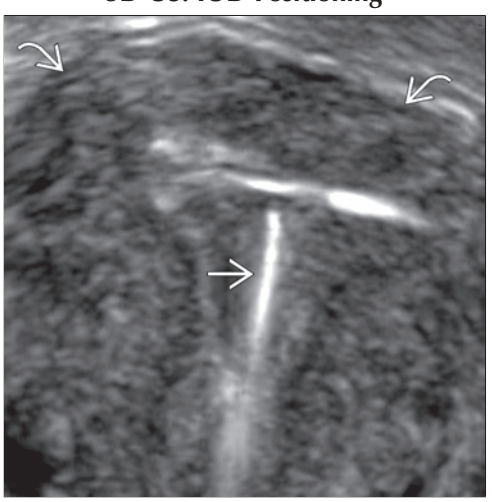
Color Doppler: Ovarian Venous Flow

(Left) *Transverse transvaginal duplex Doppler evaluation shows color flow within the right ovary with corresponding low-resistance arterial waveform on spectral analysis. Note the normal ovarian follicle.* ***(Right)*** *Transverse transvaginal duplex Doppler evaluation shows color flow within the left ovary with nonpulsatile venous waveform on spectral analysis. In cases of suspected torsion, it is crucial to evaluate the ovaries for arterial and venous waveforms.*

3D US: Endometrial Polyp



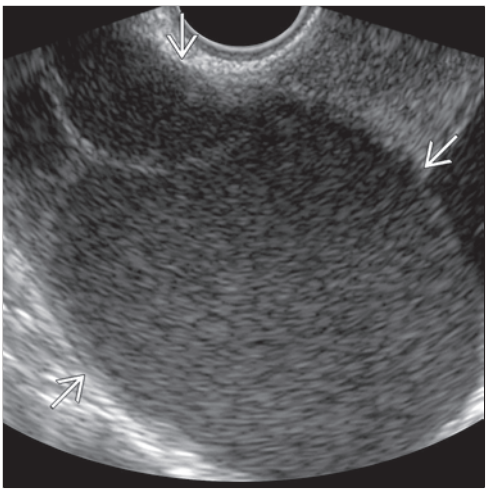
3D US: IUD Positioning



(Left) *Reconstructed coronal view of the uterus from a 3D ultrasound study shows a polypoid lesion within the endometrial cavity outlined by fluid. The polyp was not visualized on 2D ultrasound evaluation, though clearly seen on 3D reconstructions.* ***(Right)*** *Reconstructed coronal view of the uterus (fundal contour) from a 3D ultrasound shows an IUD positioned within the endometrial cavity. Uterine embedment is better evaluated on 3D reconstructions than 2D studies.*

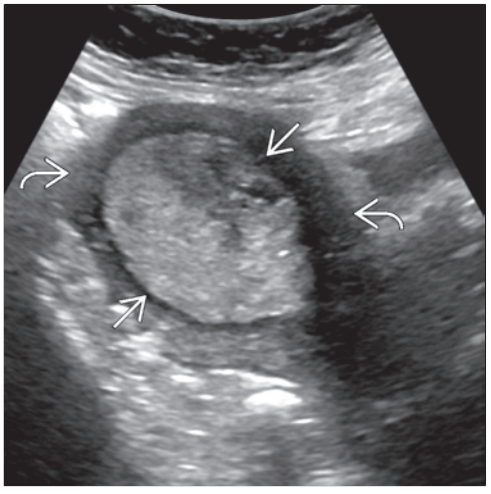
Ultrasound Probes

Transvaginal US: Endometrioma

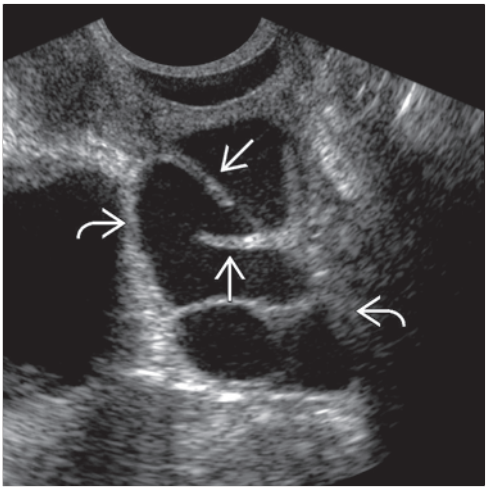


(Left) *This image demonstrates the different types of probes used in gynecological US: 2D EV probe, 3D endovaginal (EV) probe, 3D curved transabdominal (TA) probe, 2D curved TA probe, 2D sector probe, 2D linear probe.* ***(Right)*** *Transverse transvaginal pelvic ultrasound image shows a multilocular cystic adnexal mass with homogeneous low-level internal echoes. This persisted on serial imaging and was proven to be an endometrioma on MR imaging.*

Transabdominal US: Abnormal Endometrial Thickening

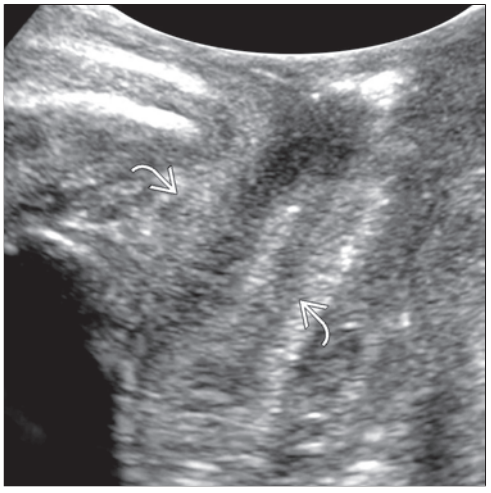


Transvaginal US: Hydrosalpinx

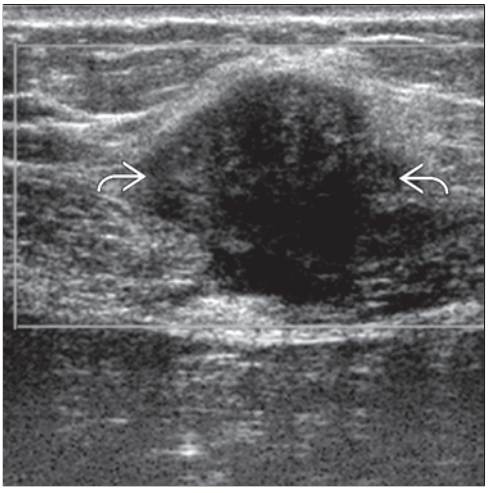


(Left) *Longitudinal transabdominal ultrasound of the pelvis shows the uterus with a grossly thickened endometrial echocomplex, proven to be malignancy in this patient with postmenopausal bleeding. Transabdominal sonography can best evaluate for uterine size and large masses.* ***(Right)*** *Longitudinal transvaginal ultrasound demonstrates a complex cystic adnexal mass with tubular elements. The incomplete septations are clues that confirm the diagnosis of hydrosalpinx.*

Transperineal US: Urethral Evaluation

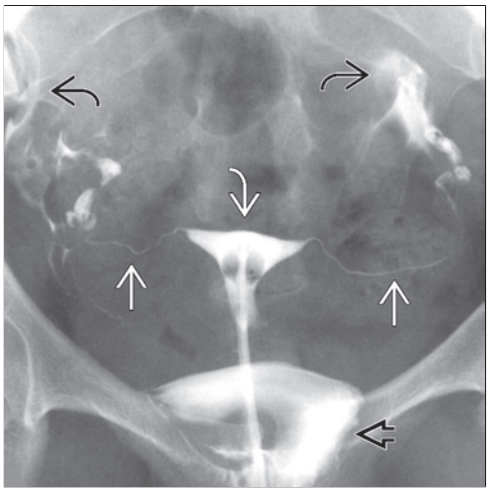


Superficial US: Pelvic Wall Mass

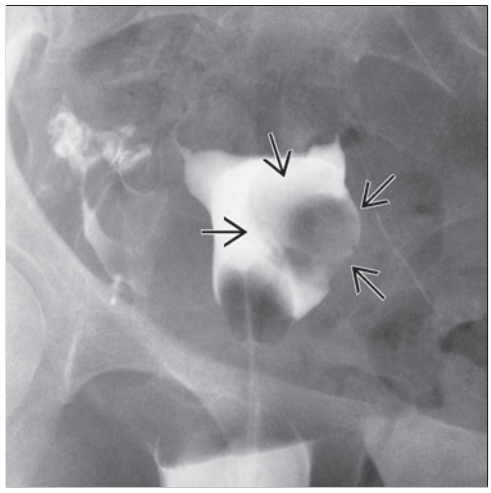


(Left) *Longitudinal transperineal ultrasound demonstrates the normal urethra. Transperineal/translabial US can be used to evaluate the vagina or urethra or when transvaginal US is contraindicated.* ***(Right)*** *Transverse ultrasound of the superficial pelvic wall in a patient with a palpable lesion and cyclical pain shows an irregular hypoechoic mass proved to be a C-section scar endometrioma on biopsy. Superficial lesions are best evaluated with high-frequency linear probes.*

HYSTEROSALPINGOGRAPHY



Frontal fluoroscopic image from an HSG shows the normal appearance of the uterus and fallopian tubes, with free spillage on contrast into the pelvis. Note the contrast reflux into the vagina.



Frontal fluoroscopic image demonstrates a fixed filling defect along the left aspect of the endometrial cavity. Subsequent MR showed this to be a submucosal fibroid.

TERMINOLOGY

Abbreviations

- Hysterosalpingogram (HSG)

Definitions

- Fluoroscopic evaluation of uterine cavity and fallopian tubes

Advantages

- Best method to assess fallopian tube patency
- Relatively easy to perform
- Medications are typically not required

Disadvantages

- Invasive procedure
- Uses ionizing radiation
- May be uncomfortable

PRE-PROCEDURE

Indications

- Primary indication: Infertility
  - Initial test in evaluation of tubal patency
  - Integral part of routine work-up in most centers
  - Typically performed in conjunction with pelvic ultrasound
- Other indications include
  - Recurrent spontaneous abortions
    - Can assess for mechanical/structural causes of secondary infertility
  - Uterine abnormalities
    - Müllerian duct anomalies
    - Polyps
    - Leiomyomas
    - Adhesions/synechia (Asherman syndrome); post procedure or post infection/inflammatory
    - Adenomyosis
    - Endometrial hyperplasia
  - Tubal abnormalities
    - Tubal occlusion
      - Identify level of tubal occlusion
      - Most common cause remains pelvic inflammatory disease (PID)
    - Tubal disease
      - Hydrosalpinx
      - Peritubal adhesions
      - Salpingitis isthmica nodosa
      - Cornual/tubal polyps
  - Tubal evaluation following intervention
    - To assess patency following tubal ligation or reversal of tubal ligation
    - Confirm occlusion by tubal occlusive devices

Contraindications

- Pregnancy
  - Risks related to ionizing radiation exposure
  - Displacement of embryo leading to potential for miscarriage
- Active PID
  - PID or history of PID in preceding 6 months
  - Can cause progression of infection, septicemia
- Severe iodine allergy
  - Extremely rare with use of currently available low-osmolar nonionic contrast agents
- Relative contraindication: Active menstrual bleeding
  - May cause difficulty in interpretation
    - Blood clots can mimic polyps or result in tubal occlusion
    - Minimize by ensuring no bleeding/spotting on day of study
  - Increased risk of contrast intravasation
    - Venous or lymphatic intravasation is clinically insignificant and not dangerous

Getting Started

- Things to check
  - β-hCG
    - Many centers routinely perform a serum pregnancy test to exclude pregnancy before procedure
  - Date of last menstrual cycle
    - Examination scheduled during days 7-12 of menstrual cycle as endometrium is thin and smooth, which facilitates image interpretation

HYSTEROSALPINGOGRAPHY

Key Facts

Terminology
- Fluoroscopic evaluation of uterine cavity and fallopian tubes

Pre-Procedure
- Infertility is primary indication
  - Other indications include recurrent spontaneous abortions, müllerian duct anomalies, uterine/endometrial masses, tubal abnormalities
- Absolute contraindications include pregnancy, active PID, iodine allergy
  - Relative contraindication: Active menstrual bleeding
- Confirmation of nonpregnant status is necessary prior to procedure
- Prophylactic or postprocedural antibiotics are usually not necessary

Procedure
- Detailed explanation of procedure and patient reassurance are vital, followed by written consent
- Procedure involves cannulation of cervix with a balloon-tipped catheter and injection of contrast into endometrial cavity under fluoroscopy
  - Fallopian tube morphology is evaluated, and patency is confirmed with free spillage of contrast into peritoneal cavity

Post-Procedure
- Significant complications are rare; minor complications include cramping and minimal bleeding

    - Day 1 is defined as 1st day of menstrual bleeding
    - Patient should call to schedule on 1st day of menstrual bleeding if menstrual cycle is irregular
  - Abstinence from sexual intercourse from time menstrual bleeding ends until day of study
    - Reduces potential for early pregnancy
  - If there is suspected PID
    - Erythrocyte sedimentation rate (ESR) may be measured to evaluate for active PID
    - Negative gonorrhea and chlamydia cultures are acceptable in patients with coexistent inflammatory conditions (e.g., arthritis, sarcoidosis, collagen vascular disease)
    - Antibiotic prophylaxis should be considered with history of prior PID
  - Evaluate for history of severe iodine allergy or latex allergy
- Medications
  - Patient advised to take over-the-counter NSAID pain reliever 1 hour prior to procedure (acetaminophen, ibuprofen)
  - Glucagon or butylscopolamine can be used to prevent tubal spasm
    - Not routinely required
    - Contraindications to glucagon include pheochromocytoma and insulinoma
  - Anxiolytics may be helpful in some patients
  - Antibiotics are not routine but may be considered in select patients in consultation with referring OB/GYN
    - History of PID: Doxycycline 100 mg p.o. b.i.d. for 5 days beginning 2 days prior to procedure
    - Hydrosalpinx diagnosed on HSG: Doxycycline 100 mg p.o. b.i.d. for 5 days after procedure
- Equipment list
  - Private fluoroscopic suite with adequate lighting
  - Female chaperone for all fluoroscopists
  - Stirrups for fluoroscopy table
  - Sterile equipment
    - Vaginal speculum
      - Disposable plastic speculum with integrated light source
      - Sterile metal speculum; single-sided specula make removal around catheter easier
      - Medium sized speculum is adequate for most patients
    - 5-French balloon-tipped HSG catheter
      - Other catheter types are infrequently used
    - Cervical dilator (if needed)
  - Water-soluble, nonionic contrast medium
    - Dedicated HSG contrast agents are available
    - Conventional iodinated intravenous contrast agents may be used
    - Prepare at least 10 mL of contrast media, more is rarely necessary
  - Oil-based agents may also be used
    - Higher rate of complications (oil emboli and granuloma formation) with oil-based agents

PROCEDURE

Patient Position/Location
- Best procedure approach
  - Cervical cannulation: Lithotomy position with feet in stirrups
    - Patient's buttocks positioned slightly over edge of table
    - If stirrups are not available, feet placed on fluoroscopy table in frog-leg position with pelvis elevated off table with towels/cushion
  - Contrast administration and imaging: Supine position
    - Patient carefully moved to center of fluoroscopy table after catheter placement and speculum removal

Equipment Preparation
- Inspect sterile pack to ensure necessary equipment is available
- Procedure performed under sterile conditions with sterile gloves
- Test inflate catheter balloon and flush catheter with contrast to eliminate air from system

Procedure Steps
- Careful and detailed procedural explanation and patient reassurance is vital
- Obtain written and oral informed consent

HYSTEROSALPINGOGRAPHY

- Insert sterile lubricated speculum into vagina and obtain clear view of cervical os
- Sterilize cervix 3x using iodine solution
  - Can use noniodinated agent for patients with iodine allergy
- Cannulate cervical os with a 5-French HSG catheter
  - Use catheter stiffener to help guide catheter through external os
  - Pass catheter as far as possible into endometrial lumen
  - Alternatively, catheter/balloon may be positioned in endocervical canal, but usually results in greater patient discomfort
- Fully inflate balloon (slowly), or to extent that patient can tolerate
  - Do not over inflate balloon with more air than in syringe
- Gently provide traction on catheter to ensure positioning within endometrial lumen and seat against internal os
  - Cervix should slightly bulge with gentle traction
- Carefully withdraw speculum from vagina, making sure to not dislodge catheter
  - Some fluoroscopists leave speculum in place, though this may obscure pathology
- Obtain a scout radiograph of pelvis with catheter in place before contrast medium is instilled
- Under fluoroscopic imaging, slowly instill iodinated contrast medium
  - Avoid air bubbles as they can hinder interpretation
  - Typically < 10 mL of contrast is necessary
- Obtain spot radiographs after contrast instillation
  - Early frontal filling view of uterus: Evaluate for any filling defects or contour abnormalities
  - Frontal view of fully distended uterus: Evaluate uterine morphology
  - Bilateral shallow oblique frontal views: Evaluate fallopian tubes
  - Delayed frontal view of uterus: Document free intraperitoneal spillage of contrast material
- Additional spot radiographs are necessary to document any abnormality
- Oblique views of fallopian tubes help to "elongate" tube and displace superimposed structures
- If no free intraperitoneal spill of contrast is visualized, continue gentle contrast medium injection
  - If occlusion is due to tubal spasm, continued injection will opacify tube after spontaneous relaxation
  - Glucagon or butylscopolamine may be administered in cases of suspected tubal spasm, though not regularly performed
  - Stop injection if contrast intravasation is observed or if patient is too uncomfortable
- "Pull-back" view may be obtained to evaluate lower uterine segment obscured by inflated balloon
  - Balloon is deflated and catheter is partially withdrawn into endocervical canal
  - Gently inject more contrast and reimage lower uterine segment

Findings and Reporting

- Normal findings
  - Smooth uterine cavity contour, patent fallopian tubes, and bilateral free peritoneal spillage of contrast medium
  - Other normal findings include myometrial folds, C-section scar/defect, endocervical gland opacification
- Abnormal findings
  - Uterine abnormalities
    - Congenital abnormalities/müllerian duct anomalies
    - Luminal filling defects (endometrial polyps, synechia, fibroids)
    - Adenomyosis
  - Tubal occlusion (postinflammatory or after occlusive procedure)
  - Other tubal abnormalities: Hydrosalpinx, tubal adhesions, loculated spillage (indicative of local adhesions or peritoneal inclusion cyst)
- Venous/lymphatic intravasation can be seen with increased/excessive contrast injection pressure
  - Progressive opacification of uterine arcuate, parametrial, and pelvic venous vasculature
  - Seen in up to 6% of patients, though more common in setting of tubal occlusion
  - No clinical significance in isolation

Alternative Procedures/Therapies

- Radiologic
  - Sonohysterography
    - Similar technique
    - No ionizing radiation
    - Real-time imaging
    - Superior for evaluation of endometrium (abnormal uterine bleeding, polyps) and ovaries
    - Less accurate for tubal patency
      - Can infer tubal patency by pooling of saline in cul-de-sac
  - MR
    - No ionizing radiation
    - Assessment of entire pelvis
    - Multiplanar imaging capability and superb tissue contrast
    - Best used for evaluation of uterine congenital anomalies, myometrium, and ovaries
  - Ultrasound (US)
    - No ionizing radiation
    - Real-time imaging
    - 3D US can be used to evaluate uterine morphology in cases of suspected müllerian duct anomalies
    - 3D US may also be used in evaluation of endometrial polyps
- Surgical
  - Hysteroscopy
    - Direct visualization of uterine cavity
    - Limited evaluation of fallopian tubes
  - Laparoscopic evaluation with dye test
    - Requires general anesthesia
    - Uterine cannulation is performed under direct visualization
    - Methylene blue contrast is injected into uterine cavity
    - Spill of methylene blue is visualized via laparoscope into peritoneal cavity
    - Ovaries can be evaluated

        - Traditional gold standard in evaluation of infertility, though invasive and typically not necessary
- Other
    - Hormone profile as part of infertility work-up
    - Chlamydia serology for PID
    - Evaluation for male factor in the work-up of infertility

POST-PROCEDURE

Expected Outcome

- Significant complications are rare
- Minor pain and cramping
    - During positioning of catheter and inflation of balloon
    - Also secondary to uterotubal distension or peritoneal spill
        - Reduced by slow injection of contrast medium
    - Self-limited, usually resolves quickly
    - Treated with over-the-counter NSAIDs
- Minor bleeding: Light spotting after procedure, usually lasting < 24 hours
- Higher rates of fertility after HSG are reported, though this relationship is controversial

Things to Do

- Instruct patients to expect passage of small amount of contrast from vagina
    - May be tinged with blood
    - Patients should use a pad and avoid tampon use
- Instruct patients to watch for signs of possible infection
    - Development of fever or foul-smelling vaginal discharge 2-4 days following HSG

OUTCOMES

Problems

- Difficulty in identifying cervix
    - Remove speculum and perform limited bimanual examination to palpate cervix and better direct speculum
    - For patients with redundant vaginal tissue obscuring cervix, cut tip from finger of large sterile glove and place over speculum to prevent intrusion of lateral tissue into field of view
- Failure to cannulate cervical os
    - Can be difficult in cases of cervical stenosis
    - Use progressive cervical dilators to help pass catheter
    - Can use tenaculum to provide cervical traction, though usually not necessary
- Inadequate uterine filling either due to pain or inadequate seal of balloon against cervix
    - Inject contrast medium more slowly if pain occurs
    - Provide gentle traction on catheter during injection to help seat balloon against internal os and reduce contrast reflux
    - Consider different cannula if problems with seal persist
- Tubal spasm may lead to false-positive result
    - Repeat injection or give antispasmodic (glucagon)
- Presence of blood clots in endometrial cavity may mimic polyps
    - Ensure no bleeding/spotting on day of examination
- Balloon may obscure a lower uterine segment abnormality
    - Consider deflating balloon and carefully retracting catheter into endocervical canal
    - Slowly inject additional contrast and obtain a "pull-back" view of lower uterine segment

Complications

- Most feared complication(s)
    - Irradiation of an early unsuspected pregnancy
        - Appropriate timing of procedure and negative pregnancy test before procedure minimizes risk
    - Post-HSG infection/PID is uncommon; seen in 1.4-3.4% of cases
        - Higher rates of postprocedure infection in cases of dilated fallopian tubes (11%)
- Other complications
    - Pain
        - Cramping pain is generally minor and well tolerated by majority of patients
        - Typically resolves by end of examination
    - Vasovagal reaction
        - Secondary to cervical manipulation or inflation of balloon
    - Allergic reaction to iodinated contrast
        - Systemic reaction more common with contrast intravasation
    - Uterine or tubal perforation
        - Extremely rare with conventional flexible HSG catheters

SELECTED REFERENCES

1. Maheux-Lacroix S et al: Hysterosalpingosonography for diagnosing tubal occlusion in subfertile women: a systematic review protocol. Syst Rev. 2:50, 2013
2. Trad M et al: Müllerian duct anomalies and a case study of unicornuate uterus. Radiol Technol. 84(6):571-6, 2013
3. Carrascosa PM et al: Virtual hysterosalpingography: a new multidetector CT technique for evaluating the female reproductive system. Radiographics. 30(3):643-61, 2010
4. ACOG Committee on Practice Bulletins--Gynecology: ACOG practice bulletin No. 104: antibiotic prophylaxis for gynecologic procedures. Obstet Gynecol. 113(5):1180-9, 2009
5. Chalazonitis A et al: Hysterosalpingography: technique and applications. Curr Probl Diagn Radiol. 38(5):199-205, 2009
6. Lindheim SR et al: Hysterosalpingography and sonohysterography: lessons in technique. AJR Am J Roentgenol. 186(1):24-9, 2006
7. Perquin DA et al: Routine use of hysterosalpingography prior to laparoscopy in the fertility workup: a multicentre randomized controlled trial. Hum Reprod. 2006
8. Simpson WL Jr et al: Hysterosalpingography: a reemerging study. Radiographics. 26(2):419-31, 2006
9. Spring DB et al: Enhanced fertility after diagnostic hysterosalpingography may be a myth. AJR Am J Roentgenol. 183(6):1728, 2004
10. Unterweger M et al: Three-dimensional dynamic MR-hysterosalpingography; a new, low invasive, radiation-free and less painful radiological approach to female infertility. Hum Reprod. 17(12):3138-41, 2002
11. Ubeda B et al: Hysterosalpingography: spectrum of normal variants and nonpathologic findings. AJR Am J Roentgenol. 177(1):131-5, 2001

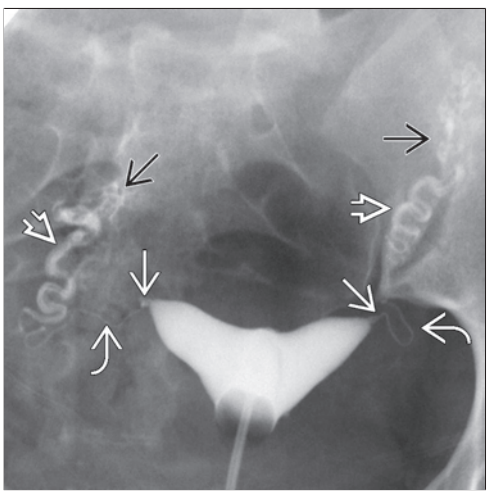
HYSTEROSALPINGOGRAPHY

Typical Hysterosalpingogram Tray

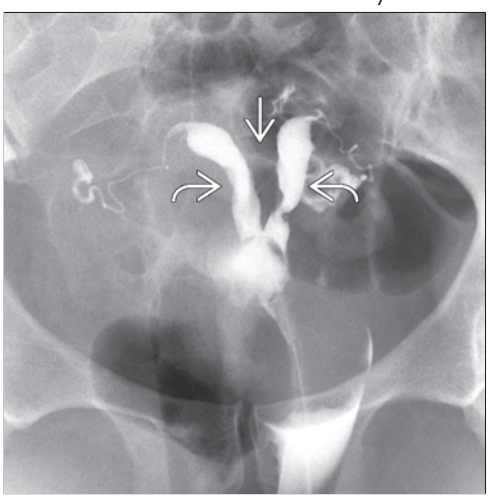
Balloon-Tipped Hysterosalpingogram Catheter

(Left) *Included in a typical HSG tray are ring forceps/tenaculum used to sterilize the cervix, speculum, iodine-based cleanser, and lubricating gel. A uterine sound is often included but rarely used.* ***(Right)*** *Image demonstrates a typical balloon-tip HSG catheter. The inflatable balloon is shown along with the plastic catheter stiffener, the contrast-filled syringe, the syringe to inflate the balloon, and the balloon stopcock.*

Normal HSG

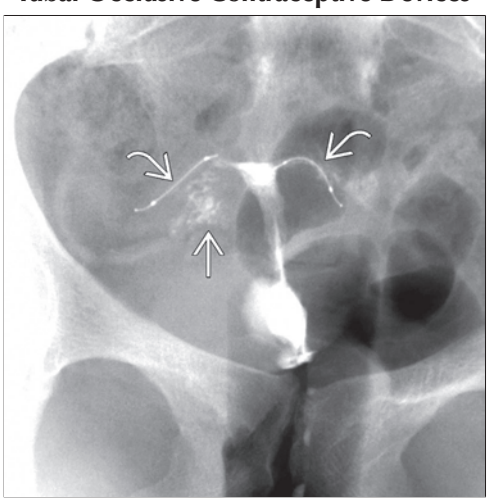


Müllerian Duct Anomaly

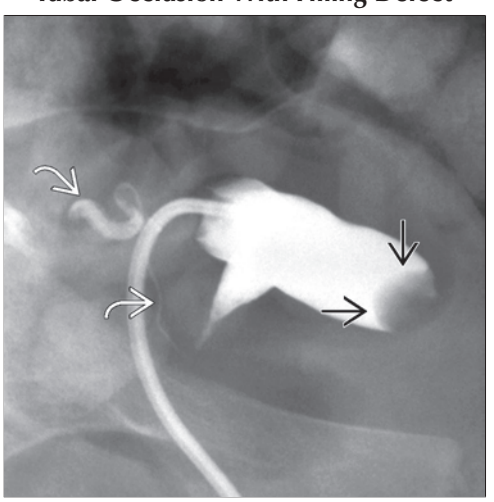


(Left) *Frontal image shows a normal HSG, with a smooth endometrial contour. The fallopian tube segments are well visualized (interstitial, isthmic, ampullary) and there is free spill of contrast from each tube.* ***(Right)*** *Frontal image shows 2 uterine cavities separated by a thick intervening septum. There was a single cervix. This may represent a septate or bicornuate uterus; MR or 3D US is necessary to evaluate the external uterine contour.*

Tubal Occlusive Contraceptive Devices

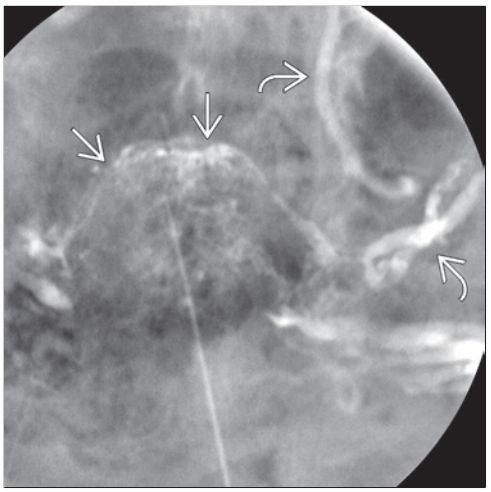


Tubal Occlusion With Filling Defect

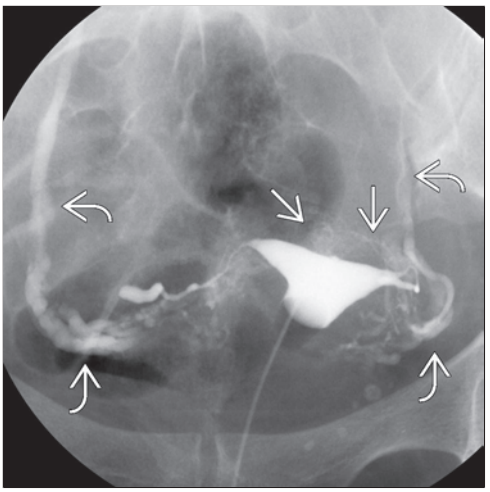


(Left) *Frontal image shows bilateral Essure tubal occlusive devices. This procedure was performed to confirm tubal occlusion after device placement. Note the small amount of contrast intravasation due to forceful injection.* ***(Right)*** *Oblique frontal image shows a large, rounded, fixed filling defect within the left uterine cornua, representing an endometrial polyp. There is resulting occlusion of the left tubal orifice. The right tube is normal.*

Contrast Intravasation

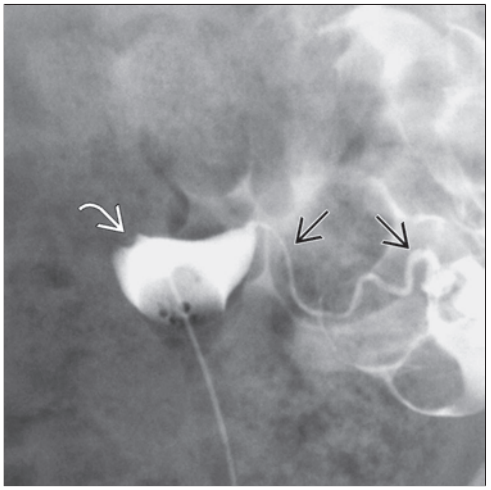


Contrast Intravasation

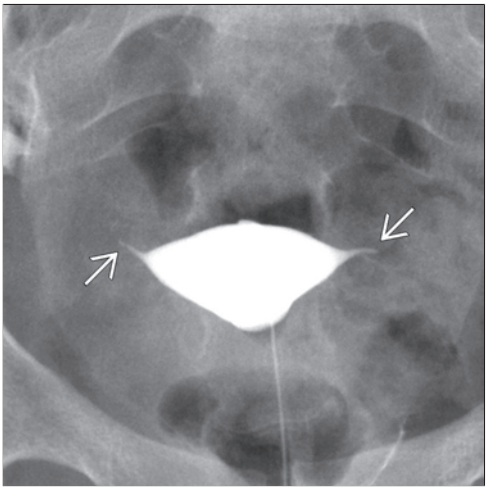


(Left) *Frontal image from an HSG shows the appearance of contrast intravasation. The arcuate veins ➔ are opacified, as is the parametrial and pelvic venous vasculature ➔. This is often the result of overdistention of the uterine lumen &/or injection of contrast with excessive pressure.* ***(Right)*** *Frontal image from an HSG shows contrast intravasation into the uterine arcuate venous vasculature ➔, with subsequent opacification of the parametrial and pelvic veins ➔.*

Tubal Occlusion With Filling Defect

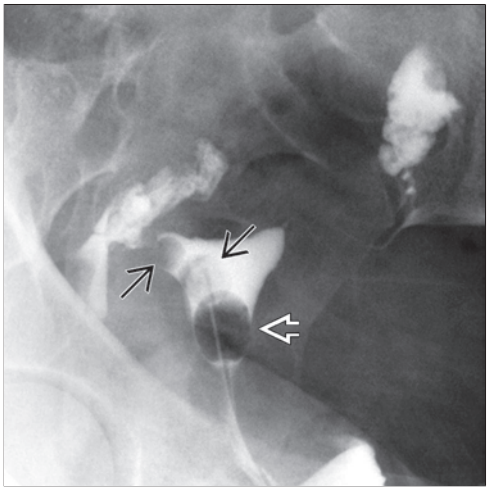


Bilateral Tubal Occlusion

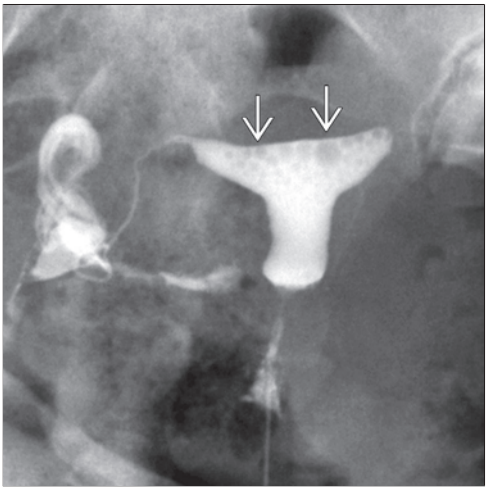


(Left) *Oblique frontal image from an HSG shows a normal left tube ➔ without opacification of the right tube. A subtle rounded filling defect ➔ is noted at the right tubal orifice, found to be a small occluding polyp.* ***(Right)*** *Frontal image shows occlusion of the bilateral fallopian tubes ➔ at the level of the proximal isthmic segment. Occlusion can be due to adhesions/scarring, tubal spasm, or rarely, tubal polyps.*

Air Bubbles



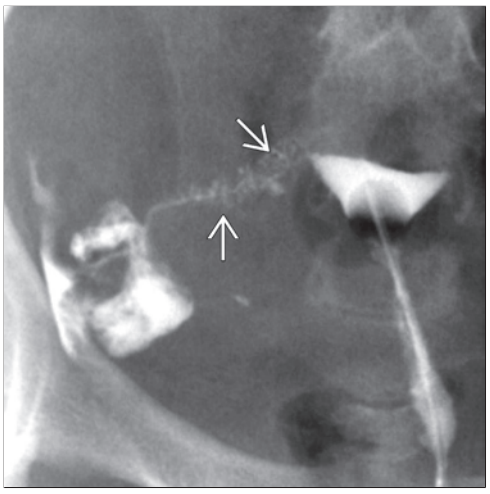
Air Bubbles



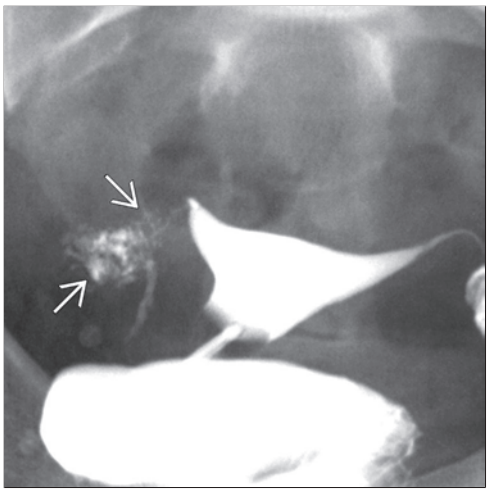
(Left) *Oblique frontal image from an HSG shows 2 rounded apparent endometrial filling defects ➔. These were mobile throughout the examination and represented air bubbles introduced during contrast administration. The catheter balloon ➔ is seen.* ***(Right)*** *Frontal image shows numerous mobile filling defects ➔ within the endometrial lumen, representing air bubbles. Bubbles can mimic endometrial polyps and can be minimized with meticulous technique.*

HYSTEROSALPINGOGRAPHY

Salpingitis Isthmica Nodosa

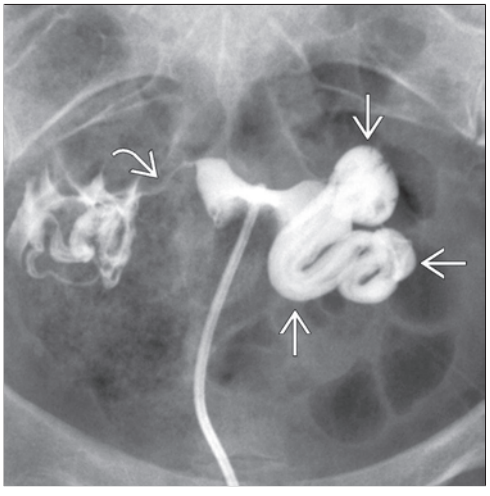


Salpingitis Isthmica Nodosa

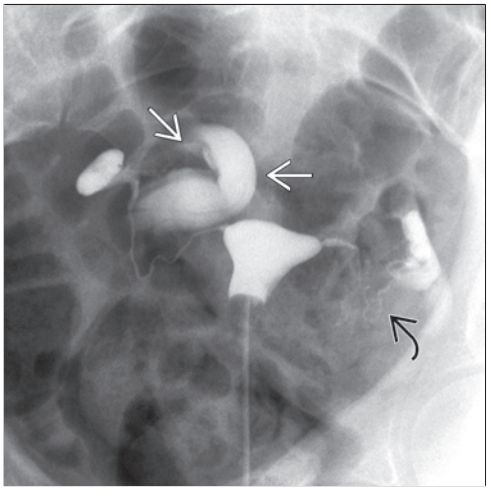


(Left) *Frontal image shows the classic appearance of salpingitis isthmica nodosa (SIN) with small diverticular outpouchings arising from the isthmic segment of the fallopian tube. SIN can be associated with infertility.* ***(Right)*** *Frontal image from an HSG shows tiny diverticular outpouchings from the isthmic segment of the right fallopian tube, consistent with SIN, which can affect 1 or both tubes.*

Hydrosalpinx

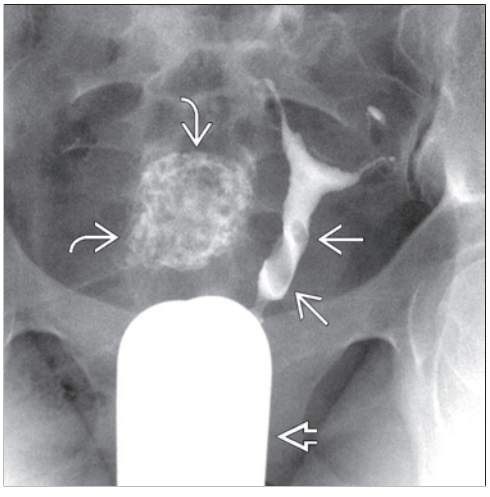


Hydrosalpinx

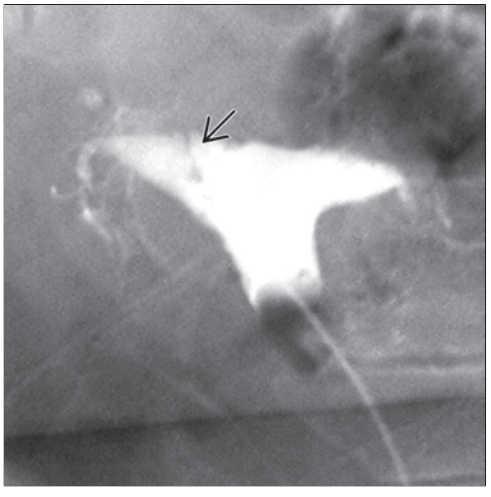


(Left) *Frontal image demonstrates a dilated and tortuous left fallopian tube, consistent with hydrosalpinx. There was no free spillage of contrast from the left tube. The right fallopian tube is normal.* ***(Right)*** *Oblique frontal image shows a dilated ampullary segment of the right fallopian tube without free spillage of contrast. This appearance is consistent with hydrosalpinx. The left tube is normal.*

Abnormal HSG

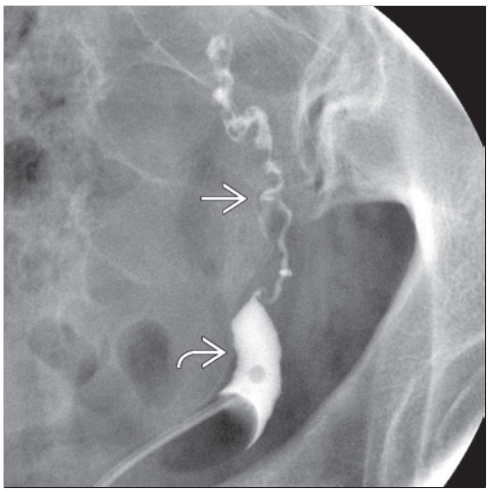


Uterine Synechia

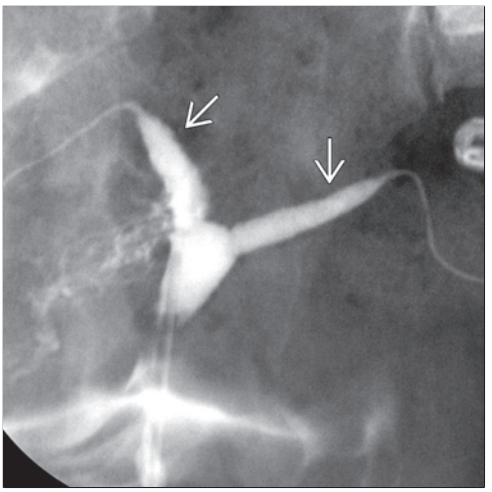


(Left) *Frontal image shows 2 ovoid fixed filling defects within the endometrial lumen, representing polyps. Note the calcified intramural fibroid exhibiting mass effect on the endometrial lumen. Note the metal vaginal speculum.* ***(Right)*** *Frontal image shows irregularity of the endometrial contour with several linear filling defects. In this patient with infertility and a history of prior dilation and curettage, this is consistent with uterine synechia (Asherman syndrome).*

Müllerian Duct Anomaly

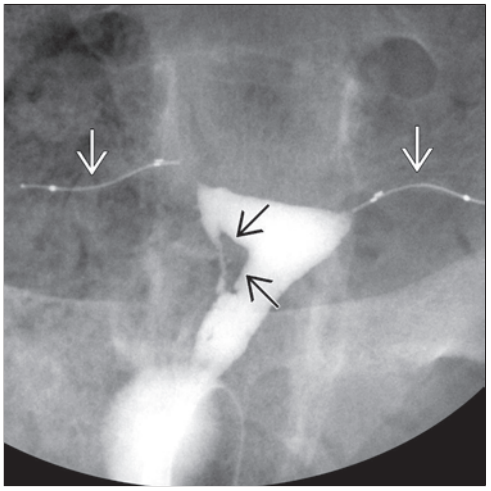


Müllerian Duct Anomaly

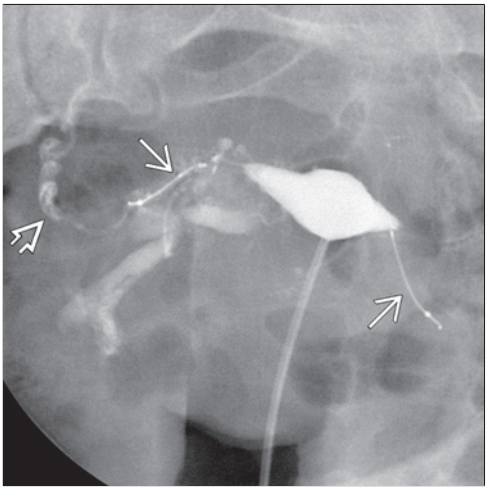


(Left) *Frontal fluoroscopic image shows a single tubular uterine horn* ➰ *with an associated normal fallopian tube* ➡, *consistent with a unicornuate uterus. MR may be necessary to evaluate for a contralateral noncommunicating rudimentary horn.* ***(Right)*** *Frontal image demonstrates 2 uterine horns* ➡ *in this patient with recurrent pregnancy loss. This appearance can be seen with septate and bicornuate uteri. MR or 3D US is necessary for further evaluation.*

Filling Defect

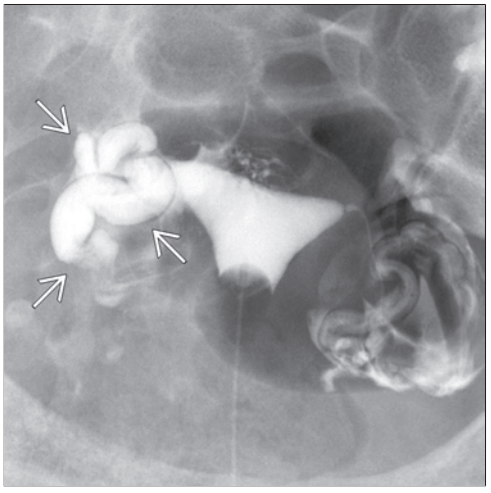


Failed Tubal Occlusion

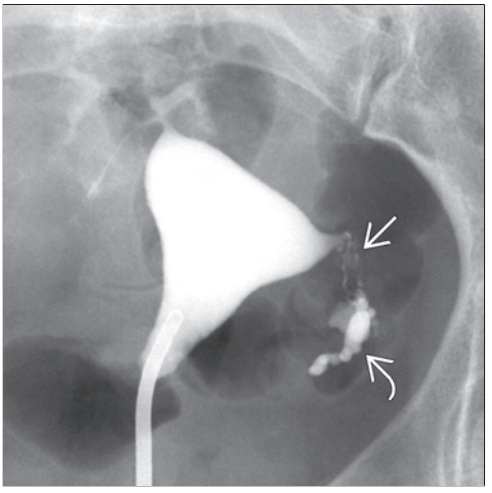


(Left) *Frontal image shows a fixed, somewhat angular filling defect* ➡ *along the right endometrial cavity, representing an endometrial adhesion. Note the bilateral tubal occlusive devices* ➡. ***(Right)*** *Frontal image demonstrates bilateral contraceptive tubal occlusive devices* ➡. *On the right, contrast opacifies the tube distal to the device* ➡ *with free spillage into the pelvis, consistent with failure of occlusion. The left tube was occluded.*

Hydrosalpinx



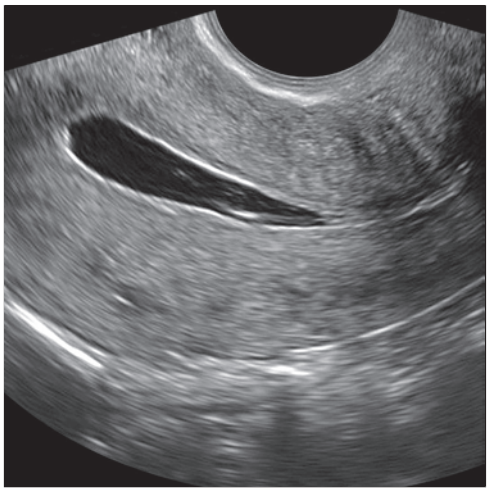
Salpingitis Isthmica Nodosa



(Left) *Frontal fluoroscopic image in a patient with infertility demonstrates a dilated and tortuous right fallopian tube* ➡, *consistent with hydrosalpinx. The left tube was normal.* ***(Right)*** *Frontal image shows an irregular obstructed ampullary segment of the left fallopian tube* ➰. *Note the subtle diverticula* ➡ *along the isthmic segment, suggestive of SIN in this patient with a history of infertility and prior PID.*

SONOHYSTEROGRAPHY

Included in a typical tray are a tenaculum, (to sterilize the cervix), speculum, cleanser, lubricating gel, a 5-7 French catheter with a 3 mL syringe for the balloon, and a 20 mL syringe containing sterile saline.



Sagittal transvaginal ultrasound during saline-infused sonohysterogram (SIS) shows distension of the uterine cavity with saline. The endometrium is of uniform thickness and homogeneous echotexture.

TERMINOLOGY

Abbreviations

- Saline-infused sonohysterogram (SIS)

Definitions

- SIS is a technique that involves placing a catheter into uterine cavity to inject sterile saline into endometrial canal

PRE-PROCEDURE

Indications

- Determine cause of abnormal vaginal bleeding
  - In premenopausal women
    - Distinguish anovulatory bleeding from anatomical lesion
  - In postmenopausal women
    - Distinguish between atrophy and anatomical lesion that may require biopsy
- Infertility and repeated abortion
- Congenital abnormality of uterine cavity
- Preoperative or postoperative evaluation of uterine myomas, polyps, or cysts
- Suspected uterine synechiae
- Further evaluation of suspected endometrial abnormalities detected by transvaginal sonogram

Contraindications

- Pregnancy
- Active pelvic infection
- Excessive vaginal bleeding
- Patients with IUD in place

Getting Started

- Things to check
  - Negative pregnancy test must be documented
- Medications
  - Anesthesia or analgesia is not usually required
  - Nonsteroidal anti-inflammatory drug may be offered 30 minutes prior to examination to help reduce pain of cramping
  - Prophylactic antibiotics are not routinely advised
    - May be administered to patients who are at increased risk for infection

Timing

- Premenopausal women
  - Early proliferative phase (day 4–10) of menstrual cycle, when endometrium is at its thinnest
    - Saline can easily distend uterine cavity and better accentuate endometrial pathology
    - Physiologic changes during secretory phase may simulate pathologic conditions
      - Irregularities in contour of endometrium may be misinterpreted as small polyps or focal areas of endometrial hyperplasia
- Postmenopausal women
  - Not undergoing hormone replacement therapy
    - Any time
  - Undergoing sequential hormone therapy (estrogen followed by progesterone)
    - At end of progesterone phase

PROCEDURE

Patient Position/Location

- Lithotomy position

Equipment Preparation

- Equipment needed
  - Sterile speculum with open side
  - Cervical sounds in event that catheter does not pass easily through cervix
  - 20 mL syringe
  - Tenaculum
    - Used to clean cervix
  - Clamps
  - 5-7 French hysterosonography catheter with a 3 mL syringe for balloon
    - Several different catheters available for SIS

Procedure Steps

- Brief bimanual examination to locate cervix
- Speculum is inserted into vagina, and cervical os is localized and cleaned with povidone iodine solution

SONOHYSTEROGRAPHY

Key Facts

Terminology
- Saline-infused sonohysterogram (SIS)
  - Technique that involves placing a catheter into uterine cavity to inject sterile saline into endometrial canal

Pre-Procedure
- Indications
  - Determine cause of abnormal vaginal bleeding
  - Infertility and repeated abortion
  - Congenital abnormality of uterine cavity
- Contraindications
  - Pregnancy
  - Active pelvic infection
  - Excessive vaginal bleeding
  - Patients with IUD in place
- Negative pregnancy test must be obtained prior to procedure
- Timing
  - Premenopausal women: Early proliferative phase (day 4–10) of menstrual cycle, when endometrium is at its thinnest
  - Postmenopausal women: Generally any time

Procedure
- Catheter must be flushed with sterile saline before insertion to remove air bubbles
- Normal uterine cavity should expand symmetrically upon saline instillation
- Endometrium should be uniform in thickness, homogeneous in echotexture

· Catheter must be flushed with sterile saline before insertion to remove air bubbles
  ◦ Air introduced into endometrial canal may obscure abnormalities during scanning
· Catheter is inserted into cervical canal
· Catheter balloon tip is then inflated using 1-2 mL of saline
· Speculum is removed
· Standard transvaginal ultrasound probe is then inserted alongside catheter
· Warm sterile saline is instilled into endometrial cavity via a 20 mL syringe attached to catheter while transducer is moved from side to side (cornua to cornua) in a long-axis position
· Amount of fluid instilled will vary depending on distention of uterus and patient tolerance
  ◦ Usually, amount of saline instilled is 40 mL
· Ideally, all portions of endometrium should be imaged to exclude any abnormalities

Findings and Reporting
· Normal uterine cavity should expand symmetrically upon saline instillation
· Endometrial thickness
  ◦ Premenopausal
    ▪ No established limit for normal
    ▪ Endometrium should be uniform in thickness, homogeneous in echotexture
  ◦ Postmenopausal
    ▪ Normal atrophic endometrium should measure < 2.5 mm in single-layer thickness
    ▪ Atrophic endometrium should be smooth and uniform in echotexture
· SIS can determine whether endometrium is diffusely thick or has focal areas of thickening
  ◦ Diffuse thickening → blind endometrial biopsy
  ◦ Focal areas of thickening → hysteroscopic biopsy

OUTCOMES

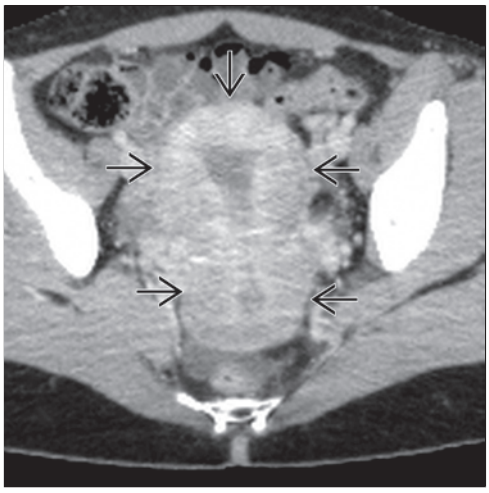
Problems
· Failure to complete procedure
  ◦ Patient discomfort
  ◦ Cervical stenosis and scarring, leading to difficult catheterization and backflow of saline
· Variable uterine position
  ◦ Can complicate catheter insertion
    ▪ Changing position of speculum by moving handle of speculum up or down, thus changing angle of access to cervix
      - Often enables successful catheter insertion
· Cervical stenosis
  ◦ Cervical dilator may be used
  ◦ Guidewire can be passed through cervical os with subsequent passage of a non-balloon-tipped catheter over guidewire into cervical os
· Difficult distension of endocervical canal
  ◦ Synchronous gentle collapse of catheter balloon while slowly instilling fluid into canal while retracting catheter or passively slipping it out of uterus
· Air introduced into endometrial canal, leading to an echogenic artifact that can obscure abnormalities
  ◦ Flushing catheter with saline before procedure is essential
· Backflow of saline around balloon and through cervix → under distension of uterine cavity → masking of endometrial pathology
  ◦ Gently retract inflated catheter balloon to occlude internal cervical os
· Balloon hyperinflation may obscure underlying pathology
  ◦ Move or partially deflate balloon

Complications
· Pelvic pain (3.8% of patients)
· Vagal symptoms (3.5% of patients)
· Nausea (1% of patients)
· Postprocedure fever (0.8% of patients)
· Rarely, endometritis

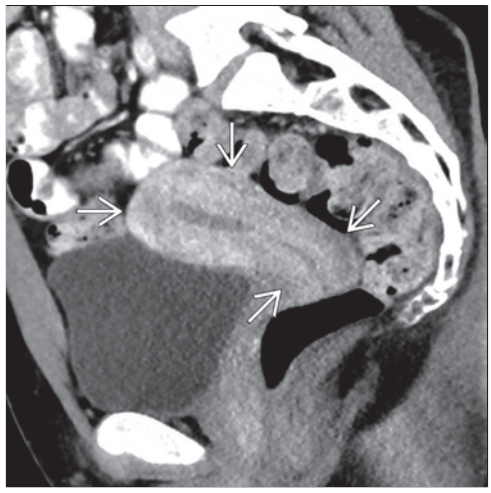
SELECTED REFERENCES

1. Yang T et al: Sonohysterography: Principles, technique and role in diagnosis of endometrial pathology. World J Radiol. 5(3):81-7, 2013
2. Allison SJ et al: saline-infused sonohysterography: tips for achieving greater success. Radiographics. 31(7):1991-2004, 2011

CT TECHNIQUE AND ANATOMY



Axial CECT shows the normal appearance of the uterus ⇨. The central endometrium appears hypodense, and the outer myometrium can have a variable pattern of enhancement.



Sagittal CECT shows the normal appearance of the uterus ➔. Most uteri are anteverted and anteflexed, as in this case. The central hypodense endometrium is best measured on sagittal images.

TERMINOLOGY

Abbreviations

- Computed tomography (CT)
- Computed tomography angiography (CTA)

PRE-PROCEDURE

Indications

- Staging of known/presumed ovarian cancer
  - Evaluate extent of disease (peritoneal spread of disease, nodal involvement, malignant ascites)
  - Helps to guide patients to surgery or neoadjuvant chemotherapy
- Local staging of advanced pelvic malignancies (such as uterine and cervical carcinoma)
  - MR is typically modality of choice
  - CT may be helpful when MR is contraindicated
- Follow-up of treated gynecologic malignancy
  - Assess for tumor recurrence
- Assessing postoperative complications
  - Abscess
  - Fistula
  - Lymphocele
- Assessment of pelvic infectious processes
  - Tubo-ovarian abscess/pyosalpinx
  - Pyometra/myometrial abscess in clinical setting of endometritis
- Localization of IUD when not visualized on ultrasound
- CT-guided biopsy
  - Provides a histological diagnosis
  - Helps to differentiate tumor recurrence from postsurgical/radiation fibrosis
- CT-guided drainage of pelvic collection
- CT is not typically used as first-line examination to characterize gynecological pathology
  - US and MR are typically utilized

Contraindications

- CT is not contraindicated in pregnancy but should be used judiciously
  - US and MR should be considered 1st
  - Avoid intravenous contrast
- Allergy to iodinated contrast is a relative contraindication
  - Requires premedication, typically with oral steroids and diphenhydramine
  - Consider noncontrast examination or alternate modality

Getting Started

- Things to check
  - Check renal function in patients receiving iodinated contrast if
    - Patient is > 60 years in age
    - History of renal impairment
    - History of hypertension requiring medication
    - History of diabetes
    - Patient is taking metformin

PROCEDURE

Patient Position/Location

- Patient is typically in supine position
- Prone or oblique imaging may be necessary for CT-guided procedures

Alternative Procedures/Therapies

- Radiologic
  - US
  - MR

Advantages

- Oral and rectal contrast opacification of gastrointestinal tract
  - Allows differentiation of bowel from pelvic viscera and tumor
- Intravenous contrast enhancement of blood vessels and viscera
  - Helps improve soft tissue differentiation
    - Pelvic blood vessels vs. lymph nodes vs. parametrial tumor extension
  - Angiographic imaging can assess pelvic vascular involvement

CT TECHNIQUE AND ANATOMY

Key Facts

Pre-Procedure

- Indications for CT imaging include
  - Staging of known/presumed ovarian cancer
  - Follow-up of treated gynecologic malignancy
  - Assessing postoperative complications
  - Assessment of pelvic infectious processes
  - Procedural guidance
- CT is not contraindicated in pregnancy but should be used judiciously
- Advantages of CT imaging include
  - Quick imaging times
  - Isotropic voxels allow for improved multiplanar reconstruction
  - Intraluminal contrast allows for easy distinction of bowel from pelvic organs/pathology
- Disadvantages of CT include
  - Use of ionizing radiation
  - Contrast agents have associated morbidity/mortality
  - Limited application in early cancer and local staging

Procedure

- Imaging is typically performed with oral and IV contrast
- While CT is not the study of choice in evaluation of gynecological pathology, pelvic organs are routinely imaged and described in imaging report
  - Uterus: May have variable enhancement patterns
  - Cervix: Typically has a targetoid appearance
  - Fallopian tubes: Usually not well visualized when normal
  - Ovaries: Easily seen in premenopausal patients, but atrophic and often difficult to visualize after menopause

- Differential enhancement patterns distinguish uterine tumor from normal myometrium
- Allows opacification of bladder and ureters
- Multidetector CT provides for very fast data acquisition
  - Rapid coverage of entire body
  - High spatial resolution
    - Acquisition of isotropic voxels allows for improved multiplanar reconstruction
  - Imaging in different circulatory phases can be acquired

Disadvantages

- Utilizes ionizing radiation
- Image quality may be degraded by
  - Body habitus
  - Metallic hardware (hip prosthesis)
- Use of iodinated contrast agents associated with morbidity and mortality
- Limited application in early-stage cancer and local staging

CT Technique

- Preprocedural administration of oral contrast medium
  - 750-1,000 mL diluted positive oral contrast 2 hours prior to examination
    - Barium or iodine based
  - Delayed oral contrast medium regimen (48 hours) may be useful if slow transit through gut
- IV contrast medium administration
  - 100-150 mL iodinated contrast medium
    - Injection rate 2-3 mL/second for routine studies
    - Rate of 4-5 mL/second for angiographic applications
  - Images acquired 70-120 seconds after contrast for routine studies
    - Bolus tracking technique vs. 20-40 second delay after contrast injection
    - Delayed imaging may be useful
      - 3-5 minutes for pelvic vein imaging (for patency/thrombosis)
      - 5-10 minutes for bladder and ureteral opacification
- Sub-mm collimation images are acquired and reconstructed into
  - 2-5 mm thick axial images
  - Sagittal and coronal images
  - 3D reconstructed images as needed
- CT cystography can be performed to evaluate bladder involvement by tumor or urogenital fistula
  - Imaging performed after bladder catheterization and instillation of contrast
  - Intravenous contrast is administered as well
  - Consider negative intravaginal contrast to better visualize fistula
- CT hysterosalpingography techniques have been described
  - Involves catheterization of endometrial cavity and injection of dilute iodinated contrast material
  - CT of pelvis is performed with multiplanar and 3D reformatted images
  - Allows for evaluation of tubal patency and uterine morphology
  - Can perform "virtual hysteroscopy" and evaluate endometrial contour

CT Anatomy

- Uterus
  - Appearance varies depending on
    - Patient age
    - Uterine positioning
    - Parity
    - Presence of leiomyoma, adenomyosis
  - Typically appears as a triangular soft-tissue structure contiguous with vagina
    - Uterus is anteverted/anteflexed in most cases
    - May appear enlarged on axial images if retroflexed/retroverted
  - Posterior to urinary bladder, anterior to rectum
  - NECT: Uterus appears homogeneous; measures soft tissue attenuation
    - Central endometrium may be faintly visible as a slightly hypodense stripe
  - CECT: Differential enhancement of myometrium and endometrium
    - Varied enhancement of myometrium based on timing of study, phase of menstrual cycle, patient age
      - Homogeneous (diffuse or minimal)

- Subendometrial (thick or thin)
- Outer myometrial
- Patchy/heterogeneous
- Myometrium enhances to a lesser degree in postmenopausal patients
- Endometrium enhances to a lesser degree on early-phase acquisitions and becomes more isodense to myometrium on delayed imaging
- Endometrial thickness may be overestimated on axial and coronal images; sagittal reformatted images provide for more accurate measurement

· Cervix
  ◦ Inferior segment of uterus, contiguous with vagina
  ◦ Rounded appearance in axial plane
  ◦ NECT: Homogeneous soft tissue density, isodense to myometrium
  ◦ CECT: Targetoid/layered appearance
    ▪ Central secretions/fluid: Hypodense
    ▪ Inner cervical mucosa: Hyperdense
    ▪ Inner stroma: Hypodense
    ▪ Outer stroma: Hyperdense
    ▪ On early postcontrast phases, cervix may appear diffusely low density and simulate pathology
· Fallopian tubes
  ◦ Normally not well visualized
  ◦ May appear as tortuous tubular structure in setting of hydrosalpinx/pyosalpinx
· Vagina
  ◦ Thin-walled tubular structure extending from cervix to introitus
  ◦ Typically collapsed; may contain a small amount of air, fluid, or tampon
  ◦ Characteristic "H" configuration
  ◦ Mucosa will demonstrate smooth enhancement
· Ovaries
  ◦ Routinely seen in premenopausal women
  ◦ Small and atrophic in postmenopausal patients; not always identified
    ▪ Often located adjacent to external iliac vasculature
  ◦ Can be identified by following ovarian vasculature into pelvis
  ◦ Uniform soft-tissue density, lower than that of enhancing myometrium
    ▪ Small low-density cystic regions represent follicles
    ▪ Irregular thick-walled enhancing structure represents corpus luteum
  ◦ Position variable
    ▪ Usually posterolateral to uterine corpus
    ▪ Anterior and medial to ureter
    ▪ Posterior to round ligament
    ▪ Medial or posteromedial to external iliac vessels
    ▪ Ovarian mass displaces ureter laterally and posteriorly vs. nodal mass lying lateral to ureter
· Pelvic ligaments
  ◦ Broad ligament
    ▪ 2 layers of peritoneum
    ▪ Extend laterally from uterus to pelvic sidewall
    ▪ Contains parametrial vasculature
    ▪ Not usually seen unless ascites is present
  ◦ Round ligament
    ▪ Thin soft tissue attenuation band
    ▪ Extends laterally from lateral fundus to internal inguinal ring
    ▪ Tapers distally
    ▪ Frequently seen
  ◦ Uterosacral ligament
    ▪ Extends posteriorly from lateral cervix and vagina
    ▪ Tapers toward anterior body of S2 or S3
    ▪ May be seen as soft tissue arcing band from cervix to sacrum
  ◦ Cardinal ligament
    ▪ Extends laterally from cervix and upper vagina
    ▪ Merges with pelvic sidewall
    ▪ May be seen as triangular soft tissue structure
    ▪ Contains uterine vasculature
  ◦ Ovarian ligaments
    ▪ Not usually identified
    ▪ Proper ovarian ligament: Extends medially from ovary to uterus
      - Arises inferior to fallopian tube ostium
    ▪ Suspensory ligament of ovary: Extends from ovary to pelvic sidewall
      - Contains ovarian vasculature

OUTCOMES

Complications

· Most feared complication(s)
  ◦ Anaphylactoid reaction to intravenous contrast administration
· Other complications
  ◦ Contrast-induced nephropathy for patients receiving intravenous iodinated contrast

SELECTED REFERENCES

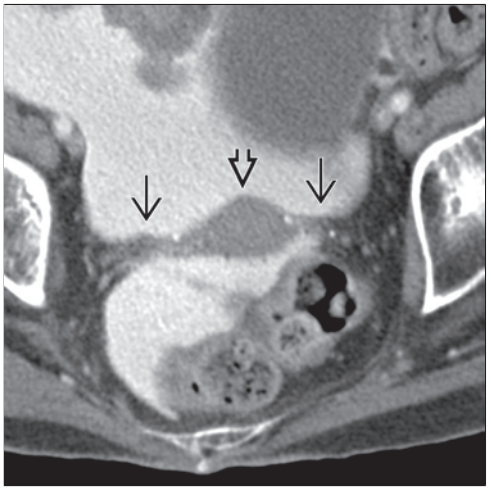
1. Katz DS et al: Computed tomography imaging of the acute pelvis in females. Can Assoc Radiol J. 64(2):108-18, 2013
2. Botsikas D et al: A new MDCT technique for the detection and anatomical exploration of urogenital fistulas. AJR Am J Roentgenol. 198(2):W160-2, 2012
3. Sierra A et al: Utility of multidetector CT in severe postpartum hemorrhage. Radiographics. 32(5):1463-81, 2012
4. Yitta S et al: Normal or abnormal? Demystifying uterine and cervical contrast enhancement at multidetector CT. Radiographics. 31(3):647-61, 2011
5. Carrascosa PM et al: Virtual hysterosalpingography: a new multidetector CT technique for evaluating the female reproductive system. Radiographics. 30(3):643-61, 2010
6. Yitta S et al: Added value of multiplanar reformation in the multidetector CT evaluation of the female pelvis: a pictorial review. Radiographics. 29(7):1987-2003, 2009
7. Chen MM et al: Guidelines for computed tomography and magnetic resonance imaging use during pregnancy and lactation. Obstet Gynecol. 112(2 Pt 1):333-40, 2008
8. Grossman J et al: Efficacy of contrast-enhanced CT in assessing the endometrium. AJR Am J Roentgenol. 191(3):664-9, 2008
9. Choi HJ et al: Computed tomography findings of ovarian metastases from colon cancer: comparison with primary malignant ovarian tumors. J Comput Assist Tomogr. 29(1):69-73, 2005
10. Funt SA et al: Role of CT in the management of recurrent ovarian cancer. AJR Am J Roentgenol. 182(2):393-8, 2004
11. Saksouk FA et al: Recognition of the ovaries and ovarian origin of pelvic masses with CT. Radiographics. 24 Suppl 1:S133-46, 2004

Cervix

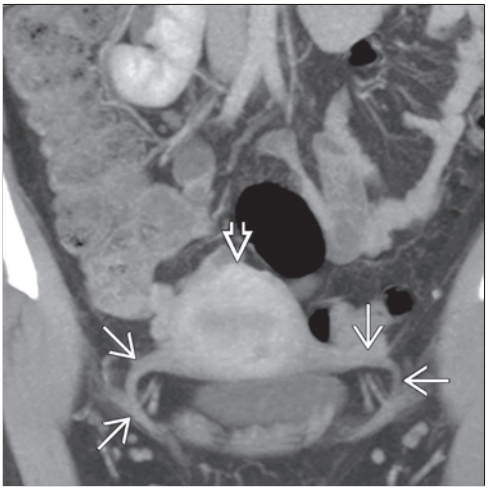
Ovaries

(Left) *Axial CECT shows the normal targetoid appearance of the cervix. The central secretions are hypodense, the mucosa is hyperdense, the inner stroma is hypodense, and the outer cervical stroma is hyperdense.* ***(Right)*** *Axial CECT shows normal-appearing ovaries, which may be more difficult to identify in postmenopausal patients due to atrophy. The ovaries appear hypodense to the myometrium, with numerous small physiologic follicles.*

Broad Ligaments

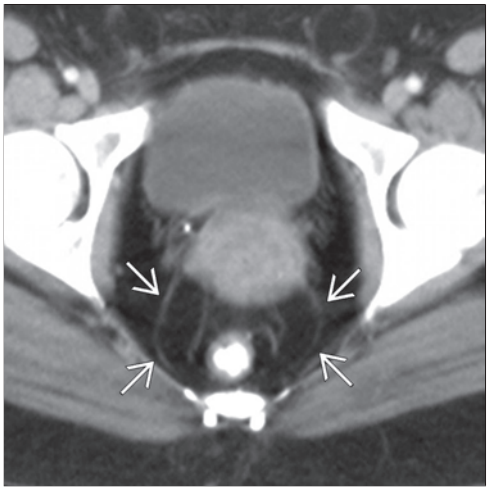


Round Ligaments

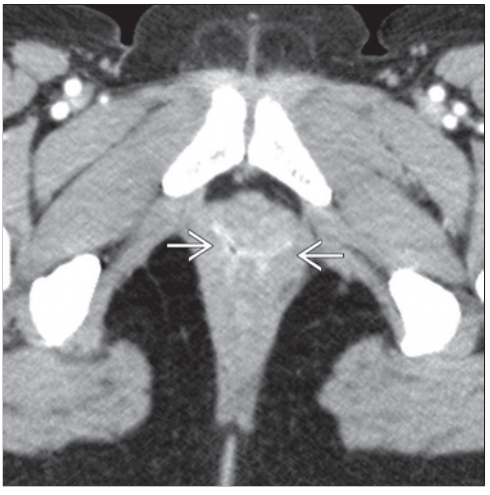


(Left) *Axial CECT demonstrates the broad ligaments as they arise from the lateral margins of the uterus and extend laterally. The broad ligaments are normally difficult to identify unless they are outlined by ascites or, as in this case, intraperitoneal oral contrast.* ***(Right)*** *Coronal CECT shows the round ligaments as they arise from the uterine fundus and extend into the inguinal canals. The round ligaments are typically well visualized on CT.*

Uterosacral Ligaments

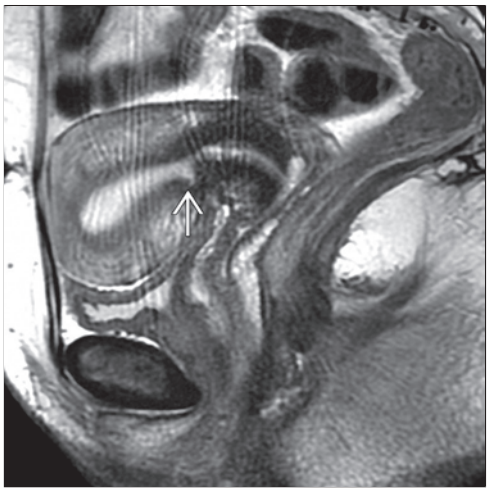


Vagina

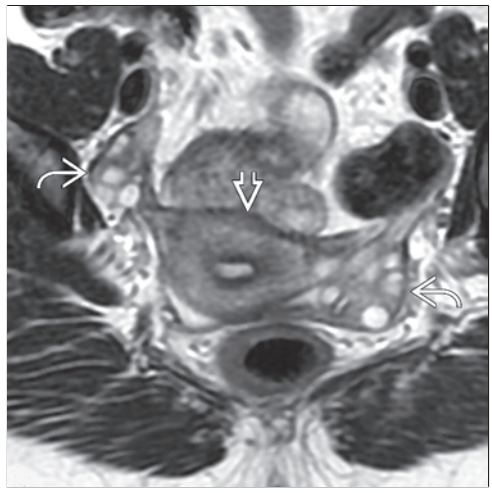


(Left) *Axial CECT shows normal bilateral uterosacral ligaments, which can be seen as thin soft tissue bands extending from the lateral cervical margins posteriorly to the sacrum. The uterosacral ligaments can be a route of disease spread, as in the setting of cervical carcinoma or endometriosis.* ***(Right)*** *Axial CECT shows a normal appearance to the decompressed vagina, which classically has an "H" configuration. The vaginal mucosa is typically smoothly enhancing.*

MR TECHNIQUE AND ANATOMY



Sagittal T2WI MR shows normal MR appearance of uterus, which is anteverted and anteflexed; uterine zonal anatomy is well visualized. Note cesarean section scar ➔ along anterior aspect of lower uterine segment.



Axial T2WI MR demonstrates a normal appearance of the ovaries ↷ and uterus ➪. Within the ovaries are scattered small physiologic follicles. Note the normal uterine zonal anatomy.

TERMINOLOGY

Definitions

- Imaging modality that measures tissue response to radiofrequency pulses in a magnetic field to generate images

PRE-PROCEDURE

Indications

- Characterization of pelvic masses
- Staging of pelvic malignancies
- Evaluation of congenital (müllerian) anomalies
- Treatment follow-up
- Pelvic floor assessment (dynamic)
- Evaluation of pelvic lymphadenopathy
- Pelvimetry
- Evaluation of pelvic pain in pregnancy

Contraindications

- Cardiac pacemakers/implantable cardioverter-defibrillators
  - Alternative modalities should be pursued
  - Patients who are not pacemaker-dependent may undergo MR evaluation in experienced centers under supervision of cardiologist if there are no suitable alternatives
- Cochlear implants
  - Certain devices may be safe for MR imaging
- Ferromagnetic intracranial aneurysm clips
- Implanted neurostimulators
  - Certain devices may be safe for MR imaging
- Ferromagnetic foreign bodies (intraocular)
- Pulmonary artery monitoring catheters, temporary transvenous pacing leads, intraaortic balloon pumps, LVADs
- Intravenous gadolinium contrast should not be administered in patients at risk for nephrogenic systemic sclerosis
  - Chronic renal insufficiency with an estimated glomerular filtration rates < 30 mL/min
  - Dialysis patients
  - Acute kidney injury
- Relative contraindications to MR include
  - Tattoos, including permanent eye liner
  - Patients who suffer with claustrophobia
  - Compromised thermoregulatory systems
- **Any implanted device must be confirmed safe for MR prior to imaging**

Getting Started

- Things to check
  - Evaluation of renal function for patients receiving contrast who meet the following criteria
    - > 60 years of age
    - History of renal disease
    - History of hypertension requiring medication
    - History of diabetes mellitus
- Medications
  - Anxiolytics may be helpful in patients with claustrophobia
  - Antiperistaltic agents (hyoscine butyl bromide or glucagon) may be used to limit small bowel motion artifact
- Patient preparation
  - Empty bladder
  - Reduce motion artifact from small bowel peristalsis
    - Fasting for 4-6 hours before MR examination
    - Antiperistaltic agent use is not routine
  - Vaginal administration of 40-60 mL of bacteriostatic surgical lubricant may be considered
    - Acts as intraluminal contrast agent
    - Allows for improved evaluation of cervix and vagina

Advantages

- No ionizing radiation
- Multiplanar capability
- Excellent spatial and tissue contrast resolution, which is improved with higher field magnets (3T)
- Can perform dynamic imaging, allowing for functional evaluation
- Allows definitive noninvasive diagnosis of certain malignant tumors and benign conditions

MR TECHNIQUE AND ANATOMY

Key Facts

Procedure

- Indications for MR include
  - Characterization of adnexal masses
  - Staging of pelvic malignancies
  - Evaluation of congenital anomalies
  - Treatment follow-up
  - Pelvic floor assessment
  - Imaging of pelvic pain during pregnancy
- Contraindications for MR include implanted medical devices, ferromagnetic foreign bodies
  - **Any implanted device must be confirmed safe for MR prior to imaging**
  - Intravenous gadolinium contrast should not be administered in patients at risk for nephrogenic systemic sclerosis
- Image is typically performed
  - In supine position using a surface array multichannel coil
  - In axial, sagittal, coronal, and oblique planes
- Sequences utilized depend on clinical problem but typically include T2WI, T1WI, and pre- and post-contrast T1WI FS
- Gynecological anatomy is well-appreciated on MR
  - Uterine and cervical zonal anatomy is well depicted on sagittal T2WI
  - Ovaries are visualized in the ovarian fossae, usually containing scattered physiologic follicles &/or corpus luteum
  - Appearance of pelvic organs varies with age, menstrual status, and parity

Disadvantages

- Longer acquisition times
- May not be as widely available as CT or US
- Increased cost

PROCEDURE

Patient Position/Location

- Patient is usually imaged in supine position

Equipment Preparation

- Coil selection
  - Image commonly performed using surface array multichannel coil
  - Abdominal/pelvic coil provides for larger field of view but decreased resolution/signal
  - Phase-array coil increases resolution and decreases imaging time
  - Endoluminal coils (endorectal and endovaginal coils) may be used in select cases
    - Advantage: Provide for high-resolution images, especially small cervical tumors or those with limited parametrial invasion
    - Disadvantage: Limited field of view that proves inadequate in assessing large tumors and extrauterine tumor extent

Alternative Procedures/Therapies

- Radiologic
  - Ultrasound
    - Useful in initial evaluation of gynecological complaints
    - Can help characterize uterine/adnexal lesions
  - CT
    - Most useful in staging of malignancy (extrapelvic involvement, lymphadenopathy)
    - Used in follow-up of treated malignancy
    - Useful in evaluation of suspected tubo-ovarian abscess

MR Technique

- Imaging planes
  - Axial plane
    - Pelvic anatomy is typically best recognized in axial plane
    - Good for evaluation of parametrium (i.e., parametrial tumor extension)
  - Sagittal plane
    - Best appreciation of uterine zonal anatomy
    - Useful in evaluation of tumor extension to bladder, cervix, rectum, and vagina
  - Coronal plane
    - Provides complementary information in assessment of uterus, cervix, parametrium, vagina, and ovaries
    - Evaluation of lymphadenopathy and adnexal masses
  - Oblique planes (axial &/or coronal)
    - Very helpful in evaluation of parametria in patients with cervical cancer
    - Allows for characterization of müllerian duct anomalies
- Sequences most commonly utilized include
  - T2WI: Superb tissue contrast resolution and demonstration of uterine and cervical zonal anatomy and ovarian anatomy
    - Imaging performed **without** fat suppression; pelvic fat serves as intrinsic contrast
  - T1WI: Evaluation of pelvic soft tissues, lymph nodes, and bone marrow
  - T1WI FS
    - Helps to differentiate between fat and blood
    - Improves detection and conspicuity of hyperintense lesions surrounded by fat
    - Provides baseline pre-contrast signal intensity to compare to post-gadolinium imaging
  - T1WI C+ FS
    - Helps in characterization of adnexal lesions
    - Essential in cervical cancer staging
      - Evaluation of extent of tumor (vaginal, parametrial, pelvic sidewall)
      - Helps identify bladder, ureteral, or rectal involvement
      - Pelvic lymphadenopathy
    - Useful in staging ovarian cancer (when CT is not performed)
    - Evaluation of vascularity of uterine leiomyomata prior to therapy

- Can be performed dynamically to evaluate lesion enhancement characteristics
- Diffusion weighted imaging (DWI)/apparent diffusion coefficient (ADC)
  - Must be evaluated in conjunction with other imaging sequences
  - Provides information about water mobility, tissue cellularity, and integrity of cellular membranes
  - Aids in diagnosis and grading of tumors as well as predicting/assessing response to treatment
    - Low ADC values are associated with malignancy (such as endometrial, ovarian, and cervical cancers), though there is overlap between malignant and benign tissues
    - Tumors with low cellularity or mucinous tumors may have high ADC values
    - Pretreatment ADC values may help predict tumor response to therapy
  - Peritoneal implants from disseminated ovarian cancers often have restricted diffusion
    - Small implants are more conspicuous than on other sequences
  - ADC values of malignant lymph nodes are typically lower than that of normal nodes
    - Inflammatory/reactive nodes may also have low ADC values
  - Can help distinguish recurrent/residual tumor from postoperative change
    - Viable tumors have low ADC values, whereas postoperative inflammation has higher ADC values
  - DWI/ADC can be used to monitor treatment of leiomyomas
    - Treated lesions have increased DWI/decreased ADC signal due to infarct-related diffusion restriction
    - ADC values may subsequently increase secondary to necrosis
- Other imaging sequences/techniques include
  - Steady-state free precession (SSFP)
    - "Bright blood" imaging technique
    - Fast imaging sequence, relatively motion insensitive
    - Can be acquired dynamically in evaluation of pelvic floor dysfunction
    - Useful in imaging of pregnant patients
  - Pelvic MRA
    - Evaluation of pelvic vasculature prior to procedure (uterine artery embolization)
    - Evaluation for vascular involvement by pelvic malignancy
  - MR perfusion
    - Displays information about tissue perfusion, microcirculation, and angiogenesis
    - Aids in lesion detection and characterization and can improve accuracy of tumor staging
    - Changes in tumor perfusion as a marker of early response to treatment may precede decrease in tumor size
  - MR hysterosalpingography
    - MR imaging is performed after cannulation of cervix and injection of dilute gadolinium contrast into endometrial cavity
    - Can evaluate for tubal patency as well as structural abnormalities
  - BOLD (**b**lood **o**xygenation **l**evel **d**ependent) MR
    - Measures differences in paramagnetic deoxyhemoglobin in blood as a marker of tumor hypoxia
    - Tumors with higher levels of hypoxia may be more aggressive and resistant to therapy
    - Identifies higher grade portions of tumor to help guide therapy
  - MR lymphography
    - Can detect metastases in normal size lymph nodes with very high sensitivity and specificity
    - Requires intravenous injection of ultra small particles iron oxide (USPIO)
    - USPIO is taken up by normal lymph nodes, whereas metastatic lymph nodes show no uptake
  - Diffusion tensor imaging (DTI)
    - Can help detect and quantify defects/asymmetries in pelvic floor musculature
    - Provides 3D representation of pelvic floor skeletal muscle
  - MR defecography
    - Imaging performed after rectal administration of contrast (typically ultrasound gel) to evaluate pelvic floor
    - Multiphase dynamic imaging performed (at rest, strain, defecation) typically with fast T2 imaging or bright-blood techniques

MR Anatomy

- Uterus
  - Divided into uterine body/corpus and cervix
    - Normal fallopian tubes usually not well seen
  - Appearance varies with age of patient, hormonal status, parity
  - Size: Varies with patient age
    - Premenarche: Body and cervix are nearly same size; uterus measures 2.5-3.5 cm in length
    - Childbearing age: Body is much larger than cervix; uterus measures 6-10 cm in length
    - Postmenopause: Body atrophies
  - Positioning
    - Uterus is centrally positioned within pelvis, though may be laterally deviated
    - Typically anteverted and anteflexed, though highly variable
  - MR signal characteristics
    - T1WI: Uterus is of low to intermediate signal intensity
    - T2WI: Uterine zonal anatomy is well visualized
      - Endometrium: Central band of uniform high signal intensity that varies in thickness with patient age and phase of menstrual cycle
      - Junctional zone: Innermost myometrium layer of low SI
      - Outer myometrium: Intermediate SI, higher than striated muscle
      - Zonal anatomy less distinct in premenarche, postmenopausal patients, and at menstruation
    - T1WI C+ FS: Homogeneous enhancement of myometrium
      - Endometrium enhances to a lesser degree than myometrium on early post-contrast phases, more isointense on delayed imaging

- Parametrium: Intermediate SI on T1WI and variable SI on T2WI
- Uterine appearance may vary with exogenous hormonal therapy
- DWI
  - Normal endometrium appears hyperintense to myometrium
  - Junctional zone is hypointense

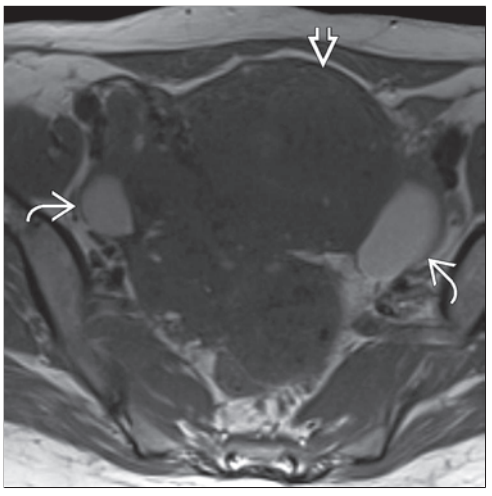
· Cervix
- Fibromuscular tubular portion of uterus between uterine body and vagina
- Typically 2.5-3 cm in length in nongravid women
  - Up to 6 cm in length during pregnancy
  - Cervical diameter is typically 3-4 cm
  - Cervix slowly increases in volume under hormonal stimulation until menopause
- MR signal characteristics
  - T1WI: Homogeneously intermediate signal intensity
  - T2WI: Cervical zonal anatomy demonstrated with T2WI; typical targetoid appearance on axial imaging
    - Central mucus/secretions: Hyperintense compared to myometrium
    - Endocervical epithelial lining: High signal intensity
    - Inner cervical stroma: Hypointense compared to myometrium
    - Outer layer of smooth muscle: Intermediate signal intensity
  - T1WI C+ FS: Endocervical mucosal lining enhances to a greater degree than cervical stroma
  - Fluid-signal nabothian cysts are commonly present and may be multiple in number
  - DWI
    - Endocervical mucosal lining appears hyperintense
    - Cervical stroma is hypointense

· Ovaries
- Well-marginated adnexal ellipsoid organs containing follicles in varied stages of development
- Vary in size depending in age
  - Premenarche: ~ 3 mL
  - Premenopausal: ~ 10 mL
  - Postmenopausal: ~ 6 mL
- Location varies based on age and parturition
  - Located in ovarian fossae in nulliparous patients
  - Variable in location in parous patients
  - Ovaries can be located by following ovarian vasculature into pelvis
- MR signal characteristics
  - T2WI: Outer cortex has slightly decreased intensity, whereas central medulla is of slightly higher signal intensity
  - T1WI: Homogeneous in signal, essentially isointense to myometrium
  - T1WI C+ FS: Ovarian parenchyma enhances to a lesser degree than myometrium
  - Normal ovaries contain scattered follicles of fluid signal intensity; corpus luteum may be present as well

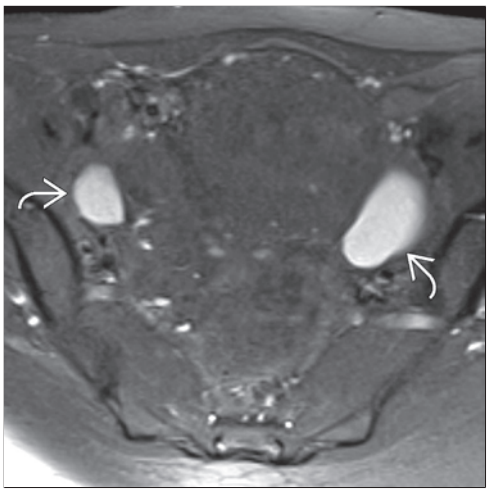
SELECTED REFERENCES

1. Sala E et al: The added role of MR imaging in treatment stratification of patients with gynecologic malignancies: what the radiologist needs to know. Radiology. 266(3):717-40, 2013
2. Wakefield JC et al: New MR techniques in gynecologic cancer. AJR Am J Roentgenol. 200(2):249-60, 2013
3. Beddy P et al: FIGO staging system for endometrial cancer: added benefits of MR imaging. Radiographics. 32(1):241-54, 2012
4. Freeman SJ et al: The revised FIGO staging system for uterine malignancies: implications for MR imaging. Radiographics. 32(6):1805-27, 2012
5. Haldorsen IS et al: Staging of endometrial carcinomas with MRI using traditional and novel MRI techniques. Clin Radiol. 67(1):2-12, 2012
6. Zijta FM et al: Evaluation of the female pelvic floor in pelvic organ prolapse using 3.0-Tesla diffusion tensor imaging and fibre tractography. Eur Radiol. 22(12):2806-13, 2012
7. Takeuchi M et al: Adenomyosis: usual and unusual imaging manifestations, pitfalls, and problem-solving MR imaging techniques. Radiographics. 31(1):99-115, 2011
8. Kyriazi S et al: Diffusion-weighted imaging of peritoneal disease for noninvasive staging of advanced ovarian cancer. Radiographics. 30(5):1269-85, 2010
9. Colaiacomo MC et al: Dynamic MR imaging of the pelvic floor: a pictorial review. Radiographics. 29(3):e35, 2009
10. Qayyum A: Diffusion-weighted imaging in the abdomen and pelvis: concepts and applications. Radiographics. 29(6):1797-810, 2009
11. Saremi F et al: Characterization of genitourinary lesions with diffusion-weighted imaging. Radiographics. 29(5):1295-317, 2009
12. Whittaker CS et al: Diffusion-weighted MR imaging of female pelvic tumors: a pictorial review. Radiographics. 29(3):759-74; discussion 774-8, 2009
13. Law YM et al: MRI of pelvic floor dysfunction: review. AJR Am J Roentgenol. 191(6 Suppl):S45-53, 2008
14. Parikh JH et al: MR imaging features of vaginal malignancies. Radiographics. 28(1):49-63; quiz 322, 2008
15. Sadowski EA et al: MR hysterosalpingography with an angiographic time-resolved 3D pulse sequence: assessment of tubal patency. AJR Am J Roentgenol. 191(5):1381-5, 2008
16. Elsayes KM et al: Vaginal masses: magnetic resonance imaging features with pathologic correlation. Acta Radiol. 48(8):921-33, 2007
17. Tamai K et al: MR features of physiologic and benign conditions of the ovary. Eur Radiol. 16(12):2700-11, 2006
18. Brown MA et al: MRI of the female pelvis using vaginal gel. AJR Am J Roentgenol. 185(5):1221-7, 2005
19. Morakkabati-Spitz N et al: 3.0-T high-field magnetic resonance imaging of the female pelvis: preliminary experiences. Eur Radiol. 15(4):639-44, 2005
20. Padhani AR et al: Perfusion MR imaging of extracranial tumor angiogenesis. Top Magn Reson Imaging. 15(1):41-57, 2004
21. Kido A et al: Diffusely enlarged uterus: evaluation with MR imaging. Radiographics. 23(6):1423-39, 2003
22. Hamm B et al: MR imaging and CT of the female pelvis: radiologic-pathologic correlation. Eur Radiol. 9(1):3-15, 1999
23. Kubik-Huch RA: Female pelvis. Eur Radiol. 9(9):1715-21, 1999

Endometriomas



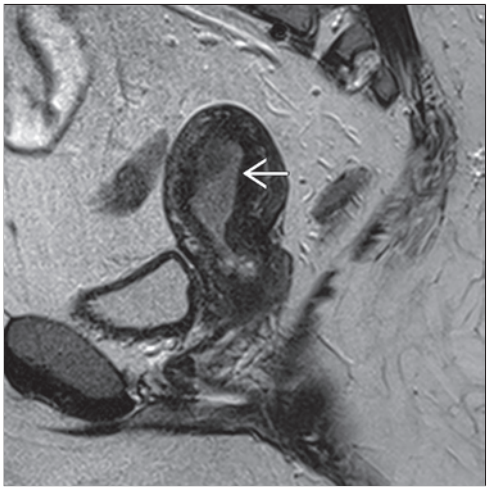
Endometriomas



(Left) *Axial T1WI MR shows bilateral ovoid, hyperintense ovarian masses. Given the T1 hyperintensity, these lesions my contain fat or blood products. Note the homogeneous intermediate signal intensity of the uterus.* ***(Right)*** *Axial T1WI FS MR shows the bilateral ovarian masses remain hyperintense upon fat suppression. The T1 hyperintensity is most indicative of blood products related to ovarian endometriomas.*

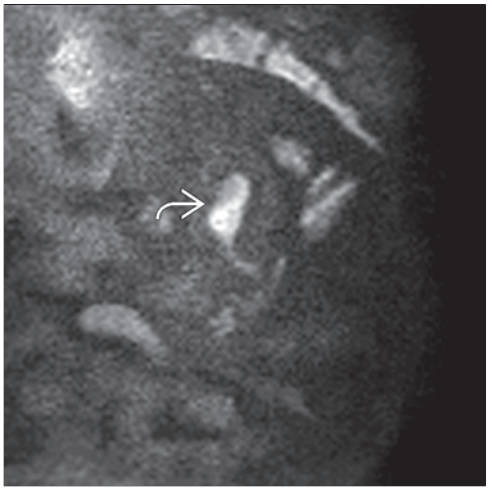
Pelvic Floor Laxity

Endometrial Carcinoma

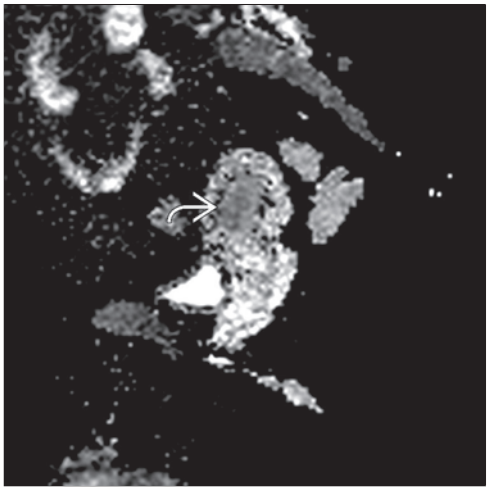


(Left) *Sagittal SSFP image from a dynamic acquisition obtained upon patient strain (Valsalva maneuver) shows abnormal middle compartment descent. Note the horizontal appearance of the urethra and small cystocele, consistent with anterior compartment involvement.* ***(Right)*** *Sagittal T2WI MR shows abnormal thickening and heterogeneity of the endometrium in this patient with biopsy-proven endometrial carcinoma.*

Endometrial Carcinoma



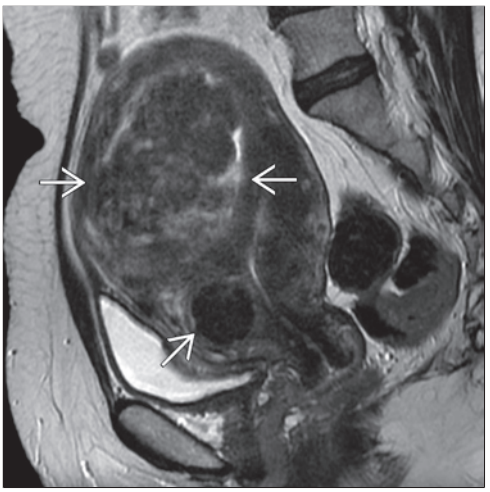
Endometrial Carcinoma



(Left) *Sagittal DWI from the same patient shows the known endometrial carcinoma to be hyperintense.* ***(Right)*** *Sagittal ADC image from the same patient shows the known endometrial carcinoma to have low ADC signal. DWI and ADC imaging can help in the diagnosis and staging of pelvic malignancy as well as provide prognostic information and measure response to therapy.*

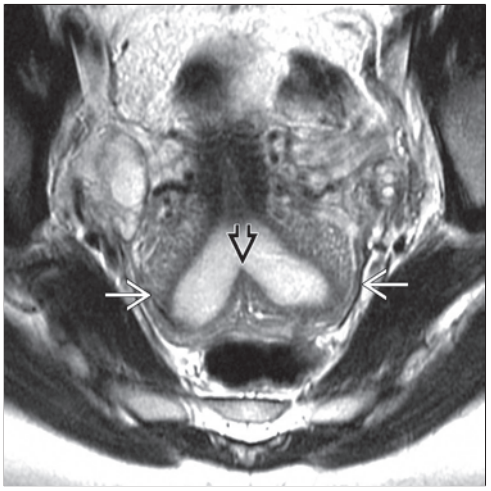
Gartner Duct Cyst

Leiomyomata



(Left) *Sagittal T2WI shows a well-marginated hyperintense mass arising from the anterior vaginal wall. Other sequences showed this mass to follow simple fluid signal and to be most suggestive of a Gartner duct cyst.* ***(Right)*** *Sagittal T2WI shows a markedly enlarged uterus with several myometrial masses consistent with leiomyomata. MR imaging can confidently diagnose leiomyomata, evaluate for degeneration, and monitor for treatment response.*

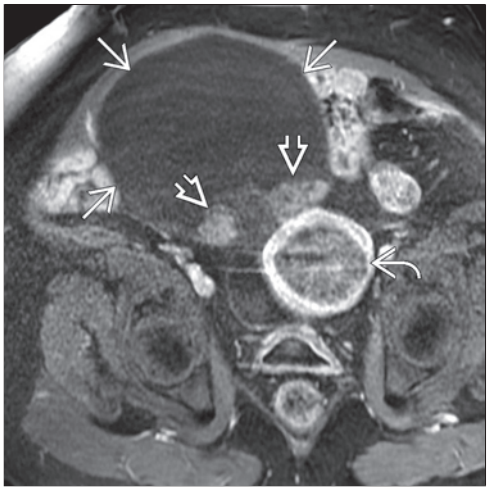
Septate Uterus



Adenomyosis

(Left) *Oblique axial T2WI shows a retroflexed uterus with a prominent fundal indentation , consistent with a septate uterus. MR imaging is ideally suited for the characterization of müllerian duct anomalies.* ***(Right)*** *Sagittal T2WI shows thickening of the junctional zone to involve the entire myometrial wall. There are small subendometrial hyperintense foci , some of which appear to communicate with the endometrium. These findings are diagnostic of adenomyosis.*

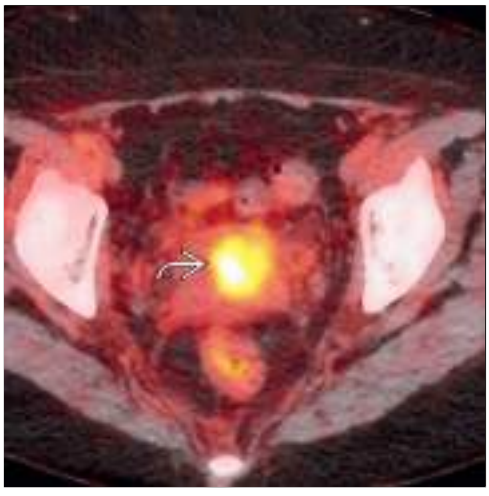
Ovarian Cancer



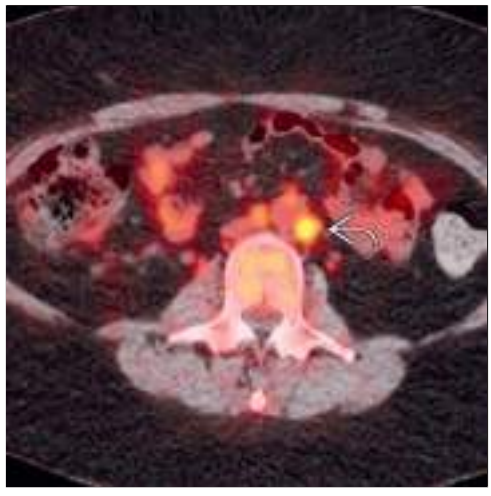
Cervical Carcinoma

(Left) *Oblique axial T1WI C+ FS MR shows a complex cystic mass arising from the right ovary with enhancing mural nodularity , suspicious for malignancy. Note the hypoenhancing fibroid within the uterine fundus.* ***(Right)*** *Sagittal T2WI shows loss of the normal hypointense cervical stroma and an ill-defined intermediate signal cervical mass that invades the lower uterine body. MR imaging is the modality of choice in the staging of cervical carcinoma.*

PET/CT TECHNIQUE AND IMAGING ISSUES



Axial PET/CT image in a patient with a diagnosis of cervical carcinoma shows focal FDG-18 uptake within the cervix with a SUV(max) of 12.5. Due to limited spatial resolution, local staging with PET can be difficult.



Axial PET/CT, same patient, shows a hypermetabolic paraaortic lymph node < 1 cm in short axis diameter, representing metastatic nodal disease. PET/CT is most useful in detecting metastases or nodal involvement.

TERMINOLOGY

Abbreviations

- Positron emission tomography (PET)
- Computed tomography (CT)

Synonyms

- 18-fluorodeoxyglucose (FDG-18) PET/CT
  - FDG-18 is the most widely used tracer in clinical practice; however, other tracers are available

Definitions

- Imaging modality that combines functional/metabolic (PET) and anatomic (CT) information
  - PET imaging relies upon increased glucose uptake and metabolism by malignant cells, though uptake can be seen in benign tissues as well

PRE-PROCEDURE

Indications

- Staging of pelvic malignancies
  - Assesses nodal disease and metastatic spread
  - Can contribute to local staging in cases of equivocal CT &/or MR findings
- Evaluation of response to therapy
  - Changes in metabolic activity as reflected by maximum standard uptake value (SUV[max]) precede tumor shrinkage
- Restaging of pelvic malignancies, particularly if follow-up surgery is being considered
- Radiation therapy planning
  - Planning radiotherapy target volume
  - Curative vs. palliative radiation therapy
- Diagnosis-specific indications
  - **Cervical carcinoma**
    - Indicated in initial staging of FIGO stage IB or higher tumors and in patients with positive paraaortic lymph nodes at surgery
    - Detection of metastatic lymph nodes with better sensitivity and specificity than MR or CT alone
      - Lymph node involvement is one of the most important prognostic factors in cervical cancer
      - Probability of lymph node involvement increases with increasing SUV(max) of primary tumor
      - Disease-free survival rates are highly associated with nodal disease patterns
    - Limited value in evaluation of local tumor extent, especially for small lesions
      - MR is superior
      - Average SUV(max) values are generally higher in squamous cell carcinomas (11.6) versus adenocarcinomas (8.85) and adenosquamous tumors (8.05)
    - Pretreatment SUV(max) can serve as a marker for 5-year survival
      - 95% for SUV(max) < 5.2
      - 70% for SUV(max) between 5.2 and 13.3
      - < 40% for SUV(max) > 13.3
    - Response to treatment can be measured by changes in SUV(max); 3-year survival rates are related to metabolic responses
      - 70% for complete metabolic response (absence of abnormal FDG-18 uptake)
      - 16% for partial response
      - 13% for progressive disease
    - Can identify recurrent disease or metastases after treatment
      - Routine use of PET/CT in surveilling asymptomatic patients is controversial
    - Has added value in patients with recurrent cervical cancer who undergo salvage therapy, as PET/CT can provide precise restaging information
  - **Endometrial carcinoma**
    - Primary indication is identification of metastases or lymph node involvement
      - Limited sensitivity in detecting metastatic lymph nodes < 1 cm
    - Evaluation of treatment response
    - Detection of recurrent disease
  - **Vaginal and vulvar carcinoma**
    - Evaluation of extent of lymph node metastases
  - **Ovarian carcinoma**

Key Facts

Terminology
- Imaging modality that combines functional/metabolic (PET) and anatomic (CT) information

Pre-Procedure
- PET/CT is ideally suited for detection of nodal/metastatic disease for initial staging, restaging, and surveillance imaging
- Indications for gynecological PET/CT imaging
  - Staging of pelvic malignancies
  - Evaluation of response to therapy
  - Restaging of pelvic malignancies
  - Radiation therapy planning
- Limitations/pitfalls of PET/CT
  - Foci of disease < 1 cm may not be detected secondary to limited resolution of PET
  - Physiological uptake in uterus and ovaries may simulate disease
  - Nonneoplastic uptake can occur with infection, inflammation, post-therapy changes
  - Benign lesions may have mild FDG-18 uptake
  - Hypermetabolic bowel serosal implants may be obscured by normal gut activity/uptake
  - Normal bladder activity from excreted radiotracer may obscure pelvic disease
  - Focal ureteric activity may simulate nodal disease

Procedure
- Low-dose NECT for attenuation correction
- PET imaging is performed from caudad to cephalad
- Subsequent diagnostic intravenous contrast-enhanced CT for coregistration and anatomic evaluation

    - Useful in staging of advanced ovarian cancer and surveillance for recurrent disease
      - Higher accuracy than with CT or PET alone
      - High positive predictive value in diagnosis of primary and recurrent ovarian cancer
      - Not typically used in primary diagnosis of ovarian malignancies; small but significant number of false-negative and false-positive cases
      - Some borderline or low-grade tumors may not have increased FDG-18 uptake
    - Can confirm local recurrence prior to pelvic exenteration
    - Identifies patients with late recurrent disease who may benefit from secondary cytoreductive surgery
    - Valuable when conventional studies are inconclusive or negative and tumor markers are rising
    - It is particularly useful for detecting tumor deposits in mesentery and bowel serosa
      - Sensitivity in detecting small tumor implants (< 1 cm) is limited
  - Other rare pelvic malignancies
    - Fallopian tube carcinomas
      - Can help distinguishing between ovarian and fallopian tube cancers in setting of unknown primary tumor
    - Uterine sarcomas: Staging and follow-up
    - Uterine lymphoma: Staging and follow-up

Contraindications
- Pregnancy
- Breastfeeding

Getting Started
- Things to check
  - If iodinated intravenous contrast is administered for CT examination
    - Renal function should be evaluated in at-risk patients
    - If patient takes metformin, appropriate precautions should be taken

Advantages
- Allows for precise localization of hypermetabolic lesions utilizing detailed anatomic information provided by CT
- Can identify small metastatic deposits difficult to see on conventional imaging
- Identifies metastatic disease in lymph nodes that are not pathologically enlarged
- PET data can be corrected for photon attenuation using CT scan to generate an attenuation map
  - Less statistical noise from CT compared with Ge-68 transmission data on stand-alone PET scanners
  - Due to fast CT data acquisition, PET/CT examination time is 15-20 minutes shorter than PET with radioactive source transmission correction
  - More efficient use of fast-decaying PET pharmaceuticals
  - Need for PET transmission hardware and cost of replacing germanium source rods is eliminated
- CECT acquired in conjunction with PET/CT examination offers a complete diagnostic imaging evaluation
- Standardized images can be transferred to a radiation therapy planning system

Disadvantages
- Utilization of ionizing radiation, with an increase in radiation dose compared to PET or CT performed alone
- Attenuation correction may be complicated by CT artifacts
  - Use of concentrated CT contrast agents
  - Beam-hardening artifacts due to metallic implants
  - Physiologic motion
- Small lesions may not be identifiable on PET secondary to limited spatial resolution

New Developments
- PET/MR scanners are particularly useful in uterine malignancies
- New tumor-specific radiotracers are becoming more widely available

Patient Preparation
- Patients without insulin-dependent diabetes mellitus (IDDM) should be instructed to

- Abstain from food at least 4-6 hours prior to procedure
- Drink plenty of water prior to procedure

· Patients with insulin-dependent diabetes mellitus (IDDM) should be instructed to
- Eat a high-protein meal ~ 4 hours prior to study and take insulin as directed
- Drink plenty of water prior to procedure

· Patients should be comfortably warm prior to procedure to reduce unwanted muscle activity and physiological brown fat uptake
- Anxiolytics may be administered 1 hour prior to imaging in order to reduce physiological brown fat uptake
  - More helpful in head and neck imaging

· Consider placement of a urinary catheter to keep bladder decompressed
- Reduces artifact of intense bladder activity from excreted radiotracer
- Aids in visualization of small foci of disease in deep pelvis

PROCEDURE

Procedure Steps

· Patient interview
- Menstrual status
- Phase of menstrual cycle if premenopausal
- Premenopausal patients should be scheduled within a week before or a few days after menses to minimize physiologic endometrial uptake

· Patient positioning
- Patients are routinely imaged in supine position with the arms raised above the head to prevent beam-hardening artifact on CT component of study

· Recommended imaging protocol
- Measurement of blood glucose level
  - Administration of rapid-acting insulin if glucose level is above 200 mg/dL
- Administration of 1 L dilute oral contrast agent 1 hour before examination
- Administration of 10-20 mCi (370–740 MBq) of FDG-18, based on patient weight, 45-90 minutes before examination
  - Dose injected via an antecubital vein
  - Note if extravasation occurs in order to avoid confusion with pathological causes of subcutaneous tracer uptake
- Bladder voiding just before examination to eliminate renally excreted FDG-18
- Low-dose CT with no IV contrast agent
  - Used for attenuation correction
  - Some advocate eliminating nonenhanced CT to reduce study time/radiation dose and using CECT for attenuation correction, though there are increased attenuation artifacts
- PET starting at mid thighs and moving cephalad to minimize pelvic image misregistration due to bladder filling
  - Both PET and CT performed during shallow respiration
- Subsequent diagnostic intravenous contrast-enhanced CT
  - Used for coregistration with PET data and anatomic evaluation
  - Typically performed similar to routine abdominopelvic CT imaging protocols

Findings and Reporting

· Dedicated PET/CT workstation is mandatory for optimal viewing of coregistered scans
- Review CT data with appropriate window settings
- Examine displays of both attenuation-corrected and non-attenuation-corrected PET data
- Review fused PET/CT data set to correlate hypermetabolic foci seen on PET with anatomic equivalent on CT
- PET/CT images can also be fused with available MR images

· Gynecological malignancies, peritoneal implants, and metastatic lymph nodes are FDG-18 avid
- Necrosis within tumor &/or lymph node can appear as photopenic area
- Low-grade tumors or those with low cellularity may have limited uptake

· Standardized uptake values (SUV) should be routinely measured and reported
- It is generally accepted that SUV > 2-3 suggests malignancy, while SUV < 2 is associated with benign lesions
- In evaluating response to treatment, imaging is ideally performed on same PET/CT scanner as initial study and with an identical technique

POST-PROCEDURE

Things to Avoid

· Contact with young children for 10 hours following injection of radiotracer

Specific Interpretation Issues

· Attenuation correction
- Overestimation of true FDG-18 activity with CT-based attenuation correction due to overcorrection of photopenic areas secondary to high-attenuation structures on CT
  - Concentrated CT contrast agents
  - CT beam-hardening artifact due to metallic implants such as hip replacements, IUD, or surgical clips
- Artifacts representing intense focal accumulation of positive oral contrast material can be resolved by
  - Viewing CT and non-attenuation-corrected PET images, which are not affected by high-density material
  - Use of diluted or negative-attenuation oral contrast material
- Coregistration with CECT data does not result in significant artifacts following CT attenuation correction

· Misregistration
- False-positive or false-negative findings from superimposition of FDG-18 activity on inappropriate anatomic structures seen at CT
  - Due to patient breathing, motion, bowel motility, distention of urinary bladder

- Normal "free" breathing (shallow breathing) is more suitable than maximum inspiratory or expiratory phases for acquisition of CT scans for coregistration
  - However, imaging upon breath-hold may be advantageous in terms of CT image quality
- Minimizing time delay between PET and CT is important in reducing patient motion between scans

Pearls and Pitfalls

- Metastatic deposits or lymph nodes < 1 cm may not be detected secondary to limited resolution of PET imaging
- Physiological uptake
  - Uterus
    - Premenopausal endometrial FDG-18 uptake changes cyclically, increasing during late proliferative and early secretory phases and peaking near ovulation
      - Increased endometrial uptake may also be seen at menstruation
    - Patients with oligomenorrhea may have increased endometrial uptake
    - Increased endometrial FDG-18 uptake is abnormal in postmenopausal patients and suspicious for malignancy
      - Hormone replacement therapy should not result in significantly increased endometrial uptake
    - Physiologic fallopian tube uptake can be seen at menses
  - Ovary
    - Mild physiologic ovarian uptake can be seen in premenopausal patients
    - Focal unilateral ovarian FDG-18 uptake can be seen within a corpus luteum
      - Corpus luteum cysts can be identified by typical CECT appearance: Small, crenelated, rim-enhancing cyst
      - SUV(max) values can exceed 3.0
    - Increased focal FDG-18 uptake in solid part of ovary that does not correspond to a corpus luteum cyst on CT should be regarded as suspicious for malignancy
    - Postmenopausal ovarian FDG-18 uptake is associated with malignancy
- Nonneoplastic hypermetabolic lesions
  - Granulomatous disease, infection/abscess, postsurgical inflammation, radiation changes, foreign body reaction
    - CT imaging component can clarify/identify nonneoplastic conditions
    - Use of CECT can augment evaluation and avoid false-positive interpretation
    - Wait at least 6 weeks after surgical intervention for PET/CT if tumor recurrence is suspected in surgical or irradiated bed
    - Interpreting physicians should be aware of any pertinent clinical symptoms suggestive of underlying inflammatory disease
  - A small focus of increased endometrial uptake adjacent to a cervical carcinoma is not confirmatory for endometrial invasion
    - Increased uptake may be secondary to reactive endometrial changes
- Benign lesions may have mild FDG-18 uptake
  - Endometrial hyperplasia, benign ovarian tumors (dermoids), endometriosis, adenomyosis, benign reactive lymph nodes
  - Leiomyomas may show increased uptake; hypermetabolic leiomyomas are more common in premenopausal patients
- Hypermetabolic bowel serosal implants may be obscured by normal gut activity/uptake
- Normal bladder activity from excreted radiotracer may obscure pelvic disease
- Focal ureteric activity may simulate nodal disease

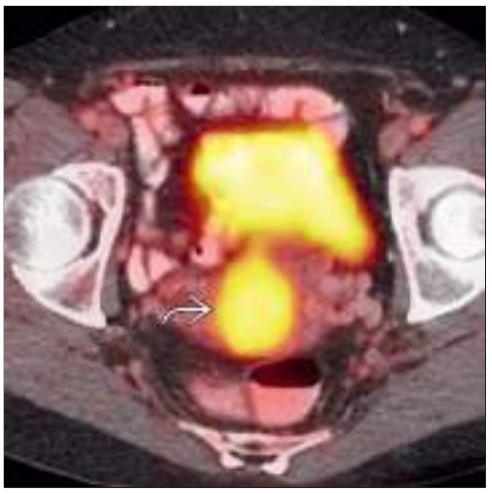
SELECTED REFERENCES

1. Mirpour S et al: The role of PET/CT in the management of cervical cancer. AJR Am J Roentgenol. 201(2):W192-205, 2013
2. Mitchell DG et al: ACR appropriateness criteria staging and follow-up of ovarian cancer. J Am Coll Radiol. 10(11):822-7, 2013
3. Navve D et al: Physiological (18)F-FDG uptake patterns in female reproductive organs before and after chemotherapy treatments: assessment by PET/CT. Med Oncol. 30(2):598, 2013
4. Viswanathan C et al: Positron emission tomography-computed tomography imaging for malignancies in women. Radiol Clin North Am. 51(6):1111-25, 2013
5. Antunovic L et al: Revisiting the clinical value of 18F-FDG PET/CT in detection of recurrent epithelial ovarian carcinomas: correlation with histology, serum CA-125 assay, and conventional radiological modalities. Clin Nucl Med. 37(8):e184-8, 2012
6. Crivellaro C et al: 18F-FDG PET/CT can predict nodal metastases but not recurrence in early stage uterine cervical cancer. Gynecol Oncol. 127(1):131-5, 2012
7. Langer JE et al: Imaging of the female pelvis through the life cycle. Radiographics. 32(6):1575-97, 2012
8. Patel CN et al: 18F-FDG PET/CT of cervical carcinoma. AJR Am J Roentgenol. 196(5):1225-33, 2011
9. Son H et al: Role of FDG PET/CT in staging of recurrent ovarian cancer. Radiographics. 31(2):569-83, 2011
10. Kitajima K et al: Spectrum of FDG PET/CT findings of uterine tumors. AJR Am J Roentgenol. 195(3):737-43, 2010
11. Prakash P et al: Role of PET/CT in ovarian cancer. AJR Am J Roentgenol. 194(6):W464-70, 2010
12. Son H et al: PET/CT evaluation of cervical cancer: spectrum of disease. Radiographics. 30(5):1251-68, 2010
13. De Gaetano AM et al: Imaging of gynecologic malignancies with FDG PET-CT: case examples, physiologic activity, and pitfalls. Abdom Imaging. 34(6):696-711, 2009
14. Suzuki R et al: Validity of positron emission tomography using fluoro-2-deoxyglucose for the preoperative evaluation of endometrial cancer. Int J Gynecol Cancer. 17(4):890-6, 2007
15. Unger JB et al: The prognostic value of pretreatment 2-[18F]-fluoro-2-deoxy-D-glucose positron emission tomography scan in women with cervical cancer. Int J Gynecol Cancer. 17(5):1062-7, 2007
16. Blake MA et al: Pearls and pitfalls in interpretation of abdominal and pelvic PET-CT. Radiographics. 26(5):1335-53, 2006
17. Kostakoglu L et al: PET-CT fusion imaging in differentiating physiologic from pathologic FDG uptake. Radiographics. 24(5):1411-31, 2004
18. Lerman H et al: Normal and abnormal 18F-FDG endometrial and ovarian uptake in pre- and postmenopausal patients: assessment by PET/CT. J Nucl Med. 45(2):266-71, 2004

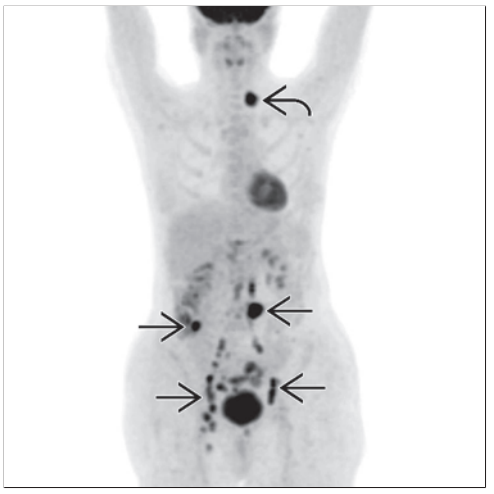
PET/CT TECHNIQUE AND IMAGING ISSUES

(Left) *Axial PET/CT from an initial staging study in a patient with a diagnosis of cervical carcinoma shows intense uptake within the cervix, consistent with the known malignancy. No other abnormal sites of uptake were noted.* ***(Right)*** *Coronal MIP PET in the same patient from a subsequent restaging exam shows the interval development of multiple abnormal foci of uptake, consistent with metastatic disease. Note the hypermetabolic left supraclavicular node.*

Axial Fused PET/CT, Cervical Carcinoma

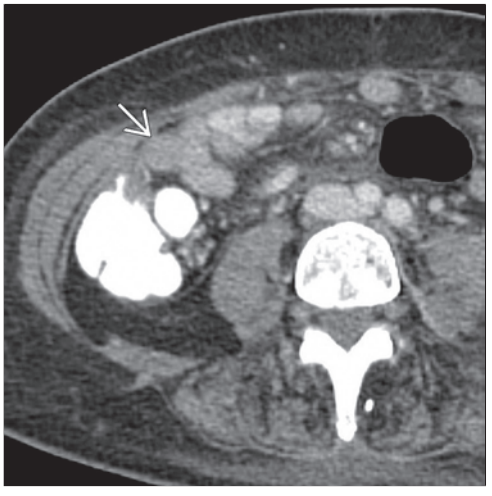


Coronal MIP PET, Cervical Carcinoma

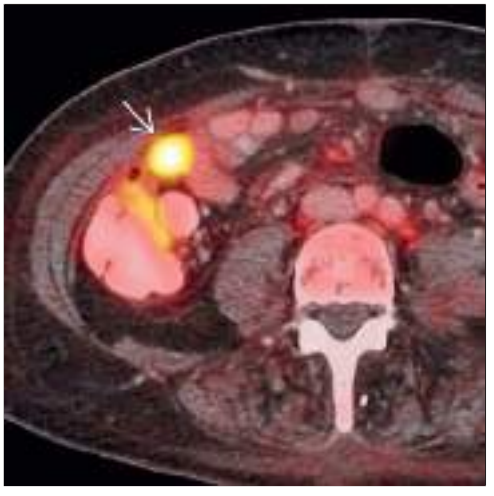


(Left) *Axial CECT in the same patient shows a small, subtle soft tissue density serosal implant within the anterior right abdomen. This could easily be overlooked on routine anatomic imaging.* ***(Right)*** *Axial PET/CT image in the same patient at the same level shows the serosal implant to be hypermetabolic and much easier to appreciate.*

Axial CECT, Cervical Carcinoma



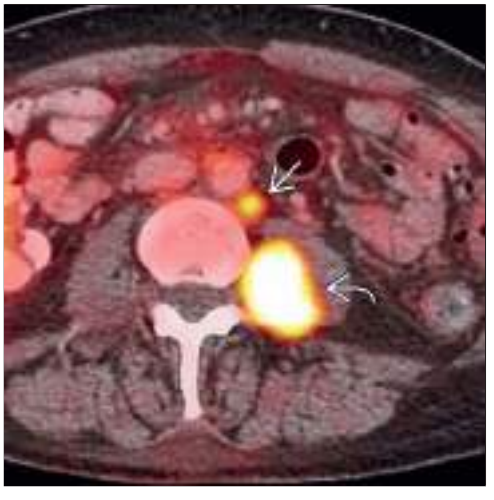
Axial Fused PET/CT, Cervical Carcinoma



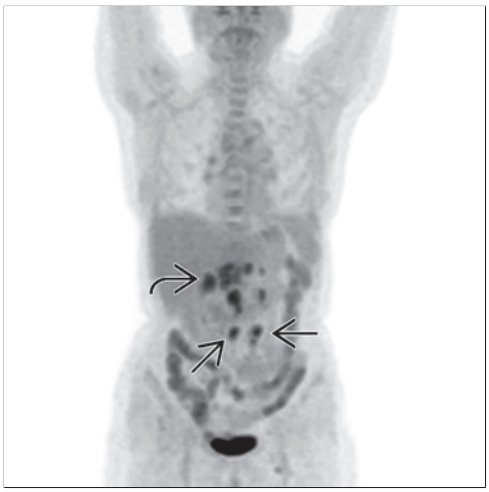
(Left) *Axial CECT in the same patient shows slight asymmetry in size of the psoas muscles, left greater than right, without a well-defined underlying mass. Note the small paraaortic lymph node.* ***(Right)*** *Axial PET/CT in the same patient at the same level shows a hypermetabolic left psoas muscle mass, accounting for the asymmetric size. Note that the small paraaortic lymph node is hypermetabolic, consistent with nodal disease.*

Axial CECT, Cervical Carcinoma

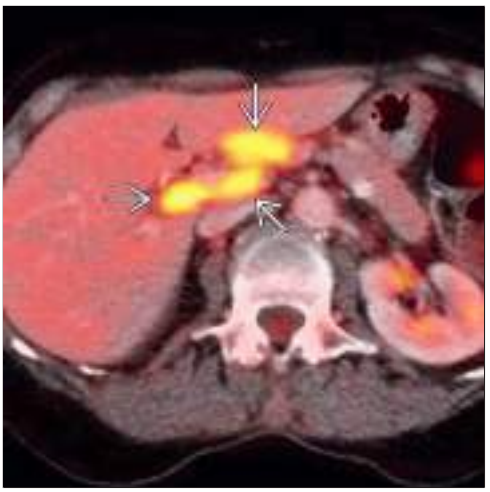
Axial Fused PET/CT, Cervical Carcinoma



Coronal MIP PET, Endometrial Carcinoma

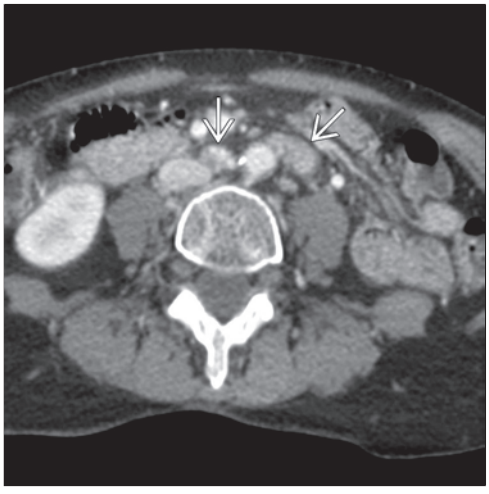


Axial Fused PET/CT, Endometrial Carcinoma

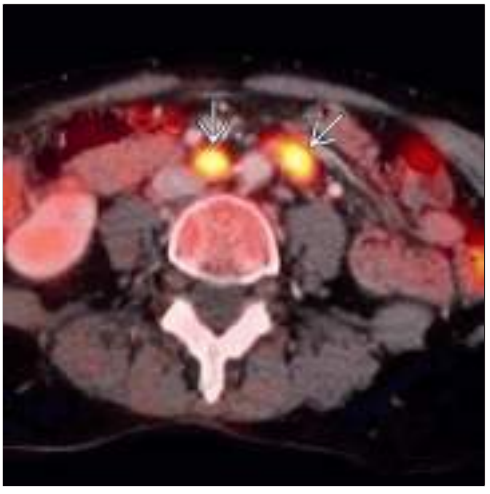


(Left) *Coronal MIP PET in a patient status post hysterectomy and pelvic nodal dissection for endometrial carcinoma shows multiple abnormal foci of uptake in the paraaortic and periportal regions.* ***(Right)*** *Axial PET/CT in the same patient shows several enlarged and hypermetabolic periportal lymph nodes, consistent with metastatic nodal disease.*

Axial CECT, Endometrial Carcinoma

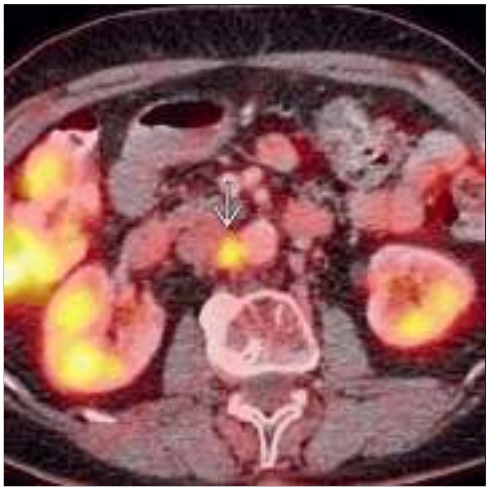


Axial Fused PET/CT, Endometrial Carcinoma



(Left) *Axial CECT in the same patient shows several enlarged paraaortic lymph nodes.* ***(Right)*** *Axial PET/CT image from the same patient shows the paraaortic lymph nodes to be hypermetabolic, confirming nodal spread of disease. PET/CT can provide information about disease extent that is essential for treatment planning.*

Axial Fused PET/CT, Cervical Carcinoma



Axial CECT, Cervical Carcinoma

(Left) *Axial PET/CT in a patient with cervical carcinoma status post resection and chemotherapy shows a hypermetabolic aorto-caval lymph node with a SUV(max) of 4.4, representative of a nodal metastasis. This was the only site of abnormal uptake.* ***(Right)*** *Axial CECT in the same patient shows the small aorto-caval lymph node, measuring 9 mm in short axis. Without the metabolic information provided by PET imaging, this may be overlooked.*

SECTION 2

Uterus

Introduction and Overview

Age-Related Changes

Congenital

Inflammation/Infection

Benign Neoplasms

Myometrium

UTERINE ANATOMY

GROSS ANATOMY

Overview

- Thick-walled, fibromuscular organ composed of myometrium and endometrium
- Flattened, inverted pear shape
- 2 major anatomic divisions
  - **Body** (corpus uteri)
    - Fundus is portion of uterus above ostia of fallopian tubes
    - Smooth, slightly convex fundal contour without cleft
    - Isthmus is the tapering of lower uterine segment at internal cervical os
    - Cornua are lateral funnel-shaped horns of superior uterus
  - **Cervix** (cervix uteri)
- **Myometrium**
  - Interwoven layers of smooth muscle with connective tissue and elastic fibers
  - Thickest at fundus, decreases in mass toward cervix
  - Thin superficial serosal covering
- **Endometrium**
  - Mucosal lining of endometrial cavity
  - Single layer of ciliated columnar cells with multiple tubular glands
  - 2 distinct components
    - **Stratum functionalis**: Superficial layer that thickens under hormonal stimulation and sloughs with menstruation
    - **Stratum basalis**: Deep supporting mesenchymal layer, densely adherent to myometrium
- **Cervix**
  - Originates at inferior narrowing of uterus (isthmus)
    - Has supravaginal and vaginal (ectocervix or portio vaginalis) portions
  - **Internal os**: Opening into uterine cavity
  - **External os**: Opening into vagina
  - Stroma is highly fibrous, with a high proportion of elastic fibers interwoven with smooth muscle
  - Numerous endocervical glands drain into endocervical canal
    - When obstructed/dilated, form nabothian cysts
  - Endocervical canal lined by single layer of ciliated mucous-secreting columnar epithelium
    - Epithelium organized in a series of small V-shaped folds (plicae palmatae)
  - Ectocervix lined by stratified squamous epithelium contiguous with vaginal mucosal lining
  - Squamocolumnar junction near external os but exact position is variable, with continuous remodeling
    - Site of development of cervical carcinoma
- Appearance, size, and morphology of uterus vary with age, estrogen stimulation, and parturition
  - **Premenarche**
    - Cervix is larger than corpus (~ 2/3 of uterine mass)
    - Uterus measures 2.5-3.5 cm in length
  - **Menarche**
    - Preferential growth of corpus in response to hormonal stimulation
    - In nulliparous women, corpus and cervix roughly equal, total 6-8 cm in length
    - In parous nonpregnant women, corpus is ~ 2/3 of uterine mass, total 9-10 cm in length
  - **Postmenopausal**
    - Corpus atrophies to premenarchal size
- **Menstrual cycle**
  - **Proliferative phase**
    - End of menstruation to ovulation (~ day 14)
    - Estrogen induces proliferation of functionalis layer
    - Corresponds to follicular phase of ovary
  - **Secretory phase**
    - Ovulation to beginning of menstruation
    - Progesterone induces endometrium to secrete glycogen, mucus, and other substances
    - Endometrial glands become enlarged and tortuous
    - Corresponds to luteal phase of ovary
  - **Menstrual phase**
    - Sloughing of functionalis layer of endometrium

Anatomic Relationships

- **Uterus is extraperitoneal**
  - Peritoneum extends over bladder dome and upper portion of anterior uterus
    - Lower portion of anterior uterus is not covered by peritoneum
    - Creates anterior cul-de-sac (vesico-uterine pouch)
  - Posteriorly, peritoneum extends inferiorly to upper portion of vagina
    - Creates posterior cul-de-sac (pouch of Douglas, recto-uterine pouch)
    - Most dependent portion of female pelvis
- Supporting ligaments
  - Broad ligament
    - Formed by the 2 layers of peritoneum contiguous with uterine peritoneal covering
    - Extends laterally to pelvic sidewall
    - Forms supporting mesentery for uterus
    - Superior portion is the mesosalpinx; supports fallopian tube
  - Round ligaments
    - Arise from uterine cornu slightly inferior and anterior to fallopian tubes
    - Course anteriorly and through inguinal canal to insert on labia majora
  - Cardinal (transverse cervical) ligaments
    - Thickened portions of base of broad ligament
    - Extend laterally to pelvic sidewall
  - Uterosacral ligaments: Extend from lateral uterus/cervix to sacrum
  - Vesicouterine/vesicocervical ligaments: Extend from lateral margins of cervix and vagina to bladder
- **Uterine positioning**
  - **Flexion** describes positioning of uterine body relative to cervix
    - Most uteri are anteflexed
  - **Version** describes axis of cervix relative to vagina
    - Most uteri are anteverted
  - To avoid confusion, can describe uterus as "antepositioned" or "retropositioned"
  - Retroverted/retroflexed uteri may be difficult to evaluate on US
- Fallopian tubes connect uterine cavity to peritoneal cavity
  - Attached to mesosalpinx (upper portion of broad ligament)
  - Originate from uterine cornua
  - 8-14 cm in length

- Covered by peritoneum, lined by single layer of columnar cells
- Muscular layer with both circular and longitudinal fibers, allows for peristalsis
- Composed of 4 segments: Interstitial, isthmus, ampulla, and infundibulum
- **Interstitial (intramural)**
  - Portion of tube that traverses uterine wall
  - ~ 1 cm in length
- **Isthmus**
  - Narrow portion of tube, immediately adjacent to uterus
  - 2-3 mm in diameter
- **Ampulla**
  - Tortuous, ectatic portion contiguous with isthmus, 5-8 mm in diameter
  - Fertilization usually occurs in this portion of tube
  - Most common location for ectopic pregnancy
- **Infundibulum**
  - Funnel-shaped opening, ringed by finger-like fimbriae
  - Opens into peritoneal cavity
  - Adjacent to posterior surface of ovary, allowing it to "capture" ovulated ova

· Uterus has dual arterial blood supply: Uterine and ovarian arteries
- **Uterine artery** variably arises as early branch of anterior division of internal iliac artery
  - Passes over ureter at level of cervix ("water under the bridge")
  - Runs within cardinal ligament
  - Courses superiorly along lateral margin of uterus and anastomoses with **ovarian artery** in broad ligament
- Uterine arteries give rise to arcuate arteries, which run in outer 1/3 of myometrium parallel to uterine surface
- Radial arteries branch perpendicularly from the arcuate arteries, extend through inner myometrium, and terminate as spiral arteries to supply endometrium

· Venous drainage
- Myometrial veins follow same course as arteries
- Forms complex venous network in parametrium
- Eventually drains to either uterine or ovarian vein in broad ligament

· Lymphatic drainage
- Largely follows venous vessels to drain to internal iliac nodes
- Minor pathways include
  - Direct drainage to external iliac or obturator nodes
  - Along round ligaments to inguinal nodes
  - Via ovarian lymphatics to paraaortic nodes
  - Along uterosacral ligaments to presacral nodes

IMAGING ANATOMY

Ultrasound

· Uterus evaluated with both transabdominal and endovaginal techniques
- Uterine size and large myometrial masses often better evaluated transabdominally
- Endometrium best seen on endovaginal evaluation

· **Myometrium**: 3 layers usually discernible
- Compacted, thin, hypoechoic inner layer forms subendometrial halo adjacent to endometrium
- Thicker, homogeneously echogenic middle layer
- Thinner, hypoechoic outer layer
  - Portion of myometrium peripheral to arcuate vessels
- Arcuate vessels may be visible in outer 1/3 of myometrium as tubular hypoechoic channels with internal Doppler flow
  - Vascular calcifications seen as linear shadowing echogenic foci in outer 1/3 of myometrium in postmenopausal patients

· **Endometrium**: Appearance varies with phase of menstrual cycle
- Proliferative phase
  - Thin, echogenic line early
  - Progressive, hypoechoic thickening (4-8 mm) later in proliferative phase
  - Trilaminar ("sandwich") appearance: Echogenic central line created where the 2 hypoechoic endometrial walls coapt
- Secretory phase: After ovulation, endometrium becomes thicker (7-14 mm) and more homogeneously echogenic

· Saline-infused sonohysterography
- Best suited to evaluate endometrial pathology
- Balloon-tipped catheter inserted through cervix
- Sterile saline infused with concurrent endovaginal evaluation
  - Separates endometrial walls, allowing for complete evaluation of endometrium

· 3D ultrasound
- Allows multiple views to be reconstructed from single sweep through uterus
- Useful in evaluating masses or IUD positioning

MR

· T1WI: Uterus and cervix have uniform intermediate signal

· T2WI: Uterus has 3 distinct zones
- High-signal **endometrium**
- Low-signal **junctional zone**
  - Decreased T2 signal from lower water content and higher density of smooth muscle fibers
  - Normal thickness: 2-8 mm
  - ≥ 12 mm abnormal (adenomyosis)
  - 9-11 mm equivocal
- Intermediate signal **myometrium**
- Prominent arcuate vasculature may appear as flow voids in outer 1/3 of myometrium

· Uterine appearance varies according to hormonal stimulation/menstrual phase
- **Premenarche**: Uterine body is small and zonal anatomy is indistinct
- **Premenopausal** (postmenarche)
  - Endometrium progressively thickens throughout proliferative and secretory phases
  - Myometrial T2 signal increases in secretory phase from increased water content and vascular flow
  - Myometrium decreases in thickness and T2 signal at menses, complicating evaluation of underlying lesions

UTERINE ANATOMY

- Junctional zone does not significantly change in thickness between proliferative and secretory phases but may be thickened &/or indistinct during menses
- **Postmenopausal**
  - Endometrium atrophies
  - Myometrium atrophies and T2 signal decreases
  - Junctional zone may be difficult to visualize
- **Oral contraceptives**
  - Thinned endometrium
  - Junctional zone thins, may be indistinct
  - Myometrium may have increased T2 signal

· Uterine contractions are transient mass-like T2-hypointense foci, which can distort uterine contour
- Persist for several minutes
- May be confused with fibroids or adenomyosis
- Disappear on subsequent sequences or cine imaging

· Cervical zonal anatomy on T2WI
- Hyperintense central mucus/secretions in canal
- High-signal endocervical epithelial lining
  - Plicae palmatae may be seen as a separate intermediate-signal zone on high-resolution scans
- Low-signal inner cervical stroma, due to large proportion of fibrous and elastic tissue
  - Contiguous with junctional zone of uterine corpus
- Outer layer of intermediate-signal smooth muscle may be variably present, contiguous with myometrium
- Cervical zonal anatomy does not significantly change in appearance throughout menstrual cycle
- Nabothian cysts are seen in > 50% of cases
  - Represent obstructed, dilated cervical glands
  - Typically asymptomatic, incidental findings
  - Low signal on T1WI, high signal on T2WI, nonenhancing, but can be variable in signal

· Parametrium
- Loose connective tissue between layers of broad ligament along lateral margin of uterine body
  - Contains rich network of blood vessels and lymphatics
- Low to intermediate signal intensity on T1WI
- Variable signal intensity on T2WI
  - Round ligament and uterosacral ligament low in signal intensity
  - Cardinal ligament and associated venous plexuses are high in signal intensity

CT

· Typically not preferred modality in uterine evaluation

· NECT
- Uterus is homogeneously soft tissue density
- Hypodense endometrium may be faintly visible

· CECT
- Myometrium shows variable contrast enhancement
  - May show subendometrial, diffuse myometrial, or patchy heterogeneous enhancement
  - Hypoenhancing in postmenopausal patients
- Endometrium appears as hypodense central stripe, best measured on sagittal image
- Cervix demonstrates targetoid enhancement pattern
  - Central secretions/fluid: Hypodense
  - Inner cervical mucosa: Hyperdense
  - Inner stroma: Hypodense
  - Outer stroma: Hyperdense

· May be useful in staging of uterine malignancies

ANATOMY IMAGING ISSUES

Imaging Recommendations

· US is primary modality in evaluation of uterus

· MR can be used as a problem-solving tool or for more precise characterization
- Modality of choice in evaluation for adenomyosis
- Evaluation of endometrium when obscured on US
- Superior in staging of uterine malignancies

Imaging Pitfalls

· Knowledge of patient's menstrual status at time of study is paramount
- Endometrium/myometrium vary in appearance throughout cycle and can simulate pathology

· Myometrial contractions can be misinterpreted as fibroids/adenomyosis but are transient

EMBRYOLOGY

Uterine Development

· Uterus and upper vagina arise from paired paramesonephric (müllerian) ducts
- Form lateral to mesonephric duct between 6 and 7 weeks of gestation

· Caudal aspect of paramesonephric ducts fuse at midline
- Fused inferior portion forms upper vagina and uterus
- Unfused superior segments empty into peritoneal cavity, persist as fallopian tubes
- Fusion abnormalities lead to müllerian duct anomalies

· Caudal end of fused paramesonephric ducts projects into urogenital sinus
- Lower vagina forms from urogenital sinus

RELATED REFERENCES

1. Yitta S et al: Normal or abnormal? Demystifying uterine and cervical contrast enhancement at multidetector CT. Radiographics. 31(3):647-61, 2011
2. Sajjad Y: Development of the genital ducts and external genitalia in the early human embryo. J Obstet Gynaecol Res. 36(5):929-37, 2010
3. Takeuchi M et al: Manifestations of the female reproductive organs on MR images: changes induced by various physiologic states. Radiographics. 30(4):1147, 2010
4. Hauth EA et al: MR imaging of the uterus and cervix in healthy women: determination of normal values. Eur Radiol. 17(3):734-42, 2007
5. Well D et al: Age-related structural and metabolic changes in the pelvic reproductive end organs. Semin Nucl Med. 37(3):173-84, 2007
6. Semelka R: Abdominal-Pelvic MRI. 2nd ed. Hoboken: Wiley, 2006
7. Cunningham F: Williams Obstetrics. 22nd ed. New York: McGraw-Hill Professional, 2005
8. Hoad CL et al: Uterine tissue development in healthy women during the normal menstrual cycle and investigations with magnetic resonance imaging. Am J Obstet Gynecol. 192(2):648-54, 2005
9. Okamoto Y et al: MR imaging of the uterine cervix: imaging-pathologic correlation. Radiographics. 23(2):425-45; quiz 534-5, 2003
10. Moore KL et al: The Developing Human: Clinically Oriented Embryology. 6th ed. Philadelphia: Saunders, 1998
11. Callen P: Ultrasonography in Obstetrics and Gynecology. 3rd ed. Philadelphia: Saunders, 1994