**PRELIMINARY PROGRAM OF EVENTS**

**Sunday, November 11**
5:30 pm–7:30 pm • Evening Welcome Reception

**Monday, November 12**
7:00 am–5:00 pm

**INTRODUCTION/ULTRASOUND FIRST**
Alfred Z. Abuhamad, MD

**WOMEN’S HEALTH**
Ultrasound First and Imaging of the Pelvis
Beryl R. Benacerraf, MD
Ultrasound First and Postmenopausal Bleeding
Steven R. Goldstein, MD

**ABDOMINAL/RENAL IMAGING**
Ultrasound First and the Pediatric Abdomen
Lynn A. Fordham, MD
Ultrasound First and Renal Colic
Speaker forthcoming

**CRITICAL CARE**
Ultrasound First and Vascular Access
Christopher L. Moore, MD, RDMS, RDCS
Echocardiography: Appropriateness for Assessment of Cardiac Structure and Function
Patricia A. Pellikka, MD
Ultrasound First on the Front Line: Austere Environments
Joel Anthony Nations, MD

**MUSCULOSKELETAL**
Ultrasound First in Sports Medicine
Levon N. Nazarian, MD
Ultrasound First in the Olympics
Bill Moreau, DC, DACBSP

**SAFETY**
Safety From Government Perspective
Brian S. Garra, MD
Safety From Science Perspective
Frederick W. Kremkau, PhD

**PANEL DISCUSSION**
Ultrasound First: Translation Into Practice
Martha Nolan, Norman Scarborough, MD, Richard A. Hoppmann, MD, Bruce R. Gilbert, MD, PhD, Moderator: Jay Smith, MD

**Lunch and Learn**
Levon N. Nazarian, MD

**BREAK OUT SESSIONS**

**Track 1** Patient Advocacy: Prostate, Breast, and Image Gently Campaign Efforts
Kevin S. Johnson, Nancy M. Cappello, PhD, Renee Cruea, MPA, Brian D. Coley, MD

**Track 2** Role of Insurers in Promoting Ultrasound First
Thomas G. Dehn, MD, Kevin McDermott, Dan O’Keeffe, MD

**Track 3** Ultrasound First in the Clinical Setting: Challenges and Opportunities From a Users Perspective
Industry Representative and Michael Blaivas, MD

**GROUP DISCUSSION**
Presentations by Group Moderators
Agenda for Future and Closing Remarks
Alfred Z. Abuhamad, MD
On Monday, November 12, 2012, the American Institute of Ultrasound in Medicine (AIUM) will host a forum on the expanding role of ultrasound as a “first” imaging exam, focusing on the diagnostic capabilities, safety, and reduced cost of ultrasound as compared to other imaging modalities or other aspects of clinical practice. We anticipate participation from a broad range of stakeholders, including representatives of specialty societies, patient advocacy groups, government agencies, insurers, industry, and others with interests in these timely issues. We hope you will join us and contribute your important perspective!

Ultrasound’s safety and value as a “first” diagnostic tool are well established for many clinical conditions. In fact, during the 2nd half of the 20th century, ultrasonography revolutionized the practice of obstetrics. Virtually replacing x-ray, ultrasound became the first choice imaging modality for diagnosing early pregnancy; for determining fetal age, size, number, and presentation; and for identifying fetal and placental malformations.

In abdominal and cardiac diagnosis, ultrasound has also come into its own in recent years, making it the first choice exam for patients with right upper quadrant pain, deep vein thrombosis, congenital heart disease, and a host of other clinical conditions. And applications continue to expand as sonographic imaging demonstrates comparative or superior value to other imaging modalities for evaluating patients with musculoskeletal and other disorders.

For appropriate clinical conditions, ultrasound offers clear safety and economic advantages over radiographic exams, and yet evidence suggests that ultrasound is underutilized. Many clinicians are unaware of the range of conditions for which “ultrasound first” is an established guideline, and the gap only grows larger as research extends ultrasound’s diagnostic value. The Ultrasound First Forum will be devoted to encouraging the use of ultrasound as a safe, effective, and affordable alternative to other diagnostic imaging modalities where scientific evidence supports its appropriateness.

On behalf of the AIUM, we would like to cordially invite you to participate in the AIUM-sponsored Ultrasound First Forum 2012, to be held at the Marriott Marquis Hotel in New York City. The meeting will commence with a reception on Sunday evening, November 11, with the Forum workshop scheduled for Monday, November 12, from 8 AM to 5 PM. On Monday, attendees will meet jointly for opening and closing remarks, and a portion of the day will be spent in participant-selected specialty workshops. Please note, attendees will be responsible for their own travel and hotel expenses, but the Forum itself is supported by the AIUM.

We hope you will join us at the Ultrasound First Forum. Please let us know your interest in attending the Forum as soon as possible.

Best regards,

Alfred Z. Abuhamad, MD
President

Carmine M. Valente, PhD, CAE
Chief Executive Officer
Invited Groups

Organizations
- Agency for Healthcare Research and Quality
- American Academy of Family Physicians
- American Academy of Nurse Practitioners
- American Academy of Orthopaedic Surgeons
- American Academy of Otolaryngology
- American Academy of Pain Medicine
- American Academy of Physician Assistants
- American Academy of Physical Medicine & Rehabilitation
- American Association of Clinical Endocrinologists
- American Academy of Neuromuscular & Electrodagnostic Medicine
- American Board of Internal Medicine
- American Chiropractic Association
- American College of Cardiology
- American College of Emergency Physicians
- American College of Nurse-Midwives
- American College of Obstetricians & Gynecologists
- American College of Osteopathic Obstetricians & Gynecologists
- American College of Physicians
- American College of Radiology
- American College of Rheumatology
- American College of Sports Medicine
- American College of Surgeons
- American Medical Society for Sports Medicine
- American Osteopathic College of Radiology
- American Registry for Diagnostic Medical Sonography
- American Society of Anesthesiologists
- American Society of Echocardiography
- American Society of Regional Anesthesia & Pain Medicine
- American Society for Reproductive Medicine
- American Urological Association
- Association for Vascular Access
- Association of Women's Health, Obstetric & Neonatal Nursing
- Infusion Nurses Society
- Intersocietal Accreditation Commission
- National Quality Forum
- Physician Assistant Education Association
- Renal Physicians Association
- Society of Critical Care Medicine
- Society of Diagnostic Medical Sonography
- Society for Maternal-Fetal Medicine
- Society for Pediatric Radiology
- Society of Radiologists in Ultrasound
- Society of Ultrasound in Medical Education
- Society for Vascular Surgery
- Society for Vascular Ultrasound
- World Federation for Ultrasound in Medicine & Biology

Third Party Payers
- AETNA
- American Imaging Management
- BlueCross BlueShield Association
- Blue Cross Blue Shield, Independence
- Highmark
- Humana
- Kaiser Permanente
- Magellan Health
- Medicare Payment Advisory Commission
- National Imaging Association
- Pilgrim Insurance Company
- Sentara Healthcare

Patient Advocacy Groups
- Consumers Union
- John D. Stoeckle Center for Primary Care Innovation

Government
- Centers for Medicare & Medicaid Services (CMS)
- Food and Drug Administration (FDA)
- Institute of Medicine (IOM)
- National Institute of Child Health and Human Development (NICHD)
- National Institutes of Health (NIH)
- White House

Media

Industry
Ultrasound First is an endeavor devoted to education and increasing awareness of the effectiveness of ultrasound in enhancing patient care.

**Safe** Ultrasound emits NO ionizing radiation. It may be all you need.

**Effective** Ultrasound has comparable or superior diagnostic capability in a growing number of imaging scenarios making it the smart diagnostic choice.

**Affordable** Ultrasound is an inexpensive and portable tool that can provide faster diagnosis. Image more for less.

**Objectives**

- Raise awareness of the value and benefits of ultrasound among patients, health care providers, and insurers
- Provide ultrasound education and evidence-based guidelines for health care providers
- Educate insurers to require ultrasound studies before considering other imaging modalities when scientific evidence supports the effectiveness of ultrasound
- Educate patients about the benefits of ultrasound as the appropriate imaging modality for their care
- Encourage the incorporation of ultrasound into medical education

Visit [www.ultrasoundfirst.org](http://www.ultrasoundfirst.org) to learn how you can get involved and support the Ultrasound First mission.
Sound Judgment

Levon N. Nazarian, MD
Editor-in-Chief

With this issue, the Journal of Ultrasound in Medicine (JUM) introduces Sound Judgment, a new series of invited articles that present clinical vignettes in which sonography should be the first, and in many cases the only, imaging modality needed to make a diagnosis or guide an interventional procedure. The creation of this new series parallels the initiative of AIUM President Alfred Abuhamad, MD, to emphasize clinical situations in which one should think of “ultrasound first.” Health care providers face a bewildering array of imaging alternatives, and the literature is replete with studies touting the advantages and disadvantages of radiography, nuclear medicine, computed tomography, magnetic resonance imaging, and sonography for a vast array of indications. However, there are few primers on appropriate imaging algorithms, such that the choice of which test to perform often depends more on physician preference or local expertise than on what is truly best for the patient.

In spite of the many proven advantages of sonography such as lower cost and lack of ionizing radiation, it tends to take a back seat to other cross-sectional imaging modalities. In fact, as an examiner for the American Board of Radiology oral examination, I am struck by how many candidates presented with pathognomonic findings on a sonographic study will be hesitant to make a diagnosis and rather will ask to see a “cross-sectional imaging study” (translation: computed tomography or magnetic resonance imaging) to “confirm” the findings. When I point out that sonography is a cross-sectional imaging study, I usually get a blank stare followed by a reluctant, “I guess you’re right.” Clearly, if radiology residents who are primed for their board examination do not even know situations for which sonography is all you need, how do we expect physicians who are not trained in imaging to know what test to order?

The intent of this series, therefore, is to educate readers as to when they can rely on sonography. A task force headed by Steven R. Goldstein, MD, an associate editor of the JUM, will solicit topics to be authored by experts in their respective fields. The manuscripts will undergo an expedited peer-review process and be a regular JUM feature. We expect that these articles will improve patient care and be widely cited. I must give credit to one of our JUM reviewers, Ann E. Podrasky, MD, for naming this series Sound Judgment. I feel that this name captures the essence of what I hope these clinical vignettes will promulgate.
I was honored and excited when Alfred Abuhamad, MD, president of the American Institute of Ultrasound in Medicine (AIUM), asked me to head a task force to educate AIUM members and nonmembers about when and how to do sonography for conditions where other imaging modalities are likely to be considered instead.

As an imaging modality, sonography is safe, effective, and affordable compared with other forms of imaging such as magnetic resonance imaging, positron emission tomography, and computed tomography. It is safer for the patient and health care provider than those techniques that use ionizing radiation. The concept of point-of-care sonography has exploded geometrically in the hands of all kinds of clinicians who use it diagnostically as well as for procedural guidance. Sonography is even making its way into undergraduate medical education to teach anatomy and physical diagnosis.

The task force will oversee the creation of a series of articles to be entitled Sound Judgment, the first appearing in this issue. The task force will rely heavily on the AIUM Communities of Practice, which are currently 17 in number but continue to grow as new users of new applications of sonography continue to emerge. Sonography has become so entwined into so many areas of medical and surgical diagnosis and management that no one person can possibly keep up and understand the myriad of uses and nuances. Because of its multidisciplinary nature, the AIUM is the only professional society that can enable a wide variety of both clinicians and basic scientists to interact and cross-pollinate.

Among areas that I can think of (and this list is far from complete) where “sound judgment” should prevail include postmenopausal bleeding (the topic of the inaugural vignette in the issue),¹ pneumothorax diagnosis and management, uterine malformations diagnosed with 3-dimensional sonography rather than magnetic resonance imaging,² diagnosis of deep endometriosis,³ diagnosis of main stem intubation and bronchial obstruction,⁴ appendicitis,⁵ increased safety in central venous catheter placement,⁶ reduction in the length of stay for trauma patients,⁷ reduced complications in thoracentesis,⁸ nerve block guidance compared with peripheral nerve stimulation,⁹ and renal colic.¹⁰ In the musculoskeletal arena, sonography allows for examination of structures at rest and motion and is useful in rotator cuff tears,¹¹ ankle injuries, and many other conditions.¹²

These examples are just a sampling—the tip of the iceberg—of areas where sonography can and should be the first, and often only, imaging modality. We hope that clinicians in a multitude of specialties will display “sound judgment” for an ever-growing number of indications.

Steven R. Goldstein, MD
Department of Obstetrics and Gynecology
New York University School of Medicine
New York, New York USA
References

Sonography in Postmenopausal Bleeding

Steven R. Goldstein, MD

Received November 10, 2011, from the Department of Obstetrics and Gynecology, New York University School of Medicine, New York, New York USA. Revision requested November 15, 2011. Revised manuscript accepted for publication December 20, 2011.

Address correspondence to Steven R. Goldstein, MD, Department of Obstetrics and Gynecology, New York University School of Medicine, 530 First Ave, Suite 10N, New York, NY 10016 USA. E-mail: steven.goldstein@nyumc.org

Postmenopausal bleeding is a serious and not uncommon clinical gynecologic occurrence that mandates evaluation. In fact, classic teaching has labeled postmenopausal bleeding as “endometrial cancer until proven otherwise.” Studies indicate that the incidence of malignancy in such patients ranges from 1% to 14%, and obviously this rate will vary depending on the years since menopause and the classic risk of factors such as obesity, hypertension, diabetes, and low parity.

Transvaginal sonography can and should be considered as a first-line approach to this clinical problem because of the extremely high negative predictive value of a thin distinct endometrial echo when adequately visualized (Table 1). The overall risk of malignancy from these large prospective trials in postmenopausal women with bleeding is 1 in 917. Clearly the thinner the “cutoff” used, the fewer the cancers that will slip through the cracks, but there will be more patients needing alternative evaluation. The American College of Obstetricians and Gynecologists has opined that in postmenopausal women with bleeding, when present, “a thin distinct endometrial echo on transvaginal ultrasonography 4 mm or less has a risk of malignancy of 1 in 917, and therefore endometrial biopsy is not required” (Figures 1 and 2). The most likely diagnosis in such cases is an atrophic endometrium.

There are some important clinical realities to this approach, however. Not all uteri lend themselves to a meaningful sonographic examination yielding an adequate depiction of the endometrial cavity (Figures 3 and 4). Previous surgery, coexisting leiomyomas, axial orientation, marked obesity, and adenomyosis can all result in an inability to find a reliable endometrial echo. In such cases, fluid enhancement by saline infusion sonohysterography will easily highlight the endometrial cavity. Sonohysterography should be thought of as a subset of transvaginal sonography to be used when an endometrial echo is not well visualized or is not thin and distinct.

When spontaneous endometrial fluid is present, it may be thought of as a “naturally occurring” sonohysterogram. If the endometrium surrounding the fluid is thin (<2 mm) on each side and symmetric, it is compatible with atrophy. Sonohysterography, when needed, is a relatively simple, inexpensive, and well-tolerated office procedure. In those cases of inadequate visualization, it will yield an excellent depiction of the endometrial thickness. In those cases of a thick endometrial echo, it will distinguish focal from global lesions (Figures 5 and 6). Why is this capability important? Blind endometrial sampling has been and, unfortunately for many clinicians, is still the first “go-to” method for endometrial evaluation in patients with postmenopausal bleeding, and when positive for cancer or even atypical complex hyperplasia,
it will allow the patient to go directly to definitive therapy. However, when negative, it is not nearly as reliable as many clinicians have been led to believe. Blind sampling began with in-hospital dilation and curettage and was then replaced by the in-office Vabra aspirator (Berkley Medical Devices, Berkley, CA) and finally the current standard: the suction piston biopsy instrument. This device was first described in 1984 by Cornier and was known as the Pipelle de Cornier. It is a plastic disposable catheter with its own internal piston to generate suction. It was designed to date the endometrium as part of an infertility workup, something no longer used in clinical practice. It was initially studied in 40 patients with known carcinoma and in that widely publicized study achieved accuracy of 97.5% (39 of 40 patients). At least 3 similar studies in patients with known carcinoma using this device were carried out. The number of cancers missed were 8%, 16%, and 33%, respectively. However, Guido et al. opened the uteri, and of 65 patients with cancer, the 11 cases that were missed all occupied less than 50% of the surface area of the uterine cavity. In addition, of 11 cancers in polyps, Pipelle missed 5. Perhaps most importantly, in only 46% of the cancers (30 of 65) did the tumor occupy more than 50% of the uterine cavity, but in all of these, Pipelle was successful in detecting the malignancy. The important message here is that endometrial cancer is often focal and not global, so blind endometrial sampling is not nearly as reliable as many clinicians would like to believe.

In summary, in women with postmenopausal bleeding, a thin distinct endometrial echo on transvaginal sonography has an extremely high negative predictive value (>99%). Not all uteri lend themselves to a meaningful sonographic evaluation. When the echo is not adequately visualized or seen but not sufficiently thin (<4 mm), saline infusion sonohysterography is a subset of transvaginal sonography that will clarify endometrial findings and triage patients to (1) no disease, (2) focal abnormality, or (3) global abnormality. Blind suction piston biopsy, unless positive, cannot be relied on to sufficiently exclude disease. Thus, “ultrasound first” as the approach to women who present with postmenopausal bleeding is “sound judgment.”

**Table 1.** Endometrial Thickness and Cancer Findings in Postmenopausal Women With Bleeding

<table>
<thead>
<tr>
<th>Reference</th>
<th>Women in Study, n</th>
<th>Endometrial Thickness, mm</th>
<th>Cases of Cancer, n</th>
<th>Negative Predictive Value, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karlsson et al⁷</td>
<td>1168</td>
<td>≤4</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Ferrazzi et al³</td>
<td>930</td>
<td>≤4</td>
<td>2</td>
<td>99.4</td>
</tr>
<tr>
<td>Guidi et al⁴</td>
<td>163</td>
<td>≤4</td>
<td>4</td>
<td>99.1</td>
</tr>
<tr>
<td>Epstein and Valentin⁵</td>
<td>97</td>
<td>≤5</td>
<td>1</td>
<td>99.4</td>
</tr>
<tr>
<td>Gull et al⁶</td>
<td>394</td>
<td>≤4</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 1. Transvaginal pelvic sonogram in the long-axis projection from a postmenopausal patient who presented with bleeding. The endometrial echo is thin, measuring 1.5 mm in maximum thickness. In large prospective studies, such a sonographic picture has been associated with a risk of malignancy of 1 in 917.

Figure 2. Video clip of a patient with postmenopausal bleeding. This long-axis view of the endometrium depicts a thin distinct endometrial echo, reliably excluding malignancy.
**Figure 3.** Transvaginal sonogram showing a retroverted long-axis view of the uterus. No distinct endometrial echo was visualized secondary to marked acoustic heterogeneity from adenomyosis. In such cases, unenhanced transvaginal sonography cannot be relied on to exclude disease.

**Figure 4.** Transvaginal sonogram showing a retroverted long-axis view of the uterus. An endometrial echo is thin and distinct and easily seen emanating from the endometrial canal. This image is a reliable depiction of a useful endometrial echo compatible with atrophy.

**Figure 5.** A. Sonogram from a patient who presented with postmenopausal bleeding. The endometrial echo is clearly thickened. B. Sonohysterogram from the same patient. Not only is the endometrium itself thickened, but there is a focal abnormality on the anterior wall halfway to the fundus measuring 1.1 cm in maximum anteroposterior diameter. It represented an endometrial polyp on a backdrop of complex endometrial hyperplasia.

**Figure 6.** Saline infusion sonohysterogram from a patient with postmenopausal bleeding whose unenhanced image was not thin and distinct. This image depicts a global endometrial process. Blind endometrial biopsy revealed simple hyperplasia.
References

Think Ultrasound When Evaluating for Pneumothorax

Vicki E. Noble, MD

When evaluating a patient with hypoxia, dyspnea, or pleurisy, the differential diagnosis a clinician generates oftentimes includes ruling in or ruling out pneumothorax. Indeed, the clinical scenarios in which this diagnosis is important to consider are almost too numerous to list: a patient begins coughing just after a difficult attempt at central line placement; ventilator setting alarms start to go off and oxygen saturations drop in a patient with obstructive pulmonary disease; a young healthy person presents to the emergency department with dyspnea and pleurisy; a trauma patient presents with hypotension; or a patient becomes short of breath immediately after a diagnostic or therapeutic thoracentesis. Moreover, in settings in which radiography is not available such as office practices and in remote settings, thoracic sonography for pneumothorax can be especially helpful. In these clinical scenarios a quick diagnostic imaging test to rule in or rule out pneumothorax not only facilitates the patient’s treatment when its findings are positive but also helps eliminate this diagnosis from the differential. In some respects the latter is even more crucial because it allows the care team to move on to treat the true source of dyspnea and not perform unnecessary therapeutic maneuvers but rather focus on accurate treatment.

As has been well described, supine chest radiographs are notoriously unreliable in making the diagnosis of pneumothorax, and sensitivity values of 25% to 75% have been reported. This situation occurs largely because layering air in the supine patient can be distributed evenly over the anterior chest and therefore can be invisible on supine radiographs. Even upright chest radiography can be challenging, however, because lines, tubes, and other folds can hide subtle pleural line abnormalities. Although chest computed tomography is quite accurate, it involves moving potentially unstable patients to a less monitored environment; it involves radiation exposure; and its increased cost makes it an inefficient screening tool. Sonography is portable, can be performed at the bedside, and has no risk associated with repeated measures as clinical scenarios change. These advantages can make it less expensive because there are no additional burdens placed on radiologic technologists, and the performance is physician dependent. Indeed, numerous studies have described near 100% sensitivity and 90% to 95% specificity if a thorough examination is performed.

The Sound Judgment Series consists of invited articles highlighting the clinical value of using ultrasound first in specific clinical diagnoses where ultrasound has shown comparative or superior value. The series is meant to serve as an educational tool for medical and sonography students and clinical practitioners and may help integrate ultrasound into clinical practice.
How to Perform

How is the examination performed? Because the pleural line is usually centimeters below the chest wall, a high-frequency (5.0–10.0 MHz) probe provides the most detailed image of the pleural line. However, any transducer can be used, and many clinicians think that the phased array probe (2.0–5.0 MHz) or “cardiac” probe sometimes provides superior imaging because its increased frame rate allows for easier visualization of the moving pleural line. In the end, any probe that can provide the clinician with information about the pleural line is sufficient.

The transducer is placed on the chest wall, starting in the third or fourth intercostal space in the midclavicular line in a supine patient or the second intercostal space in an upright patient (Figure 1), and the rib shadows are visualized with the pleural line identified just deep to the rib shadow (Figure 2). It is important to identify the rib in cross section initially because patients with deep chest walls can have intercostal fat or pectoralis muscle fascia that can mimic the pleural line (Figure 3). Once the pleural line is identified, there are two critical findings, lung sliding and comet tail artifacts, that essentially guarantee that the visceral and parietal pleura are opposed just underneath the probe footprint, thus ruling out pneumothorax in that space.

Comet tails are linear reverberation artifacts that originate at the pleural line and are caused by the bouncing back and forth of sound between the dense fibrous tissue of the visceral and parietal pleura (Figure 4). This “comet tail” reverberation artifact is only possible if the pleural layers are in opposition and there is no air between them (i.e., pneumothorax) scattering the sound and preventing this phenomenon. Lung sliding is the visualization of the...
The shimmering sliding motion of the visceral and parietal pleura with respiration and is caused by the expansion and contraction of the chest wall with breathing (Videos 1 and 2). Again, this shimmering and sliding can only be visualized when the two pleural layers are in opposition. Air between the visceral and parietal pleura will scatter the transmitted sound, thus disrupting its return to the transducer, ensuring only the fixed parietal pleura will be seen. M-mode imaging can show diagnostic findings for pneumothorax in a still image representation. The “barcode” sign is seen with a lack of lung sliding and indicates air in the pleural space, whereas the “seashore” sign or depiction of pleural sliding indicates closely opposed visceral and parietal motion with respiration as opposed to the near-field relatively fixed chest wall musculature (Figure 5).

One finding on thoracic sonography that is thought to be almost universally specific for pneumothorax is called the “lung point sign” (Video 3). This sign occurs where the point of reattachment or detachment of the pleura is found; that is, half of the image under the transducer footprint shows lung sliding and comet tails, while the other half of the image shows lack of lung sliding or a fixed parietal pleura with no comet tails. Indeed, this lung point can be followed around the chest wall to get a sense of how large the pneumothorax is. In addition, the “lung pulse” or visualization of pleural line “beats” that match the underlying heart rate is a marker of opposed visceral and parietal pleura because transmitted heart pulsations can only be seen if there is no pneumothorax or air separating the pleural layers.

The training necessary to complete this examination is minimal, and studies have demonstrated image acquisition and image interpretation mastery with several hours of didactic training and 25 practice examinations.6

Figure 4. This image shows the thin vertical line called a “comet tail” that is caused by reverberation between the visceral and parietal pleura (arrow).

Figure 5. A. Lack of lung sliding seen on M-mode imaging, also known as the “barcode” sign. B. Back-and-forth motion of the lung below the pleural line seen on M-mode imaging, also known as the “seashore” sign.
Discussion

Depending on the clinical scenario, more comprehensive interrogations of multiple rib spaces can be used to demonstrate the two critical findings of lung sliding and comet tails, thus ruling out even a small pneumothorax. The more rib spaces interrogated, the more sensitive the examination. Therefore, false-negative examinations can occur if a small pneumothorax is present and a less comprehensive examination is performed that does not evaluate from the apex to the diaphragm. However, it follows that in supine patients with severe hypoxia and hypotension, evaluating the anterior chest wall and seeing lung sliding and comet tails bilaterally can essentially rule out pneumothorax as a cause of shock, and the clinical investigation can move on to other diagnostic concerns.

In addition, there are situations in which false-positives—ie, no lung sliding seen on sonography when the patient does not have a pneumothorax—can occur. These are situations in which the pleura may be fixed for other reasons and include patients with adhesions or who have had pleurodesis or thoracic surgery. However, even in postsurgical patients, a change from lung sliding to no lung sliding in the acute setting should be considered clinically important. Blebs caused by parenchymal destruction can also result in false-positive findings because there will often be a lack of lung sliding in these cases. Occasionally, however, comet tails will still be seen as the visceral and parietal pleura are opposed; therefore, this diagnosis should be considered when there is no lung sliding but persistent comet tails.

Given the ease of performance, the low cost, and the multiple clinical scenarios in which this diagnosis is considered, application of this examination could be considered in any situation in which a chest radiograph is being ordered to evaluate for pneumothorax. Given the number of times this diagnosis is considered in the hospital setting, using thoracic sonography as a screening tool may lead to decreased ordering of chest radiographs, thus saving time and money and improving the efficiency of treatment.7

Obviously, the advent of a new diagnostic tool does not change the responsibility of the clinician to use his or her clinical judgment when deciding on intervention versus further testing. If the pretest probability of disease is low and the thoracic sonographic findings are negative, then the literature and documented clinical experience suggest that the diagnostic evaluation can stop there. If the pretest probability of disease is high and the lung sonographic findings are positive for pneumothorax, the same clinical judgments physicians currently employ should be used: stable patients can be observed, or further diagnostic imaging can be ordered to confirm or better delineate the disease process, and critical or unstable patients require tube thoracostomy. For those patients in whom the pretest probability and diagnostic test results are discordant, further diagnostic testing is warranted.

References

Sonography Should Be the First Imaging Examination Done to Evaluate Patients With Suspected Endometriosis

Beryl R. Benacerraf, MD, Yvette Groszmann, MD

Endometriosis is defined as the presence of normal endometrial tissue occurring outside the endometrial cavity. This ectopic endometrial tissue responds to normal cyclic hormonal changes, resulting in localized bleeding, inflammation, and subsequent adhesion formation.

As a result, endometriosis is a well-known cause of chronic pelvic pain in premenopausal women. The most common site and most recognized sonographic appearance of endometriosis is the ovarian cyst known as an endometrioma or chocolate cyst. Sonographically, an endometrioma is an ovarian cyst that has homogeneous low-level echoes with some areas of increased echogenicity (clot) but with no evidence of blood flow inside.1 Many years ago, the sonographic diagnosis of endometriosis was reserved for patients with obvious endometriomas, thus missing the cause of pelvic pain in a large number of patients. We now know that endometriosis is also commonly found in other dependent areas of the pelvis, including the anterior and posterior cul-de-sac, the uterosacral ligaments, the bladder and bowel wall (rectosigmoid particularly), and the rectovaginal septum.

Endometriosis can occur in the form of superficial and deep implants. The pain associated with these implants may be intense, but these lesions are often small and not easily detected by standard pelvic sonography. Some patients with extensive disease and large endometriomas may have relatively few symptoms, whereas others with small deep endometriotic implants may have severe dysmenorrhea, dyspareunia, and chronic pelvic pain.

Diagnostic laparoscopy remains the reference standard for diagnosing pelvic endometriosis. More recently, however, detailed transvaginal sonography specifically looking for endometriotic lesions in correlation with the sites of pain has been quite effective in detecting the disease.2–6 In addition, as previously described, patients with endometriosis often have severe pelvic adhesions that further contribute to their pain and can also be detected sonographically. Examples of common sonographic findings consistent with adhesions are tethering of the uterus to the uterosacral ligaments so that the uterus is in a fixed, immobile position and obliteration of the posterior cul-de-sac.

In 2004, Bazot et al7 described a group of 83 women with surgically proven deep pelvic endometriosis and found that the sensitivity and specificity for detecting the disease sonographically were...
78.5% and 95.2%, respectively. The sensitivity was best for intestinal and bladder disease and slightly less accurate for uterosacral and rectovaginal involvement. Since then, many studies have looked at the use of pain-guided transvaginal sonography to detect implants of deep endometriosis. In a systematic review and meta-analysis looking at the accuracy of transvaginal sonography for the detection of deep bowel endometriosis, Hudelist et al. found pooled estimates of sensitivity and specificity of 91% and 98%, respectively, with a positive likelihood ratio of 30.36 and a negative likelihood ratio of 0.09.

When comparing sonography and magnetic resonance imaging (MRI) as imaging modalities in 98 patients with surgically confirmed endometriosis, Abrao et al. found that transvaginal sonography had sensitivity, specificity, and accuracy of 98%, 100%, and 99%, respectively, compared to MRI’s sensitivity, specificity, and accuracy of 83%, 98%, and 90% for rectosigmoid endometriosis. In a study by Saba et al., the specificity and sensitivity for detecting endometriosis by sonography were 86% and 73%, respectively, whereas for MRI they were 90% and 73%, respectively. Other investigators have shown that transvaginal sonography performs similarly to MRI in the diagnosis of intestinal endometriosis, although MRI may have slightly higher sensitivity for uterosacral disease. Pascual et al. found that introital 3-dimensional sonography was highly effective in detecting endometriosis of the rectovaginal septum. Others have advocated using a bowel preparation for better visualization of the bowel wall or extra gel in the vagina to distance the probe from the area of interest, resulting in improved imaging quality.

**Technique**

The standard transvaginal sonographic examination based on the American Institute of Ultrasound in Medicine practice guideline includes imaging of the uterus and ovaries. In a patient with chronic pelvic pain, this process is only a small part of the procedure, and the examiner must extend the study beyond the standard protocol. The most important portion of the examination for these patients is evaluation of the cul-de-sac, bowel wall, and rectovaginal septum while gently palpating with the probe to elicit the areas of tenderness. This procedure is called tenderness-guided transvaginal sonography and is very accurate in the identification of rectosigmoid endometriosis.

It is best to start on one side, palpating the ovary with the probe and then proceeding posteriorly toward the cul-de-sac by small increments, still palpating and guided by the patient’s discomfort. In the process, one can assess the region of the uterosacral ligament and the bowel wall while compressing it slightly. Then looking at the posterior aspect of the cervix and top of the rectovaginal septum, one can evaluate the wall of the rectum and the back of the cervix. There is often a small amount of free fluid in healthy patients, which is very helpful in outlining the posterior limit of the cervix, normally smooth and closely applied to the surrounding bowel. Small implants of endometriosis may appear as small bumps or irregularities on the posterior aspect of the cervix.

In doing this part of the examination, it is important to move the cervix lightly while observing the organs glide past each other. This technique should be used throughout the pelvis to detect adhesions. Even a small implant of endometriosis on the back of the cervix can cause adhesions to the nearby bowel, thus causing pain and lack of normal motion of the cervix. The technique of testing the mobility of the organs was first introduced to determine whether there were adhesions between the bowel and periumbilical areas before placing a trocar for laparoscopy.

Deep implants of endometriosis are solid in appearance sonographically and have very little if any detectable blood flow on color Doppler imaging. When in the bowel wall, the implant takes the form of a nodular and fusiform swelling of one side of the bowel wall. In other areas, the implant may be a small rounded solid structure adherent to the back of the cervix or pelvic ligaments. It is often helpful to observe the peristalsis in the surrounding bowel, as the implant will stand out because of its immobility.
Conclusions

Transvaginal sonography when performed as described above is accurate and effective in detecting endometriosis without the need for MRI. It does not take much time to perform this additional search for deep pelvic endometriosis, is much more cost-effective than MRI, has a high level of patient acceptance, and when the disease is discovered, often explains years of chronic pelvic pain or infertility. Studies have shown that sonography is at least as sensitive and specific as MRI in detecting deep implants of endometriosis and thus is the imaging examination of choice in patients suspected of having endometriosis.

References

Sonography of Adenomyosis

Khaled Sakhel, MD, Alfred Abuhamad, MD

Adenomyosis was first described by Rokitansky in 1860 as "cystosarcoma adenoides uterinum" and was later defined by Von Recklinghausen in 1896. It is a common condition that predominantly affects women in the late reproductive years. Adenomyosis has been noted to occur in about 30% of the general female population and in up to 70% of hysterectomy specimens depending on the definition of the entity. The diagnosis can be made with sonography or magnetic resonance imaging (MRI), but this article will show that sonography should be the imaging modality of choice for adenomyosis.

Definition

Adenomyosis is defined by the presence of ectopic endometrial glands and stroma within the myometrium. The presence of ectopic endometrial glands and stroma induces a hypertrophic and hyperplastic reaction in the surrounding myometrial tissue.

Clinical Presentation

Most patients with adenomyosis are asymptomatic. Symptoms related to adenomyosis include dysmenorrhea, dyspareunia, chronic pelvic pain, and menstrual menometrorrhagia. Adenomyosis presents most commonly as a diffuse disease involving the entire myometrium (Figure 1). It can also present in a focal area of the uterus, known as adenomyoma (Figure 2). Adenomyosis can also be associated with other conditions, such as leiomyomata, endometrial polyps, and endometriosis. The establishment of the clinical diagnosis of adenomyosis is difficult because of its vague presenting symptoms. A homogeneously enlarged (globular) uterus on pelvic examination is suggestive of the diagnosis.

Diagnosis

The diagnosis of adenomyosis is made on a pathologic specimen, obtained after hysterectomy. The pathologic diagnosis is dependent on the visualization of endometrial glands and stroma in more than 1 low-powered field (2.5 mm) from the endometrial basalis layer. The diagnosis can also be made by imaging with the use of sonography or MRI. A recent meta-analysis on the accuracy of sonography in the diagnosis of adenomyosis showed that it had sensitivity of 82.5% (95% confidence interval, 77.5–87.9) and specificity of 84.6% (79.8–89.8) with a positive likelihood ratio of 4.7 (3.1–7.0) and a negative likelihood ratio of 0.26 (0.18–0.39). The sensitivity
and specificity of MRI in diagnosing adenomyosis are similar to those for sonography and have been reported as 77.5% and 92.5% respectively. In the presence of adenomyosis, when the transvaginal ultrasound probe touches the corpus of the uterus, tenderness is commonly noted. The presence of leiomyomata can adversely affect the diagnostic capability of sonography, and the presence of leiomyomata is generally associated with adenomyosis in 36% to 50% of cases.

Sonographic Findings

The sonographic findings of adenomyosis, best obtained by transvaginal sonography, include the following:

1. Uterine enlargement—Globular uterine enlargement that is generally up to 12 cm in uterine length and that is not explained by the presence of leiomyomata is a characteristic finding (Figure 3).

2. Cystic anechoic spaces or lakes in the myometrium—The cystic anechoic spaces within the myometrium are variable in size and can occur throughout the myometrium (Figure 4). The cystic changes in the outer myometrium may on occasion represent small arcuate veins rather than adenomyomata. The application of color Doppler imaging at low velocity scales may help in this differentiation.

3. Uterine wall thickening—The uterine wall thickening can show anteroposterior asymmetry, especially when the disease is focal (Figure 5).

4. Subendometrial echogenic linear striations—Invasion of the endometrial glands into the subendometrial tissue induces a hyperplastic reaction, which appears as echogenic linear striations fanning out from the endometrial layer (Figure 6).

5. Heterogeneous echo texture—There is a lack of homogeneity within the myometrium with evidence of architectural disturbance (Figures 1 and 4). This finding has been shown to be the most predictive of adenomyosis.

6. Obscure endometrial/myometrial border—Invasion of the myometrium by the glands also obscures the normally distinct endometrial/myometrial border (Figures 2–6).

7. Thickening of the transition zone—This zone is a layer that appears as a hypoechoic halo surrounding the endometrial layer. A thickness of 12 mm or greater has been shown to be associated with adenomyosis.
There is literature to support the observations that a globular uterus, cystic spaces, and linear striations are the most specific findings in the diagnosis of adenomyosis. Chiang et al used color Doppler sonography to differentiate adenomyosis from leiomyomas. In their study, 87% of the cases of adenomyosis had randomly scattered vessels or intramural signals. In 88% of leiomyoma cases, however, peripheral scattered vessels or outer feeding vessels were noted. In addition, in 82% of the adenomyomas, arteries within or around the uterine tumors had a pulsatility index of greater than 1.17, and 84% of leiomyomas had a pulsatility index of 1.17 or less.

Conclusions

Adenomyosis is a common finding in women of reproductive age. Most women with adenomyosis are asymptomatic. When symptomatic, adenomyosis can cause pelvic pain and abnormal uterine bleeding. The diagnosis of adenomyosis by sonography has been well defined and has diagnostic capabilities comparable to MRI. When a diagnostic imaging modality is required for suspected adenomyosis, sonography should be given first consideration given its efficacy, safety, and lower cost.

References


Lung Ultrasound in Evaluation of Pneumonia

Michael Blaivas, MD

The Sound Judgment Series consists of invited articles highlighting the clinical value of using ultrasound first in specific clinical diagnoses where ultrasound has shown comparative or superior value. The series is meant to serve as an educational tool for medical and sonography students and clinical practitioners and may help integrate ultrasound into clinical practice.

Revised manuscript accepted for publication March 14, 2012.

Address correspondence to Michael Blaivas, MD, Department of Emergency Medicine, Northside Hospital Forsyth, Cumming, Georgia USA. Revised manuscript accepted for publication March 14, 2012.

Abbreviations
ARDS, acute respiratory distress syndrome; CT, computed tomography

During the last 20 years, ultrasound has been shown to be highly effective in evaluating a range of pathologic pulmonary conditions. One of the most widely studied and practiced applications is the evaluation of pneumonia with ultrasound. Ultrasound interrogation of the thorax for detection of pneumonia has been explored most in critical care and emergency department settings. However, recently, the application has spread to general practice and even prehospital settings. A number of scanning approaches exist, ranging from highly involved research scanning tools to rapid and focused surveillance scans. The most widely accepted protocol is performed rapidly and easily and has proved to be sensitive and specific in adult and pediatric patients. Multiple studies have shown lung ultrasound imaging to be more accurate than chest radiography and in some cases rivals the accuracy of computed tomography (CT), such as in the diagnosis of lung abscesses. This article reviews clinical scenarios in which the lung ultrasound examination is useful in suspected pneumonia, describes pathologic findings, and presents a commonly accepted scanning protocol.

Overview and Clinical Problem

The diagnosis of pneumonia, once thought to be accomplished simply by physical examination, history taking, and specific auscultatory findings, has recently become highly dependent on imaging. There is, in general, a method behind this apparent clinical madness. Despite a long-held belief that physical examination findings and proper auscultation are sufficient to rule in, or out, the presence of pneumonia, multiple pressures in clinical practice have driven increased use of chest radiography and occasionally CT. The physical examination has proved to be unreliable for detection of pneumonia, even in expert hands. Studies comparing examinations by expert physicians to chest radiography have verified the failure of auscultation as a diagnostic method in evaluation of pneumonia, yet physicians are under an increasing burden to be more accurate, and missing pneumonia is seen as a substantial liability. Additionally, the common approach in general private practice of prescribing antibiotics to any patient presenting with a cough and fever contributes to increasing antibiotic resistance and is actively combated by the US Centers for Disease Control and Prevention.
When faced with a patient with any combination of fever, cough, shortness of breath, and hypoxia, clinicians think they have little option but to obtain an imaging study or empirically prescribe antibiotics. In hospital settings, patients may receive chest radiography routinely, not only for most presentations to the emergency department with a cough but also in hospital wards and intensive care units. In the latter two locations, chest radiography may be a daily occurrence for some patients. However, one of the most clinically frustrating aspects of searching for pneumonia with chest radiography is the relatively low accuracy of this traditional imaging standby. Clinicians frequently discover pneumonia on CT that was not seen on chest radiography while searching for other pathologic conditions such as pulmonary embolisms. Additionally, common chest radiography is associated with considerable practical delays in most settings where a trained technologist obtains an image and then processes it, both frequently away from the immediate clinical setting. Point-of-care ultrasound imaging, performed at the patient’s bedside, decreases the delays of chest radiography in diagnosis of pneumonia. Studies showing the efficacy of lung ultrasound in detecting and ruling out pneumonia date back approximately 20 years. Originally unrecognized by most in the medical community, ultrasound imaging has proved superior to chest radiography in almost every setting ranging from intensive care units to emergency departments and outpatient clinics. The term “lung ultrasound” is the most widely accepted one but is effectively equivalent to “thoracic ultrasound” and “pleural ultrasound,” both of which have occasionally been used in the literature.

Ultrasound Use

Performing the examination is easy and can be accomplished after focused training. The original descriptions used a micro-convex ultrasound transducer in the 5-MHz range. Little or no image postprocessing was available at the time, and much of the science of lung ultrasound was built on artifacts noted when the ultrasonic waves hit the pleural surface. In recent years, a variety of ultrasound transducer types have been used to image the lung. The most common, in addition to the micro-convex type, are linear and phased array cardiac transducers, typically ranging from 10 to 5 and 5 to 2.5 MHz, respectively. The linear arrays, much like a curved linear abdominal probe, have difficulty getting in between ribs, substantially limiting imaging in some patients. However, the pleura and near-pleural abnormalities are seen much better than with the micro-convex and phased array transducers, which are probably best suited for general lung applications such as pneumonia screening in most patients. In the adult patient, the field depth is typically set at 16 to 18 cm, commonly found on most machine presets. Image postprocessing settings such as tissue harmonics and multibeam functions are best turned off if possible. Such settings may eliminate artifacts and could impede diagnosis. The ultrasound transducer is moved until a rib interspace is located. The probe is then panned horizontally and vertically to the extent possible to allow the broadest sweep through the area being imaged. The transducer indicator is pointed cephalad and then to the patient’s right, allowing for the best ultrasound penetration between ribs. Holding the transducer perpendicular to the chest wall and panning of the beam are accomplished with subtle movements and angle variations. For the most consistent and accurate results, the operator should use a methodical scan to map out the entire thorax. The micro-convex and phased array transducers are ideal for manipulating the ultrasonic beam in the rib interspaces. One exception is the young pediatric patient, for whom linear array or high-resolution micro-convex transducers are best suited to the small body size.

When evaluating for pneumonia, the ultrasound transducer is typically applied to 4 different windows on each hemithorax. In a reclined or semireclined patient, the 8 regions include the upper and lower regions of the anterior hemithorax and upper and lower regions of the lateral hemithorax (Figure 1). An entire region is surveyed by angling and sliding the ultrasound transducer as needed. The pleural surface of the lung acts as an acoustic reflector, reflecting nearly 80% of the ultrasonic beam it encounters. As seen with other anatomic structures with high impedance, horizontal reverberation artifacts are readily created and are known as A-lines in the lung ultrasound lexicon (Figure 2). The healthy, well-aerated, and inflated lung has a density of approximately 0.32 g/mL and is not acoustically penetrated by medical ultrasound to an appreciable

Figure 1. The scanning position for the lateral chest is shown. A phased array cardiac transducer was used for this 8-point pneumonia survey.
When the fluid content of the lung increases, substantial impedance differences are encountered in close proximity, leading to generation of additional artifacts termed B-lines, which are frequently seen in pulmonary edema. These artifacts are classically described as discrete laser-like vertical hyperechoic entities, which appear to arise at the pleural line and extend to the bottom of the ultrasound image without fading. Debate still exists about their exact source.

The key to ultrasound visualization of pneumonia in the lungs is relative loss of aeration of a portion of the lung and a concomitant increase in the fluid content, which is seen in lung consolidation. Once this consolidation reaches the pleura, it can be seen with ultrasound. Although some very early pneumonias must be so localized as to not abut the lung pleura, most make contact at some point inside the chest in clinically symptomatic patients and can thus be imaged with ultrasound. Current literature suggests that most pneumonias in critically ill patients (up to 98%) will contact the pleura. On a standard ultrasound examination, lung consolidation from pneumonia is often described as having a tissue-like pattern and is referred to as “hepatization” to illustrate its gray scale density and general appearance (Figure 3). Boundaries of a consolidated lung segment are defined by the pleural line, the adjacent aerated lung, and any effusion that may be present. The boundary created by adjacent aerated lung will naturally appear irregular. An exception is when an entire lobe is affected, in which case the boundary will be regular and well defined. A dendrite-like air bronchogram and a large number scatter artifacts from air are frequently traceable up to the pleura (Figure 4). In real time, air can be seen moving through bronchi, and this finding is known as a dynamic air bronchogram (Video 1). On color or power Doppler imaging, vascular flow in cases of pneumonia is seen as a classic branching pattern in the infected/consolidated lung. Table 1 summarizes the typical ultrasound findings associated with pneumonia.

The sensitivity of B-mode ultrasound imaging is about 90%. Consolidation and dynamic air bronchograms have the highest specificity for pneumonia. Several studies showed that ultrasound imaging outperformed chest radiography with CT of the chest as a reference standard.

Figure 2. Arrows show multiple bright repeating horizontal lines, known as A-lines.

Figure 3. This image shows a solid organ–appearing structure in the near field. In actuality, the scan was performed through the lateral thorax. The lung is consolidated in a case of pneumonia and has an echo texture similar to that of the liver (Lung). Adjacent to it, the heart is shown, which is not possible through healthy lung. Several vessels are shown near the heart with a great vessel (GV).

Figure 4. This image shows air bronchograms. The liver is shown on the right side of the screen with the diaphragm just to the left. The content of the thorax above the diaphragm is easily visualized (Lung) and appears to have a liver-like echo texture. Arrows point to bright branching signals within the consolidated lung, which represent the air bronchograms.
Interestingly, lung ultrasound has grown to such an extent that an evidence-based consensus conference was held in 2010 and 2011, grading supporting evidence and bringing together dozens of published experts from multiple countries around the world. The consensus conference found that lung ultrasound has broad utility in evaluating patients for pneumonia, lung contusions, pneumothorax, pulmonary edema, pulmonary embolisms, and other pathologic conditions. In general, ultrasound imaging performed better than plain radiography.

Discussion

Lung ultrasound imaging for the detection of pneumonia is highly accurate but like most diagnostic tests is not perfect. It is important for the sonologist to realize that lung consolidation can result from several different pathologic conditions. These include not only pneumonia but also acute respiratory distress syndrome (ARDS), lung contusions, and atelectasis. Although differentiating between pneumonia and atelectasis is probably the most difficult on the basis of clinical grounds, it is easily accomplished with ultrasound. Atelectatic lung segments (clinically the most commonly encountered mimickers) will show the absence of regional blood flow in the affected area of the lung on color or power Doppler interrogation. Patients with ARDS and lung contusions are often obviously clinically but will show the presence of blood flow on Doppler imaging. Lung contusions are typically encountered in patients with blunt trauma and will show abolishment of lung sliding; in some cases, they have even been mistaken for pneumothorax. However, ARDS will almost always show pleural line irregularities and will frequently show subpleural consolidation. These signs can allow clinicians to distinguish between major causes of lung consolidation on ultrasound imaging. As with any ultrasound application, operator competency is critical, and error can occur if the operator is not properly trained and experienced. Fortunately, it appears that lung ultrasound imaging has a favorable learning curve. However, misdiagnosis of pneumonia or, worse, failing to detect pneumonia could negatively affect the patient.

The use of lung ultrasound in the evaluation of pneumonia is growing rapidly and in each clinical setting shows increased efficiency as accurate bedside diagnosis is made possible. Although many traditional imaging applications are still indicated and will be used indefinitely for patients with possible pneumonia, lung ultrasound can substantially decrease the practical delays associated with plain chest radiography and in some cases can obviate the need for chest CT when a definitive diagnosis is obtained on ultrasound imaging, avoiding a large radiation dose. In many cases when pneumonia is in the differential diagnosis, lung ultrasound should come first.

References

Ultrasound-Guided Interscalene Blocks

Andrew Gorlin, MD, Lisa Warren, MD

Anesthesiologists routinely use peripheral nerve blocks as an alternative or an adjunct to general anesthesia in addition to postoperative analgesia for a wide variety of procedures. More recently, emergency physicians have also begun using regional techniques in lieu of procedural sedation for a wide variety of extremity procedures such as reduction of shoulder dislocation. The goal of a peripheral nerve block is to apply a local anesthetic directly onto a peripheral nerve or nerve plexus to completely anesthetize the surgical site.

Historically, anesthesiologists have performed peripheral nerve blocks using the paresthesia technique, in which the needle is inserted at a point determined by standard anatomic landmarks and then advanced until the patient feels paresthesia in the relevant sensory distribution. In the 1970s and 1980s, anesthesiologists began using a nerve stimulator to improve needle localization. Essentially, a nerve stimulator is a device that sends current through the block needle to elicit contraction of relevant muscle groups when in close proximity to the nerve of interest. These techniques are effective and are still in use, although they have many drawbacks. Over the past decade, ultrasound has gained popularity for peripheral nerve blockade because it allows the anesthesiologist to directly visualize the nerves of interest, the needle tip itself, and the spread of the local anesthetic in the desired location. In addition, the ultrasound image reliably depicts other structures such as blood vessels and lungs that the anesthesiologist wants to avoid. For these reasons, ultrasound guidance has increasingly become the standard technique for regional anesthesia.

Brachial plexus blockade has long been used for upper extremity surgery, and there are several standard techniques. The interscalene block is especially useful for shoulder surgery. In this article, we will describe the technique of an ultrasound-guided interscalene block and then discuss its advantages over the traditional landmark technique.

Description of the Procedure

The brachial plexus is derived from the C4–T1 spinal nerve roots. The nerve roots exit the intervertebral foramina and pass anterolaterally and inferiorly to lie between the anterior and middle scalene muscles. Beyond that point, the nerve roots coalesce to form the superior, middle, and inferior trunks, which then go on to further divide and coalesce sequentially into divisions, cords, and then finally the individual peripheral nerves of the upper extremity.
The interscalene block targets the C4, C5, and C6 nerve roots where they lie between the anterior and middle scalene muscles near the level of the cricoid cartilage. Because the block is typically performed cephalad to the exit points of the C7 and T1 nerve roots, the interscalene block typically requires supplementation with an ulnar nerve block to be useful for forearm or hand surgery. For shoulder surgery, however, it is extremely reliable as a sole block.

Before performing the block, the patient requires an intravenous line and standard American Society of Anesthesiologists monitors, including blood pressure, electrocardiography, and continuous pulse oximetry. Emergency resuscitation equipment, including airway devices, advanced cardiac life support drugs, and intravenous fat emulsions for local anesthetic toxicity, must be immediately available. Oxygen is administered by nasal cannula. Sedation is optional because the procedure is usually short with minimal discomfort, although in our experience, most patients are quite anxious and do well with mild sedation (we typically use low doses of midazolam and fentanyl).

The patient is then positioned supine with the head turned away from the side to be injected, and the site is marked. Some patients require a roll under the shoulder to enhance neck extension. The operator dons a cap, mask, and sterile gloves and the patient’s neck is prepared widely with chlorhexidine. The ultrasound probe is placed in a sterile probe sheath. We use a LOGIQ e ultrasound machine with a 12L-RS linear array, 42 × 7-mm, 5- to 13-MHz transducer (GE Healthcare, Milwaukee, WI). For most interscalene blocks, we set the ultrasound machine for 10 MHz with a 3-cm depth.

After a procedure time-out, the ultrasound probe is placed over the patient’s neck, oriented roughly in the axial plane (Figure 1). By convention, we position the probe with the direction indicator medially on the neck. The probe is positioned over the sternocleidomastoid at the level of the cricoid cartilage. After identifying the jugular vein and carotid artery in the short axis, the operator slides the probe laterally/posteriorly until the brachial plexus nerve roots are visualized. At this level, the nerve roots of the brachial plexus will appear as 2 to 4 round hypoechoic circles lying between the anterior and middle scalene muscles (Figure 2). Occasionally, the brachial plexus can be difficult to find using this method. Another useful approach is to visualize the subclavian artery just above the clavicle. The brachial plexus lies in a cluster around the artery at this level and is very easy to identify. The operator then slides the ultrasound probe cephalad, tracking the brachial plexus until the interscalene target is identified. The nerve roots should be positioned toward the medial edge of the screen (away from the needle insertion point) to maximize needle visualization during the block. The great vessels should not be in view during the block. If both vessels are in view, the transducer is likely too medial.

Once an optimal view of the nerve roots is established and color Doppler imaging confirms the absence of blood vessels in the trajectory of the needle, the operator prepares for the block. The ideal needle insertion point is roughly 1 cm lateral to the lateral edge of the ultrasound probe (Figure 3). The skin is anesthetized with 1 to 2 mL of lidocaine, 1%. While holding the ultrasound transducer with the nondominant hand, the operator then inserts a 22-gauge × 50-mm nerve block needle “in plane” with the ultrasound probe, allowing visualization of the entire needle (Figure 4). The needle can also be inserted “out of plane,” although we think that the in-plane technique is more effective and safer because needle tip visualization is easier. The operator advances the needle slowly, taking care to avoid any vascular structures and keeping the needle tip in view at all times. Once the needle tip is adjacent to the brachial plexus, an assistant will aspirate (checking for intravascular needle placement) and then inject 1 mL of a local anesthetic. The optimal needle location can be shown by visualizing the spread of the local anesthetic as a hypoechoic area around the nerve roots (Figure 5). If adequate spread is not seen, then the needle tip has probably not penetrated through the fascial plane that separates the middle scalene and the brachial plexus sheath. If that is the case, the needle will need to be advanced slightly. Once the ideal local anesthetic spread is visualized, the assistant injects a local anesthetic (we use 12 to 25 mL of bupivacaine, 0.5%, with epinephrine, 1:400,000), taking care to aspirate intermittently to ensure that the needle tip remains extravascular (Video 1). The needle is then removed.
Discussion

Before the introduction of ultrasound guidance, anesthetists performed regional blocks using classic landmark techniques with or without nerve stimulation. For a landmark-based interscalene block, the needle insertion point is at the interscalene groove just posterolateral to the sternocleidomastoid muscle at the level of the cricoid cartilage. The needle is inserted at a 45° caudal and slightly posterior angle and advanced until either paresthesia or appropriate nerve stimulation is achieved in the C4, C5, or C6 distribution. At that point, the anesthesiologist aspirates the needle to make sure the needle tip is not intravascular and then injects the local anesthetic.1

Although typically effective, the landmark-based technique is problematic in that it is a “blind” procedure. Because of anatomic variation and occasional difficulty palpating the interscalene groove, the landmark technique is subject to failure or the need for multiple needle passes.

Furthermore, there are many vulnerable anatomic structures in close proximity to the brachial plexus, including the carotid artery, jugular vein, vertebral artery, phrenic and laryngeal nerves, dura mater, and dome of the pleura. Thus, a slightly errant needle can result in serious complications, including nerve injury, intravascular injection with subsequent local anesthetic toxicity, total spinal anesthesia, and pneumothorax.3,5 In theory, ultrasound guidance mitigates these problems because the anesthesiologist can directly visualize the anatomy as well as the needle. The question remains, however, of whether there is literature to support the superiority of ultrasound guidance versus traditional techniques for an interscalene block.

Figure 2. Interscalene brachial plexus anatomy. ASM indicates anterior scalene muscle; BP, brachial plexus, nerve roots of C4, C5, and C6; CA, carotid artery; MSM, middle scalene muscle; and SCM, sternocleidomastoid muscle.

Figure 3. Needle insertion.

Figure 4. Needle placement “in plane.” The needle tip is within the brachial plexus sheath, sitting between the nerve roots of C4 and C5.

Figure 5. Spread of the local anesthetic shown as a hypoechoic area just inferior to the needle tip and brachial plexus.
There is substantial evidence that ultrasound guidance increases the efficacy and decreases the performance time of interscalene blocks. In a randomized study, Kapral et al. showed that ultrasound guidance was 99% successful in achieving surgical anesthesia compared with 91% for landmark/nerve stimulation. Furthermore, Liu et al. reported a reduced number of block attempts as well as improved motor blockade in ultrasound-guided interscalene blocks versus landmark/nerve stimulation blocks. Antonakakis et al. reviewed 19 randomized controlled trials of ultrasound versus landmark/nerve stimulation blocks. Antonakakis et al. showed that ultrasound guidance was 99% successful in the incidence of neurologic injury.7,9 Several randomized controlled trials also showed a decreased incidence of vascular puncture using ultrasound guidance versus traditional techniques. However, to our knowledge, no study has shown a significant reduction in the incidence of local anesthetic toxicity. Investigators have shown that ultrasound guidance does allow for a substantial reduction in the volume of injectate required for a successful block, which results in a lower incidence of phrenic nerve palsy and diaphragmatic paresis. In theory, the lower local anesthetic volume might also reduce the incidence or severity of other complications, such as stellate ganglion blocks, recurrent laryngeal nerve blocks, spinal and epidural anesthesia, and the toxic sequelae following inadvertent intravascular injection.7,8 It is possible that given the rarity of most of these complications, the studies thus far have been underpowered to detect any difference.

In a broader sense, the use of ultrasound may find its greatest benefit in that it expands the use of regional anesthesia for shoulder surgery, which has been shown to have many clinical benefits, including less pain, earlier ambulation, earlier discharge from the recovery area, fewer subsequent hospital admissions, and greater patient satisfaction.10 Antonakakis and Sites pointed out that the use of ultrasound has resulted in an enormous increase in the application of regional anesthesia, probably because of its ease of use and anesthesiologists’ perception of improved safety. They argued that, ultimately, ultrasound guidance for nerve blocks benefits patients simply because more patients are getting regional anesthesia for surgery. Similarly, ultrasound guidance has expanded the application of regional anesthesia to other specialties such as emergency medicine as well as other settings such as combat trauma hospitals and rehabilitation centers.12

In conclusion, ultrasound guidance has emerged as a standard technique for performing interscalene blocks as well as a number of other regional anesthetic blocks. Ultrasound guidance for interscalene blocks may be superior in terms of efficacy and safety compared with the traditional landmark technique because it allows direct visualization of the nerve targets, other adjacent anatomic structures, and the needle itself. There is substantial evidence to support the efficacy of ultrasound guidance for interscalene blocks (as well as other nerve blocks), although improved safety has not been clearly shown compared with the landmark technique, probably because of the rarity of serious complications. In practice, ultrasound has dramatically increased the use of regional anesthesia, which offers many important clinical benefits to patients recovering from surgery.

References

7. Liu SS, Zayas VM, Gordon MA, et al. A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for...


Sonography for Surveillance of Patients With Crohn Disease

Kerri L. Novak, MSc, MD, FRCPC, Stephanie R. Wilson, MD, FRCPC

Crohn disease is a chronic inflammatory condition of the bowel characterized by periods of quiescence and inflammatory activity or "disease flares." Although genetic factors, dysbiosis, and altered immunity are implicated in inflammatory bowel disease, the etiology is unknown. The peak age of onset is early in life, between 15 and 40 years, thus affecting patients during their most productive years with potential for substantial social and personal costs. Crohn disease tends to complicate over time, with the development of fistulas and fibrostenotic lesions. As a result, surgical intervention rates in the prebiologic era were high. However, early and appropriate medical management can alter the course of this disease, with reductions in surgical rates and hospitalization.

Detection of disease activity through objective monitoring is key to changing the long-term outcome and disability. Monitoring clinical symptoms alone is inadequate: the presence or absence of these does not reflect disease activity. Routine endoscopic monitoring is also not feasible because it is an invasive examination with associated risks and the need for preparation. Computed tomography (CT) with dedicated small-bowel imaging or enterography has been the modality of choice to date, but there is mounting evidence questioning its safety and repeatability, given ionizing radiation exposure in these young patients. Magnetic resonance imaging (MRI) is a radiation-free alternative and has also been shown to be effective in detection of inflammatory activity. However, this modality is expensive, and the lack of access precludes routine use.

Transabdominal sonography is a highly effective modality for detecting inflammatory activity in Crohn disease, equal to that of CT or MRI. Sonography is particularly sensitive in detecting ileocolic Crohn disease compared to the reference standard ileocolonoscopy and thus is a useful initial screening tool to aid in diagnosis. Postoperative Crohn disease recurrence is also reliably detected with sonography, a suggested surrogate for endoscopic evaluation. It is an effective modality in the detection of complications such as strictures, fistulas, and abscesses, with surgical pathologic confirmation showing sensitivity as high as 100%. Although there are little existing data on the utility of any transmural modality in routine monitoring of disease activity in asymptomatic patients, there is a move toward more frequent observation, given the disconnect between symptoms and disease. Sonography is a superb modality for monitoring stable patients with a
number of additional advantages: it is inexpensive and widely available, and real-time imaging with potential for 3-dimensional reconstruction can optimally characterize complications such as partial small-bowel obstruction. It is safe and noninvasive with easy repeatability and patient tolerability. Inflammatory activity, reflected by excess blood flow in the bowel wall, is shown on color Doppler imaging and more sensitively with the use of contrast agents, with potential for actual quantification and objective measurement of blood flow and therefore inflammatory activity.\textsuperscript{15}

Although sonography of the bowel is a highly effective modality, there are limitations. First, operator experience and expertise are more important in evaluation of the bowel compared to sonographic evaluation of other abdominal organs. Acquisition of technical expertise and adequate time are essential to survey the entire small and large bowel. The reproducibility of sonographic inflammatory parameters is a commonly suggested limitation of bowel sonography; however, there is strong evidence that inter-rater agreement on key parameters such as bowel wall thickness is high.\textsuperscript{16}

Consistent identification of the anatomic site of inflammation is also identified as a potential limitation. More than 80\% of patients with Crohn disease have small-bowel involvement, often the distal terminal ileum. Patients with active Crohn disease generally have a distinctively thickened bowel, which becomes relatively gasless compared to the normal bowel. This condition creates a mass effect. Therefore, as disease worsens, the pathologic characteristics improve the likelihood of detection. Areas that may be more challenging to identify include those deeper within the pelvis (rectum or ileoanal pouch) and proximal small bowel (duodenum). Considerable challenges may also arise with a complex surgical history, and accurate identification of the anatomic location can be limited in this circumstance.

Obesity, particularly body mass indices of 30 or greater, may hamper a sonographic study of any portion of the abdomen. Failure of sonography should not be predicated on body habitus alone, however. A low body mass index with little abdominal wall fat is advantageous for sonography compared to CT and MRI, which are both improved by the presence of intra-abdominal fat.

Complications associated with Crohn disease are well appreciated on sonography, but open fistulas and drainage sites may be problematic in patients with severe fistulizing disease, limiting transducer placement on the skin. In addition, discomfort may further limit examination. Complex fistulizing disease is often readily identified; however, there may be challenges associated with mapping of tracks, given surrounding inflammation and tethering, similar to any other modality. Certainly, partial small-bowel obstructions are shown on real-time sonography, and examination of complex disease is generally well tolerated by patients, given the lack of bowel preparation or need for contrast agents.

Although the above factors are considerations in the choice of sonography for the study of the bowel, as avid ultrasound enthusiasts, we support the use and choice of sonography as a first-line modality for evaluation of all patients with Crohn disease, both for routine surveillance and for evaluation at the time of acute exacerbation.

Case Description

A 38-year-old man with long-standing ileocolonic Crohn disease diagnosed at 21 years of age underwent emergent ileocolonic resection at presentation for suspected acute appendicitis. He was well for a decade, but after symptoms of intermittent severe abdominal pain developed, he was referred to gastroenterology. Ileocolonoscopy revealed an ulcerated and stenosed ileocolic anastomosis with a completely normal colon. He also had a cutaneous perianal opening with active drainage on perianal examination, consistent with a perianal fistula. He was given combination therapy of infliximab and methotrexate and was in clinical remission for 2 years with normal blood test results and a lack of perianal symptoms. A sonographic examination performed 1 year after initiation of medical therapy showed no abnormalities with no evidence of inflammatory activity, including the perianum.

One year later, the patient continued to be in clinical remission, with no symptoms of Crohn disease, other than intermittent scant drainage from his known perianal cutaneous opening. Subsequent surveillance sonographic examinations, however, revealed dramatic interval deterioration with extensive small-bowel thickening (Figure 1, A and B), hyperemia of the bowel on color Doppler imaging (Figure 1, C and D), abundant mesenteric inflammatory fat, and proximal disease in a skip lesion distribution. There were also multiple sites of narrowing with incomplete mechanical bowel obstruction (Figure 1, E–G), evidenced by fluid-filled dilated segments of the small bowel with to-and-fro peristalsis before segments with constant luminal apposition and wall thickening. The total length of the abnormal bowel was estimated to be 40 cm. Maximal wall thickness was measured at 8 mm. In addition, a clear intersphincteric rectocutaneous fistulous tract was identified on transperineal sonography (Figure 1H) without associated complications, specifically no ischiorectal fossa abscess.
Figure 1. Images from a 38-year-old man with Crohn disease for 17 years who previously underwent ileocolic resection. He was feeling well after 2 years of taking infliximab and methotrexate for recurrent disease in the neoterminal ileum. A previous sonographic examination 1 year earlier yielded normal findings, showing a marked initial positive response to therapy. The following images are from a surveillance scan. A and B, Long-axis and axial images of the neoterminal ileum show marked wall thickening with some loss of wall layering. The bowel measures 9 mm in thickness (threshold is 3 mm). C and D, Corresponding color Doppler images. The profuse easily shown blood flow is a reflection of active inflammation. (continued)
Commentary

The lack of clinical symptoms despite active disease, confirmed on endoscopy, is well documented. Furthermore, postoperative recurrence of Crohn disease is almost inevitable over time, and the need for a second operation in the absence of medical therapy is high. Many of these patients remain asymptomatic despite disease recurrence. Alternatively, the number of patients with Crohn disease who have typical symptoms such as diarrhea and abdominal pain in the context of quiescent disease is high, approaching 60%. Therefore, differentiating active from inactive disease clinically is challenging. Serologic measures of inflammation such as C-reactive protein are also unreliable in consistently detecting disease. Therefore, other noninvasive means of routinely evaluating the inflammatory activity in patients with Crohn disease is imperative to detect disease and prevent complications even when patients feel well. Sonography is an ideal modality for this purpose. It is key in the routine management of inflammatory bowel disease in a number of countries in Europe and in our department.

Figure 1. (continued) E, Fixed angulation of a very thick and black neoterminal ileum, well proximal to the anastomosis. On the left, the lumen shows fixed apposition, and on the right, there is fluid distention suggesting an element of stricture. There is abundant echogenic inflammatory fat. F, At a point more proximal in the neoterminal ileum, there is dilated bowel on the left with an abrupt transition to thick bowel with luminal apposition on the right, suggestive of another stricture with incomplete mechanical bowel obstruction. G, At yet another point more proximal, there is a fixed, very acute angulation of a thickened segment. Dilated fluid-filled bowel is shown both proximally and distally. H, Axial transperineal view of the anal canal. There is a hypoechoic inflammatory mass (arrows) posterolateral to the left side of the anal canal. The internal opening, in the 6-o’clock position directly posterior, is slightly more caudal and not shown here. Impression: active recurrent disease of the neoterminal ileum. There is a multifocal stricture, fixed acute angulation, incomplete mechanical bowel obstruction, and a perianal inflammatory mass.
The interval or frequency for transmural monitoring of Crohn disease is uncertain. In the case described here, the surveillance interval was likely too long: despite highly effective medical therapy and the absence of clinical symptoms, the patient had severe active persistent disease detectable 1 year after an examination yielded normal findings. This situation is not uncommon: a substantial number of patients who respond initially to biologic therapy lose the response over time. The reference number of patients who respond initially to biologic therapy and the absence of clinical symptoms, the patient had severe active persistent disease effective medical therapy and the absence of clinical symptoms. The surveillance interval was likely too long: despite highly effective medical therapy is endoscopic, to establish mucosal healing, but frequent routine endoscopic evaluation is not acceptable to most patients. There are no clearly established surrogates for mucosal healing in widespread use, but sono- graphic assessment is certainly a candidate. There is a need for a validated scoring system reflecting sonographic inflammatory activity to be included with other measures of disease activity.

Wall thickness measurement is central to sonographic determination of disease activity. However, the addition of color Doppler evaluation of the bowel in this case further illustrates the severity of the disease. This combined demonstration of severe disease strongly substantiates the presence of inflammation; therefore, contrast-enhanced sonography if performed is less additive in this case. Although contrast enhancement is a powerful tool for showing inflammation, this case is an excellent example of demonstrated severe active disease without the requirement for either intravenous access or contrast agent injection.

Given the predilection of Crohn disease for the terminal ileum and right colon, a sonographic examination starts with axial orientation of the right flank from the hepatic edge to the right iliac fossa looking for the wall and gas shadow suggestive of the ascending colon. Once localized, the terminal ileum is identified at the ileocecal valve. The remainder of the colon can generally be continuously followed from the ascending colon to the rectum. Furthermore, because of their fixed mesenteric locations, the segments of the colon can all be identified on the basis of their known locations and positions within the abdomen.

The entire small bowel is systematically evaluated by performing a series of axial scans from the right flank to the left flank with overlap of the scanning planes. The small bowel is not as easy to strictly identify; however, both the location and appearance are helpful. The jejunum is localized in the left upper quadrant with a characteristic feathery appearance of the valvulae conniventes. The small bowel in the 3 remaining quadrants is more likely to be ileum, with a more variable appearance.

Selection of the correct ultrasound probe is critical for successful sonographic evaluation of the bowel. The initial survey may be performed with a 4- to 6-MHz probe for systematic identification of thickened segments of bowel and evidence of complications. These low-frequency evaluations are necessary to avoid overlooking deeply positioned fluid collections. Localized regions of interest should then undergo detailed evaluation with higher-frequency probes (7–9 MHz), either linear or curved, for superior bowel wall resolution. In women, endovaginal probes are ideal to study both the rectosigmoid colon and portions of the terminal ileum located deep in the true pelvis. Finally, the ultrasound machine should be optimized for high contrast and low flow on color Doppler imaging.

For many years, we have performed transperineal sonographic evaluation of the anal canal and perianal soft tissues in patients with Crohn disease who have known fistulas or perianal pain. The technique is established as an accurate modality in both men and women, with potential for the addition of transvaginal scanning to increase accuracy in women. The identification of internal and external openings, inflammatory tracts, and any associated abscess is noninvasive, accurate, and easily repeated, facilitating close monitoring. Thus, monitoring responses to both surgical and medical therapy of perianal disease is readily accessible. Transrectal sonography can facilitate characterization of disease in patients with more proximal disease or suprapelvic extension of inflammatory changes. This examination can be painful for patients, however, and is infrequently performed for this indication in our center.

Fibrostenotic complications or strictures are areas of fixed luminal apposition with dilated proximal bowel, often accompanied by excess and dysfunctional to-and-fro peristalsis. Accurate assessment of the degree to which the stricture is inflammatory versus fibrotic in nature continues to be a challenge regardless of the transmural imaging modality. The inflammatory activity of a stricture is similar to non-narrowed thickened bowel with an increased blood supply, shown on Doppler imaging, which may be further characterized with microbubble contrast agents. Contrast further increases the sensitivity for detecting inflammation. Elastography used to evaluate bowel wall stiffness is a promising technology that may prove helpful in discerning the predominant etiology of the stricture. It is currently being investigated in our center.
Summary

Crohn disease is a complex chronic systemic inflammatory disease that frequently has complications and requires close monitoring to prevent disability. Current medical therapies have demonstrated success in the alteration of the natural history; however, a substantial number of patients do not respond to medical therapy or lose the response over time, as shown here. There is a shift in the management of Crohn disease to move beyond symptoms in identifying disease activity early and to treat to target, with mucosal healing as the goal, and not just for improvement of symptoms. Sonographic measurements of wall thickness and blood flow to the bowel wall are accurate measures of disease activity. Sonography is an excellent surrogate for mucosal healing, with easy repeatability so that frequent assessments can be made to facilitate early intervention.

References

Acute appendicitis is the most common cause of abdominal pain requiring urgent surgery in children and is a true gastrointestinal emergency. The diagnosis is suspected and made primarily on the basis of clinical findings. Classically, these clinical findings consist of periumbilical pain migrating to the right lower quadrant, accompanied by fever and leukocytosis. However, the classic signs are not always present, and symptoms can be nonspecific and overlap with other causes of abdominal pain. The clinical presentation is also complicated in young children by their limited communication skills.

Historically, computed tomography (CT) has been the first choice of imaging in acute abdominal pain, with sensitivity of up to 96% and specificity of up to 97%. However, because of the increasing awareness of the radiation dose imparted to patients by CT and the theoretical increased risk of cancer that it causes, there is a nationwide campaign to reduce the radiation from diagnostic imaging in children (Image Gently). Sonography uses sound waves instead of ionizing radiation to evaluate for disease and in some studies has demonstrated accuracy similar to that of CT. Therefore, sonography should be used as the primary diagnostic modality in the evaluation of suspected acute appendicitis in children.

Sonography is widely available, can be performed at the bedside, involves a short acquisition time, does not use ionizing radiation, is relatively inexpensive, and may show evidence of other causes of abdominal pain. It is particularly useful in evaluating young women, in whom the radiation dose to the reproductive organs should be minimized and for whom it is important to exclude ovarian and uterine conditions that might mimic appendicitis.

There have been multiple studies evaluating the value of sonography in the evaluation of appendicitis, showing varying sensitivity, specificity, and accuracy. However, a recent study by Pacharn et al found that sonography for acute appendicitis had a negative predictive value of 95%, making it an excellent screening tool in the evaluation of acute appendicitis. Goldin et al suggested that standardizing the technique and criteria will decrease variability in the diagnostic accuracy of sonography across institutions.
Technique

The standard sonographic evaluation of the abdomen based on the American Institute of Ultrasound in Medicine practice guideline includes imaging of the appendix. A complete abdominal sonographic examination does not need to be performed in the evaluation of acute appendicitis. However, because the appendix is not always located in the right lower quadrant and an abscess could be present, imaging should include not only the right lower quadrant but also the pelvis and left lower quadrant. A survey of the abdomen for free fluid or bowel thickening elsewhere is also helpful, especially in cases of suspected perforation.

At the start of the examination, it is helpful to ask the patient to point to the site of maximal tenderness and begin scanning in this location. Using a high-resolution linear transducer, the abdomen should be compressed while scanning, which moves bowel gas out of the field of view. This compression sonography is performed with an empty bladder. The most reliable way to identify the appendix is to find the ascending colon, follow the colon proximally to the cecum, and then find the appendix extending off the cecum.

Figure 1. A, Longitudinal image of the right lower quadrant showing a normal appendix. The maximal outer wall diameters are 5.3 and 5.7 mm. Less than 6 mm is considered normal. B, Transverse images of the right lower quadrant. The image on the left shows a normal appendix (arrows). The image on the right is with compression; the appendix compresses (arrow).
If the appendix cannot be seen in the supine position, it may be helpful to place the patient in the left lateral decubitus position to cause a retrocecal appendix to be better seen. Scanning with a full bladder may also be helpful because it can better delineate a deep pelvic appendix that might be obscured by overlying bowel.

The complete appendix should be visualized, including the tip. The maximal outer wall diameter should be measured, and the wall thickness should be measured along the course of the appendix. The normal maximal outer wall diameter of the appendix is less than 6 mm, and the mural thickness is less than 2 mm (Figure 1A). Compression of the appendix should be performed, with documentation of the appearance of the appendix during compression. A normal appendix compresses (Figure 1B). Secondary signs such as free fluid, a fecalith, and hyperechoic surrounding fat should be documented. Doppler imaging is helpful to evaluate for hyperemia; however, a necrotic appendix will have decreased or no blood flow. Video clips should be obtained to show normal peristalsis unless the physician is present during the scan. If an abscess is suspected, a lower-frequency curved array transducer may be used for a larger field of view and deeper penetration.

It is not always necessary to identify a normal appendix to consider the findings negative. If there are no secondary signs as mentioned above, and clinical suspicion is moderately low for appendicitis, many institutions stop the evaluation and consider the sonographic findings negative for appendicitis.

In the setting of acute appendicitis, the appendix is noncompressible, and the maximal outer wall diameter is greater than 6 mm (Figure 2). An appendicolith may be present, helping the diagnosis (Figure 3); however, an appendicolith can be present without acute appendicitis, and the presence of an appendicolith does not confirm acute appendicitis. There may also be secondary signs of inflammation, such as hyperechoic surrounding fat, free fluid, or an abscess (Figure 4). The wall may be hyperemic (Figure 5). Enlarged nodes can also be seen in the right lower quadrant, but this finding is nonspecific and can also be seen in patients without appendicitis. The surrounding bowel may be dilated with loss of normal peristalsis due to ileus.

Conclusions

Right lower quadrant sonography, when performed using rigorous technique and criteria for diagnosis, is an excellent screening tool for acute appendicitis. This examination is quick and painless and does not involve the use of ionizing radiation. Although the sensitivity, specificity, and accuracy of sonography vary greatly in studies evaluating the imaging diagnosis of acute appendicitis, it should be the first imaging modality when there is clinical concern for acute appendicitis. Only if the examination is equivocal or if the appendix cannot be identified should other imaging modalities such as CT be considered.

Figure 2. Longitudinal images of the right lower quadrant. The image on the left shows a dilated, thickened appendix. The maximal outer wall diameter of this appendix is 6.6 mm. The image on the right is with compression; there is no change in the appearance of the appendix.
Figure 3. Longitudinal image of the right lower quadrant showing an echogenic shadowing structure within a dilated appendix. It is an appendicolith associated with appendicitis.

Figure 4. Secondary signs of appendicitis. A, The fat surrounding this dilated tubular structure is echogenic (asterisks). This appearance is due to edema in the fat surrounding the appendix. B, Free fluid (arrow). C, Abscess appearing as a debris-filled fluid collection (asterisk) with surrounding echogenic fat.
References


Shoulder Sonography
Why We Do It

Sharlene A. Teefey, MD

One of the most common causes of shoulder pain is rotator cuff disease. It is the third most prevalent musculoskeletal disorder after low back and neck pain. Shoulder pain is usually due to one of several causes: subacromial impingement and bursopathy, tendinopathy, a tendon tear, a frozen shoulder, ligamentous instability, and osteoarthritis. Rotator cuff disease (tendinopathy or tear) highly correlates with increasing age. In one study, the average age for patients with a painful unilateral partial- or full-thickness tear was 58.7 years, and it was 68.7 years for those with bilateral partial- or full-thickness tears. This study also showed that patients with a painful unilateral full-thickness tear had a 35.5% prevalence of an asymptomatic tear on the contralateral side. This is important because a substantial number of patients with asymptomatic tears become symptomatic after short-term follow-up (which has been associated with tear size progression) and have deterioration of shoulder function.

There are several imaging techniques that can be used to diagnose rotator cuff disease, including sonography, magnetic resonance imaging (MRI), magnetic resonance arthrography, and computed tomographic arthrography. This article will focus on the role of sonography in evaluating the patient with shoulder pain, in particular, rotator cuff disease.

Accuracy of Sonography

Sonography has become an accepted imaging technique for evaluating the patient with suspected cuff disease. It can be used to accurately diagnose and quantify full- and partial-thickness tears and recurrent tears in the postoperative shoulder, determine the tear location, and evaluate the cuff muscles for fatty degeneration. It can also be used to diagnose other cuff disorders such as tendinopathy and calcific tendinitis and noncuff pathology of the biceps tendon, acromioclavicular joint, posterior labrum (paralabral cyst), and subdeltoid bursa.

Several studies have reported high sensitivity, specificity, and accuracy for diagnosing full- and partial-thickness tears. A meta-analysis by de Jesus et al showed that sonography and MRI were comparable in both sensitivity and specificity for diagnosing full- and partial-thickness cuff tears. It is important to accurately diagnose and characterize cuff tears for treatment planning. Sonographic findings help the orthopedic surgeon decide whether treatment should be surgical or nonsurgical; if arthroscopy is indicated, sonographic findings help the orthopedic surgeon counsel patients regarding surgical and functional outcomes. If a nonsurgical...
approach is chosen, sonography can be used to follow patients for tear size progression. It can also be used to evaluate the cuff muscles for fatty degeneration, which is an important prognostic factor regarding the patient outcome; fatty degeneration portends a poor functional outcome and places the patient at risk of a retear. Two studies have shown that there is a good correlation between sonography and MRI for assessing cuff muscle atrophy and fatty degeneration, and that the diagnostic performance between the two studies was comparable for diagnosing fatty degeneration.

Sonography has also been shown to be very sensitive for diagnosing calcific tendinitis and may be used to guide aspiration of calcific deposits. Aspiration has been shown to provide prompt and long-term pain relief at 1 year. Little has been published regarding cuff tendinopathy, although it has been described in a few textbooks. A cadaveric study comparing sonographic findings to histopathologic changes showed a significant relationship between cuff tendinopathy and thickening in 21 cadaver shoulders (N. Dahiga, MD, S. Teefey, MD, W. Middleton, MD, M. Kim, MD, and C. Hildebolt, PhD, unpublished data, 2007). The diagnosis should be considered when the cuff measures greater than 5.5 mm, based on data from a study that measured cuff thickness in 100 asymptomatic men and showed a mean thickness ± SD of 4.6 ± 0.9 mm. These authors also showed that there were no significant relationships between sex, age, and cuff thickness in the absence or presence of shoulder pain. Thus, this value can be generalized to men and women regardless of age and the presence of shoulder pain.

Sonography is very accurate for diagnosing biceps tendon subluxation, dislocation, and rupture, although it was not able to distinguish a high-grade (≥70%) partial-thickness tear from a rupture. It has low sensitivity for diagnosing tenosynovitis, tendinopathy, and low-grade partial-thickness tears.

Changes to the acromioclavicular joint such as synovitis, effusion, osteoarthritis, and osteolysis are easily diagnosed with sonography. A paralbral cyst, which is usually located in the spinoglenoid notch, can be identified with sonography and aspirated under sonographic guidance for pain relief before definitive surgery. Subdeltoid bursal disorders such as an effusion and bursitis can readily be diagnosed with sonography.

**Sonographic Technique**

Shoulder sonography is performed using a high-frequency linear array transducer. At our institution, the patient is seated on a rotatable stool. The radiologist stands behind the patient to scan; however, at other institutions, the radiologist sits and faces the patient. The biceps tendon is the first structure to be examined; the arm is slightly externally rotated with the forearm in a supinated position resting on the thigh. This positioning ensures optimal visualization of the bicipital groove. The tendon is initially examined in a transverse plane from the level where it emerges beneath the acromion to the musculotendinous junction. The transducer is gently rocked to maintain the normal echogenicity of the biceps tendon. The transducer is then rotated 90° to examine the tendon in a longitudinal plane. It is important to orient the ultrasound beam perpendicular to the long axis of the tendon to visualize the normal echogenic, fibular pattern. This process may require gently pushing the inferior aspect of the transducer against the patient’s arm to ensure that the tendon fibers are oriented perpendicular to the ultrasound beam.

The subscapularis tendon is imaged next. The patient’s arm may need to be further externally rotated to optimally visualize the tendon. The transducer is initially placed in a transverse orientation at the level of the lesser tuberosity and moved medially along the long axis of the tendon. Internal and external rotation of the arm confirms that the tendon is intact. The transducer is then turned 90° to view the tendon fibers perpendicular to their long axis. This view is useful to diagnose superior partial- or full-thickness tears.

To visualize the supraspinatus and infraspinatus tendons, the patient is asked to extend his or her arm posteriorly and place the palmar side of the hand on the superior aspect of the iliac wing with the elbow flexed and directed toward the midline of the back. When scanning the cuff tendons in their long axis, it is important to remember that the long axis of the tendons is approximately 45° between the sagittal and coronal planes. It is also important to recognize that the cuff begins within a few millimeters posterior to the intra-articular portion of the biceps tendon. This portion of the biceps tendon should be identified when scanning in the long axis to ensure that the anterior aspect of the cuff is visualized. The cuff should be evaluated from the most lateral aspect of the greater tuberosity where it inserts to as far medially as possible to ensure that more medial mid substance tears are not missed. Because the cuff assumes a convex curvilinear course as it passes over the humeral head, the transducer should be gently rocked to visualize the various portions of the cuff in a plane perpendicular to the ultrasound beam as it is moved anterior to posterior. It is also important to compress the transducer against the deltoid muscle to detect any nonretracted tears. The transducer is then turned 90° to visualize the cuff in a transverse (short-
axis) orientation. This view is useful to measure the width and determine the location of a cuff tear. Next, the posterior glenohumeral joint and the posterior aspect of the infraspinatus and teres minor tendons are evaluated from a posterior approach with the patient resting his or her forearm on the thigh. To identify the glenohumeral joint and the more posterior aspect of the infraspinatus tendon, the transducer is placed immediately below the scapular spine and angled slightly inferiorly. Internal and external rotation of the arm helps better visualize the infraspinatus attachment and the posterior cartilaginous labrum.

Finally, each of the posterior cuff muscles should be evaluated in long and short axes for fatty degeneration. The transducer is first placed superior to the scapular spine to image the supraspinatus muscle and then moved inferior to the scapular spine to visualize the infraspinatus muscle. The transducer is then moved slightly more inferiorly to visualize the teres minor muscle and its short tendon, most of which attaches to the surgical neck of the humerus.19 To visualize the entire tendon and its muscle, the transducer should be placed at the level of the surgical neck in a sagittal orientation and moved lateral to medial along the muscle.

**Figure 1.** Full-thickness cuff tear in a 74-year-old woman. A, The longitudinal image shows that the cuff is retracted medially, and the torn tendon end (T) is surrounded by fluid. B, The transverse image shows the width of the tear (between cursors).

The acromioclavicular joint can be imaged in both coronal and sagittal planes but is best evaluated when the transducer is oriented along the long axis of the clavicle. This view optimizes visualization of the joint space, synovium, capsule, and bony margins of the joint.

**Sonographic Findings of Shoulder Disorders**

Most cuff tears begin approximately 15 mm posterior to the intra-articular portion of the biceps tendon.20 There may be associated bony changes on the greater tuberosity. On sonography, a full-thickness cuff tear is characterized by a focal defect created by a variable degree of retraction between the torn tendon ends. When there is fluid between the torn tendon ends, it is easy to visualize a tear (Figure 1). In the absence of an effusion, the deltoid muscle and peribursal fat occupy the space created by the defect and oppose the overlying humeral head cartilage (Figure 2). If the subdeltoid synovial tissue is thickened and inflamed, the tissue will abut the cartilage, and on sonography, a subtle loss of the normal convexity of the cuff or flattening of the cuff will be visualized. Nonretracted tears are difficult to identify. It is important to compress the deltoid with the
transducer in an attempt to show the defect. Less often, a
tear will occur more medially within the mid substance of
the cuff; thus, it is important to evaluate the cuff where it
exits beneath the acromion to the lateral aspect of the
greater tuberosity. In a patient with a massive tear, the cuff
is often not visualized and is retracted beneath the acromion
on longitudinal views (Figure 3). Because of the size of the
tear, it is usually not possible to measure an accurate width.
These cuff tears are often chronic and most commonly
seen in elderly patients.21 Subscapularis tears are uncom-
mon and usually occur in patients with massive cuff tears or
recurrent anterior shoulder dislocation. It is important to
diagnose a subscapularis tear because it may alter the sur-
gical approach.

Partial-thickness tears can be more difficult to iden-
tify than full-thickness tears. These tears usually occur
along the deep side of the cuff at the level of anatomic
humeral neck and can be recognized as distinct hypoechoic
or mixed hyperechoic and hypoechoic defects on both lon-
gitudinal and transverse views (Figure 4).8 It is important
not to mistake anisotropy for a partial-thickness tear;
anisotropy produces a much less well-defined, uniformly
hypoechoic region in the deep portion of the cuff. By
angling the transducer such that those fibers become per-
pendicular to the ultrasound beam, normal tendon fibers
will be noted inserting onto the greater tuberosity. A partial-
thickness tear that involves more than 50% of the sub-
stance of the cuff may be compressible with the transducer
and simulate a full-thickness tear. Misdiagnosing an exten-
sive partial-thickness tear for a full-thickness tear is usually
not clinically relevant because it is often treated as if it were
a full-thickness tear. Partial-thickness tears may occur on
the bursal side of the cuff but are much less common; small
bursal-side tears are often difficult to distinguish from small
full-thickness tears because both produce a focal defect or
concavity on the bursal side of the cuff. Linear tears may
also occur within the substance of the cuff but are more dif-
cult to visualize than on MRI.

Fatty degeneration of the cuff muscles can be diag-
nosed as described by Strobel et al.22 These authors eval-
uated the visibility of the muscle contours, pennate pattern,
and central tendon and assessed the echogenicity of the
cuff muscles in comparison to the deltoid muscle to grade
the degree of fatty degeneration. When fatty degeneration
is severe, one or more muscles will become homoge-
neously hyperechoic (Figure 5). A recent study showed
that fatty degeneration of the cuff muscles is closely asso-
ciated with the tear size and location. The greater the size
of the tear, the greater the risk of fatty degeneration, and
the closer the tear begins to the intra-articular portion of
the biceps tendon, the greater the risk of fatty degenera-
tion. The mechanism for the latter may be due to disruption
of the rotator cable insertion (the anterior part of the
supraspinatus tendon is the site of the anterior cable inser-
tion), resulting in greater retraction of the tendon and sub-
sequent fatty degeneration over time.

Although little has been published on the sonographic
appearance of tendinopathy, on the basis of our observations,
it may be a focal or diffuse process; the cuff is typically thick-
ened, heterogeneous, and hypoechoic (Figure 6). Calcific
tendinitis may be diagnosed when echogenic foci of varying
size that may or may not shadow are visualized within the
substance of the tendon. The calcifications are often located
at the most lateral aspect of the greater tuberosity.

Disorders of the biceps tendon are commonly associ-
ated with rotator cuff disease and are important sources
of shoulder pain. When the biceps tendon is thickened
and hypoechoic, tendinopathy should be considered.
Tendinopathy usually occurs in patients with large chronic
cuff tears. Intrasubstance tears may also occur and appear as
linear hypoechoic defects. Tenosynovitis is often associated
with an effusion. A thickened tendon sheath with or with-
out flow on color or power Doppler imaging is diagnostic of
tenosynovitis (Figure 7). Tendon subluxation is considered
present when the tendon partially extends above a line
drawn from the lesser to the greater tuberosity and dislo-
cated when perched or medial to the lesser tuberosity. Ten-
don rupture can be diagnosed when the bicipital groove is
empty; however, a 70% or greater high-grade partial-thick-
ness tear cannot be distinguished from rupture because the
few remaining fibers are usually not visible on sonography.

The subdeltoid bursa is a potential space and normally
does not contain fluid. The presence of fluid is abnormal,
and if there is concern for infection, sonography can be
used to provide guidance for aspiration. Bursitis can be an
overlooked cause of shoulder pain. It can be diagnosed if
the subdeltoid bursa is thicker than the humeral head car-
tilage (Figure 8). Shoulder abduction with real-time obser-
vation helps distinguish the cuff from thickened bursa.

![Figure 5. Marked fatty degeneration of the supraspinatus tendon in a 70-year-old man with a full-thickness cuff tear. The longitudinal image shows a homogeneously echogenic supraspinatus muscle.](image)

![Figure 6. Marked tendinopathy in a 75-year-old man. The longitudinal image shows a hypoechoic and very thickened cuff.](image)

![Figure 7. Tenosynovitis of the biceps tendon sheath in an 81-year-old woman. The transverse image shows thickening of the biceps tendon sheath. There is increased flow of the thickened synovium on color Doppler imaging.](image)
A paralabral cyst is caused by a posterior capsulolabral avulsion or tear with subsequent leakage of fluid. It is best seen from a posterior approach; the transducer should be placed at the level of the infraspinatus muscle. These anechoic cysts typically occur in the spinoglenoid notch and may extend into the supraspinous or infraspinous fossa. It is important to evaluate the supraspinatus and infraspinatus muscles for fatty degeneration, which may occur if the supraspinal nerve (a mixed motor/sensory nerve) is compressed by the cyst.

The acromioclavicular joint may become infected or inflamed, causing the joint to distend with fluid and the capsule to bulge. The fluid is easily aspirated under sonographic guidance. A synovial cyst, which may be anechoic or contain debris on sonography, if found to communicate with the acromioclavicular joint, should prompt investigation of the rotator cuff because it is associated with a long-standing full-thickness cuff tear. Osteolysis appears as joint space widening and irregularity and erosions of the bony margins.

Conclusions

In summary, sonography is an excellent modality for diagnosing rotator cuff disease. It is preferred by patients, accurate, noninvasive, rapidly performed, and less expensive than MRI. Furthermore, it is a dynamic, global examination and can provide bilateral information. There is also the opportunity to interact with the patient and explain the results of the examination. However, it is important to recognize that the learning curve is long and steep, and results are operator dependent. It is also more difficult to visualize the entire cuff in obese patients and in patients with decreased range of motion, and evaluation of the labrum, joint capsule, ligaments, bone, and cartilage is limited.

Thus, whereas sonography and MRI have comparable accuracy for diagnosing rotator cuff disease, these tests should be viewed as complementary rather than competitive. Which test to perform should be based on the clinical information sought and the inherent strengths and weaknesses of each test.

References


Figure 8. Bursitis in a 34-year-old woman. The transverse image shows marked thickening of the subdeltoid bursa (between cursors).


DIAGNOSTIC ULTRASOUND UTILIZATION AND EDUCATION

RESOLVED, That our AMA affirms that ultrasound imaging is a safe, effective, and efficient tool when utilized by, or under the direction of, appropriately trained physicians. (New HOD Policy)

RESOLVED, That our AMA support the educational efforts and widespread integration of ultrasound throughout the continuum of medical education. (New HOD Policy)

Adopted by the American Medical Association
June 19, 2012
12 Ways YOU Can Make Ultrasound First in 2013

1. Hold a course or session on a point-of-care ultrasound application at your primary society's annual meeting.

2. Encourage the addition of ultrasound into your medical school's curriculum (alumni and professors).

3. Perform a research study to measure competence of individuals who use 1 or more point-of-care ultrasound applications.

4. Involve public officials such as mayors, governors, and state legislators. Let them help you make 2013: the Year of Ultrasound a newsworthy event in your city or state by issuing an official proclamation.

5. Write and submit an article to your primary society's journal that focuses on one clinical problem and describes the use of ultrasound, in contrast to other diagnostic tests, to solve that problem.

6. Share how ultrasound has helped the bottom line in your institution.

7. Mentor a colleague on an ultrasound application.


9. Develop and share curriculum ideas.

10. Start a journal club focusing on articles that show how ultrasound has provided early detection of an asymptomatic disease condition.

11. Share how ultrasound has been used to confirm or reject findings from a physical examination.

12. Post your stories about using ultrasound in the patient exam or screening, especially for abnormalities that would normally be delayed until symptoms are present.