Neuroradiology
Headaches are a common complaint, and the majority are due to tension or chronic migraine, which can be diagnosed clinically without the need for imaging. The prevalence of significant abnormalities found on neuroimaging studies in the setting of uncomplicated headache is <1%. Performing low yield neuroimaging studies for uncomplicated and chronic headaches increases the likelihood for false positive results, which can result in additional unnecessary work-up; unnecessary patient radiation exposure; and, contribution to national healthcare costs.

**Redflags that support imaging**

- Abnormal neurological examination (e.g. papilledema, altered mental status)
- Signs of systemic illness (e.g. fever, stiff neck, rash)
- Worst headache ever
- Progressive in frequency and severity
- New headache in patient older than 50 years (hemorrhage, intracranial mass)
- Sudden onset of headache
- New-onset headache in an immunocompromised or cancer patient
- Headache after head trauma
- Headache worsening with Valsalva
### Nontraumatic headache

<table>
<thead>
<tr>
<th>Noncontrast CT</th>
<th>MR preferred over CT</th>
<th>CTA head &amp; neck with IV contrast or MRA</th>
</tr>
</thead>
</table>
| • Sudden onset of severe headache (“thunderclap”)  
• Worst headache of life | • New headache with focal neurologic deficit or papilledema  
• Chronic headache with new features or neurologic deficit  
• Pain of trigeminal autonomic origin  
• Skull base, orbital or periorbital pain  
• Suspect complications of sinusitis  
• New headache in elderly patient  
• New headache in cancer or immunocompromised patient  
• New headache, suspect meningitis, encephalitis  
• Positional headache (MRI >> CT)  
• Headache exacerbated by cough or exertion  
• New headache in pregnant patient (no contrast) | • Sudden onset unilateral headache  
• Suspect carotid or vertebral artery dissection  
• Ipsilateral Horner syndrome |

### Traumatic headache

- CT without contrast most appropriate in acute setting
- For suspected diffuse axonal injury or subacute trauma, include GRE sequences

### References:
American Academy of Neurology:  
https://www.aan.com/Guidelines/Home/ByTopic?topicId=16  
American College of Radiology:  
https://acsearch.acr.org/docs/69482/Narrative/
Recommended imaging for neck and cervical pain differs between the evaluation of acute spinal trauma and that of chronic neck pain. In many cases, it may be safe to defer imaging for traumatic neck pain if the patient is low risk by NEXUS criteria (summarized below) or by the Canadian cervical spine rule. Contrary to often common clinical practice, a cervical spine x-ray is not the best imaging modality in suspected acute cervical spine trauma in adults and children over age 14, and should only be used as a preliminary assessment if it is not immediately possible to perform a CT scan or if a CT scan is nondiagnostic due to artifacts. In contrast, plain radiographs are almost always first line in the evaluation of chronic neck pain.

**Suspected Spine Trauma**

NEXUS cervical spine rule. Imaging can safely not be performed if **ALL** the following criteria are present:
1. There is no posterior midline cervical tenderness.
2. The patient has no focal neurologic deficit.
3. The patient is fully alert.
4. There is no evidence of intoxication.
5. There are no painful distracting injuries.

**Red flags that support imaging:**

- Altered mental status
- Age greater than 65
- Multiple fractures
- Significant head or facial trauma
- Neurologic deficits
- High-risk injury including fall from greater than 3 feet, axial load to the head, or high speed motor vehicle collision
First line imaging test for adults and children 14 and older when imaging is indicated: **CT cervical spine without IV contrast**, thin-sections with sagittal and coronal reconstructions

For children younger than 14: **Cervical spine AP, lateral and open-mouth radiographs.**

**MRI of the cervical spine** may be useful if there is a need for more thorough evaluation of ligamentous injury or if there is concern for cord compression due to disk protrusion or hematoma.

**Chronic Neck Pain**

For almost all cases of chronic neck pain, including patients with prior history of trauma, history of malignancy or prior spinal surgery, the first imaging test should be **cervical spine AP and lateral radiographs.**

When radiographs are normal:
- If no neurologic signs or symptoms are present, no additional imaging is likely needed.
- If the patient has neurologic signs or symptoms, then order an **MRI cervical spine without IV contrast.**

**References:**
Patients with Transient Ischemic Attack (TIA) are at high risk for future stroke and other adverse events. The greatest risk is soon after a TIA; 5 percent of patients return within 48 hours with stroke, and 25 percent return within 90 days with adverse events including stroke, cardiovascular events, death or recurrent TIA.

According to the American Stroke Association, TIA is a “transient episode of neurological dysfunction caused by focal brain, spinal cord or retinal ischemia, without acute infarction.” This new tissue-based diagnosis relies on imaging to determine the presence of infarct or ischemia, rather than symptom duration. Patients with suspected TIA require immediate imaging due to the imminent risk of future stroke and to confirm the diagnosis.

**Preferred initial urgent imaging:**
- MRI head with and without IV gadolinium contrast (unless contrast contraindicated) AND
- MRA head and neck with and without IV contrast

**Alternative urgent imaging if MRI is contraindicated or unavailable:**
- CT head without IV contrast
- CT head and neck with IV iodinated contrast
- Lower yield: CT head perfusion with IV contrast

MRI is more sensitive than CT for acute ischemic infarct, but CT is often more readily available in emergent situation.
Alternative neck vessel imaging if iodinated or gadolinium contrast is contraindicated:
- Carotid duplex Doppler ultrasound

Acute onset focal neurological deficit

Often when a patient presents with acute onset focal neurological deficit, it is not initially clear whether this represents a TIA or stroke. In this case, stroke must be suspected and imaging is required to determine: hemorrhagic versus ischemic process, infarction versus ischemia, and small versus large vessel. Therapeutic options include intravenous tPA or endovascular therapy. Therapy selection depends on the duration of symptoms, as well as which vessel is affected. A suggested algorithm for initial imaging selection is below.

References:
**Suspected stroke**
CT head without contrast
*Assess for ischemic versus hemorrhagic process*

- Hemorrhagic stroke
- Ischemic stroke

**<6 hours since symptom onset**
CT head & neck with IV contrast (immediately after head CT)
- Assess for small versus large vessel
- Large vessels such as distal ICA and proximal MCA may respond better to endovascular recanalization procedures than to IV tPA.
- Endovascular recanalization may be beneficial ≤6 hours after symptom onset.

If available and timely, MRI head with and without IV contrast + MRA head and neck with and without IV contrast.

**>6 hours since symptom onset**
MRI head with and without IV contrast
MRA head and neck with and without IV contrast
- Assess for infarction versus ischemia.
- MR is more sensitive for acute infarct than CT.
Vertigo is a common symptom and can have a variety of etiologies ranging from benign pathologies such as benign positional paroxysmal vertigo (BPPV) and labyrinthitis, to more concerning diseases such as stroke or cerebellopontine angle tumors. Not uncommonly, vertigo may also be a side effect of a medication. Vertigo can be classified as peripheral or central depending on whether the origin of vertigo is the inner ear or central neurologic pathways in the brainstem or cerebellum. Symptoms that favor a peripheral etiology of vertigo include auditory neurologic symptoms such as hearing loss and tinnitus, whereas findings such as nonfatigable nystagmus favor more central etiologies. Regardless of the etiology, MRI is typically the best modality when imaging is indicated.

**When to image?**

Red flags that favor imaging:
1. Presence of nonauditory neurologic deficits
2. Strong risk factors for cerebrovascular disease
3. Hearing loss that is progressive and asymmetric
4. Asymmetric cerebellar findings
5. Suggestion of a central cause for vertigo without clear etiology

Imaging is not needed when there is a typical history for a peripheral cause of vertigo such as:
- **BPPV:** Episodic vertigo, <1 minute in duration, brought on by head movement, without additional neurologic symptoms
- **Vestibular neuritis or labyrinthitis:** Post-viral, acute onset, with only peripheral symptoms and gradual improvement after 24-72 hours
What test to order?

Regardless of suspicion for peripheral or central etiology, for episodic or persistent vertigo, if imaging is indicated the best test is **MRI head and internal auditory canal without and with IV contrast.**

MRI is preferred over CT due to its superiority in visualizing the posterior fossa, which is often the location for a central etiology of vertigo. MRI will rule out acute and chronic ischemic disease, cerebellopontine lesions such as vestibular schwannomas and meningiomas, as well as multiple sclerosis.

Alternative tests include:

- MRA or CTA of the head and neck if a vascular etiology such as dissection or vascular insufficiency is suspected
- Noncontrast CT as a triage study to rule out stroke
- CT of the temporal bone without contrast if semicircular canal fistula or a specific bony abnormality is suspected

**References:**
Abdominopelvic
ORDERING FOR
BODY CT IMAGING

NONCONTRAST

Chest
• Lung nodule follow up
• Coronary calcium screening
• Fever in immunocompromised patient
• Lung cancer screening
• Neutropenic fever
• Interstitial lung disease

Abdomen/Pelvis (no IV or oral)
• Renal calculus
  (limited for other diagnoses)
• Neutropenic fever
• Retroperitoneal bleed (prefer IV)

*At Johns Hopkins Medical Imaging, radiologists may modify the protocol after reviewing the clinical history in EPIC.
**WITH IV ONLY**

**Chest with IV**
- Suspect lung cancer
- Atelectasis on CXR
- Mediastinal abnormality (mass, adenopathy)
- Pleural/chest wall abnormality

**Abdomen/Pelvis with IV & oral contrast (positive oral contrast or water depending on protocol)**
- Abdominal or pelvic abscess
- Appendicitis (RLQ pain/Crohn’s/IBD)
- Diverticulitis (LLQ pain/Crohn’s/IBD)
- Generalized abdominal pain (or any quadrant)
- Jaundice/pancreatic cancer/cyst
- Suspect malignancy or staging known malignancy (except GU)
- Pancreatitis
- SBO vs ileus

**Abdomen/Pelvis with IV, but NO oral contrast**
- Mesenteric ischemia
- High-grade small bowel obstruction
- Pyelonephritis

**WITH AND W/O IV**

**Chest with and without IV**
- Coronary CTA

**Abdomen/Pelvis with and without IV (no oral for any of these)**
- S/P aortoiliac stent
- Adrenal nodule work-up
- Gastrointestinal bleed
- Renal lesion/hydronephrosis/hematuria

**References:**
Premenopausal women with acute pelvic pain often present with nonspecific signs and symptoms such as nausea, vomiting and leukocytosis, which often make it challenging to diagnose. The differential considerations include those that are gynecological (pelvic inflammatory disease, ovarian torsion, ectopic pregnancy) and nongynecological (appendicitis, inflammatory bowel disease, diverticulitis, urolithiasis, pyelonephritis). The choice of imaging modality is determined by the most likely, clinically suspected differential diagnosis.

**Serum β-hCG**

This is the first step for menstruating females with acute pelvic pain. Knowledge of pregnancy will determine whether pregnancy-related cause of pain, especially ectopic pregnancy, should be considered. Pregnancy status also affects choice of imaging, due to concerns for fetal exposure to ionizing radiation (computed tomography—CT) and gadolinium (MRI contrast).

When β-hCG levels are > 1,000-2,000, transvaginal ultrasound can usually identify an intrauterine pregnancy.

**Gynecologic Etiology of Pain**

If gynecologic etiology of pain is suspected, pelvic ultrasound (US) is the first-line imaging study. US is useful in differentiating between hemorrhagic cyst or pelvic inflammatory disease, which can most often be treated medically, and ovarian torsion, ectopic pregnancy or placental abruption, which are surgical emergencies.
If US is inconclusive, MRI can be helpful to evaluate for nonemergent pathologies such as endometriosis or adenomyosis, and to further characterize adnexal masses. CT does not provide the anatomic detail for the ovaries and uterus that MRI provides.

**Nongynecological Etiology of Pain in Nonpregnant Patients**

CT with IV contrast is best for identifying gastrointestinal and urinary tract causes of acute pelvic pain such as appendicitis, inflammatory bowel disease, diverticulitis, colitis and obstructive uropathy.

**References:**
1. American College of Radiology: https://acsearch.acr.org/docs/69503/Narrative/
3. ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation: www.acr.org/~/media/ACR/Documents/PGTS/guidelines/Pregnant_Patients.pdf?la=en
Cardiothoracic
SUSPECTED PULMONARY EMBOLISM
IMAGING APPROPRIATENESS

Over 290,000 cases of fatal pulmonary thromboembolism (PE) and 230,000 cases of nonfatal PE are estimated to occur in the United States each year. PE can be a severe disease and often difficult to diagnose given its nonspecific signs and symptoms. Because of this, testing patients with suspected PE has increased dramatically. However, the overuse of some tests, particularly computed tomography (CT) and plasma D-dimer, may not improve care and may potentially lead to patient harm and unnecessary expense. Thus, current guidelines recommend using a clinical decision tree, most notably Wells criteria, in conjunction with imaging and serum assay for D-dimer.

Overview of Imaging Modalities

- Chest radiography – Important initial study. May eliminate the need for additional radiographic procedures by revealing an alternate reason for acute symptoms.
- Multidetector CT pulmonary angiography (CTPA) – Primary imaging modality for diagnosis. Has a high sensitivity and specificity for PE.
- Ventilation and perfusion imaging (V/Q scan) – Second choice modality. May be useful if unable to get CTPA and/or contraindication to CTPA.
- Lower extremity duplex ultrasonography – Because of the high association of deep vein thrombosis (DVT) and PE, may be useful especially for patients who also have signs and symptoms of DVT. The presence of DVT, whether or not associated with PE, has identical treatment. This is especially useful for patients with contraindications to CTPA.
Imaging Modalities by Clinical Scenario

• Low pretest probability – Generally, no imaging or D-dimer assay is necessary.
• Intermediate pretest probability –
  o For intermediate clinical probability with negative D-dimer, no further imaging is necessary.
  o For intermediate clinical probability with positive D-dimer, then CTPA is indicated.
• High pretest probability – If high pretest probability, then proceed directly to CTPA. D-dimer assay is not necessary.
• Pregnant patient – The modality of choice (CTPA versus V/Q scan) has been a matter of debate. American College of Radiology appropriateness criteria recommend lower extremity duplex ultrasonography and radiograph as initial imaging tests.

References:
1. American College of Radiology - https://acsearch.acr.org/docs/69404/Narrative/
Screening
In 2008, the American Cancer Society, American College of Radiology and the U.S. Multi-Society Task Force on Colorectal Cancer (including the American Gastroenterological Association, American College of Gastroenterology and American Society for Gastrointestinal Endoscopy) issued joint recommendations regarding screening modalities to detect and prevent CRC, of which CTC was included. Optical colonoscopy remains the gold-standard tool for CRC screening, however, health care providers should be aware of clinical situations in which CTC is appropriate for screening while being knowledgeable of the test’s risks/limitations.

**CTC Technique**

- Prior, adequate colonic prep with cathartic tagging agents
- Insufflation of the colon via a pressure-regulated device inserted a short distance into the rectum with carbon dioxide or room air

**Indications for CTC**

- Colon cancer screening in average risk patients ≥ 50 years of age
- Follow-up of an incomplete conventional colonoscopy
- Evaluation of nonvisualized colon proximal to an obstructing mass detected on conventional colonoscopy
- Patient refusal of conventional colonoscopy
- Situations in which conventional colonoscopy is contraindicated:
  - High bleeding risk
  - High sedation risk
Risks/Limitations of CTC

- Not indicated for high risk patients (e.g., patients with familial colon cancer syndromes, Crohn’s disease or ulcerative colitis)
- Perforation risk (i.e., recent large colonic biopsy or polypectomy); incidence <1:10,000
- Radiation exposure (low dose studies available)

<table>
<thead>
<tr>
<th>Modality</th>
<th>Frequency</th>
<th>Effect on CRC mortality</th>
<th>Benefits</th>
<th>Risks/limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional colonoscopy</td>
<td>Every 10 years</td>
<td>60 to 70 percent on left colon; uncertain effect on right colon</td>
<td>Gold standard</td>
<td>Bleeding, Sedation, Perforation</td>
</tr>
<tr>
<td>Flexible sigmoidoscopy</td>
<td>Every 5 years (w/ HS-FOBT every three years)</td>
<td>50 percent on left colon; 25 percent total</td>
<td>Safer and more expedient than colonoscopy</td>
<td>Incomplete colonic visualization</td>
</tr>
<tr>
<td>CT colonography</td>
<td>Every 5 years</td>
<td>Undetermined</td>
<td>Less invasive, No sedation</td>
<td>Perforation, Radiation exposure</td>
</tr>
<tr>
<td>HS-FOBT</td>
<td>Annual</td>
<td>None</td>
<td>Noninvasive</td>
<td>No effect on CRC mortality</td>
</tr>
</tbody>
</table>

References:
Breast Imaging
Breast pain or tenderness occurs in 70 to 80 percent of women during their lifetime. It is not a common symptom of underlying malignancy. Breast imaging often provides reassurance if negative, but it may also lead to further clinical and imaging evaluation. Nevertheless, a persistent or focal area of pain or tenderness is an indication for imaging according to the American College of Radiology (ACR) practice guidelines. Imaging recommendations under these circumstances focus on non-high-risk patients assumed to have appropriate routine screening mammography according to the ACR guidelines.

**Nonbreast Cancer Causes**

Hormonal medicines; selective serotonin reuptake inhibitors; psychological causes; duct ectasia with periductal inflammation; mastitis or breast abscess; trauma; surgery or implants; pregnancy and breast-feeding; thelarche; nerve irritation; musculoskeletal causes; coronary, pulmonary, esophageal, gallbladder pathology.

**Breast Cancer Causes**

Advanced breast cancer with significant tissue invasion; invasive lobular carcinoma; anaplastic carcinoma; adenoid cystic carcinoma.

**Types of Breast Pain**

**Cyclical** (most common, diffuse, unilateral or bilateral, third decade)—sensitivity to normal hormonal levels, these women undergo more frequent breast investigations.
Noncyclical (25 percent, focal, unilateral, fourth decade)—inflammatory, may need evaluation to exclude malignancy

**Summary Recommendations**

1. Women with cyclical and/or bilateral nonfocal pain or tenderness usually do not require nonroutine imaging.
2. Women with noncyclical, unilateral or focal breast pain that is not extramammary in origin may benefit from imaging to exclude breast cancer, determine benign but treatable etiology, or to offer reassurance that there is no causative abnormality.
   - Ultrasound in symptomatic women < 30, or pregnant or lactating women.
   - Diagnostic mammography (DM) or digital breast tomosynthesis (DBT) (unilateral or bilateral) may be added to ultrasound in symptomatic women age 30 to 39, or symptomatic women < 30 with suspicious ultrasound, at the radiologist’s discretion.
   - DM or DBT and ultrasound in symptomatic women 40 and older, or in any patient qualifying for mammography, based on risk factors and the date of the last mammogram.
3. There is no evidence to suggest that breast MRI or nuclear imaging (molecular breast imaging or positron emission mammography) meet risk/benefit or cost-effectiveness criteria to be used in the work-up of breast pain or tenderness.

**References:**

PALPABLE BREAST MASSES
IMAGING APPROPRIATENESS CRITERIA

Most palpable lumps are benign, but a new palpable breast mass is a common presenting sign of breast cancer. Imaging evaluation is necessary in almost all cases to characterize the palpable lesion. Recommended imaging options include diagnostic mammography and targeted breast ultrasound, and are dependent on patient age and degree of radiologic suspicion. Any highly suspicious mass detected by imaging or palpation should undergo image-guided core biopsy (ultrasound guided, stereotactic, or digital breast tomosynthesis guided) unless contraindicated.

Mammography and Digital Breast Tomosynthesis

Diagnostic mammography (DM) is indicated for women age 40 or over who are presenting with a palpable lump. If a clearly benign correlate for a palpable finding (oil cyst, lipoma, etc.) can be identified on DM, this modality alone may be sufficient, and clinical follow-up would be appropriate. If DM is negative or an imaging correlate is identified that is not clearly benign, multimodality imaging is usually indicated in this age group, with targeted ultrasound (US) directed to the palpable finding. Digital breast tomosynthesis (DBT) can address some of the limitations encountered with standard DM views. DM or DBT may also be helpful in women ages 30 to 39 with palpable lumps and in women younger than 30 with palpable lumps and suspicious findings on US.

Ultrasound

US is recommended as the first line investigation for a palpable lump in women under age 30, and in pregnant and lactating women. In the
event of a suspicious finding on ultrasound, DM or DBT is warranted even in younger women in order to better delineate disease and identify features of malignancy that may be seen on DM or DBT alone. US can be used as the initial means of image evaluation for women age 30 to 39 with a palpable breast mass, although DM or DBT may also be appropriate in this age group. US is also an essential next step in evaluating women ≥40 years with a palpable mass and either a negative DM or a finding not unequivocally characterized as benign on DM or DBT.

Summary Recommendations

1. DM or DBT initially for women age 40 or older, followed by targeted US as needed
   - Suspicious or negative findings → US
   - Probably benign findings → US, or mammography/DBT short interval follow-up

2. US initially for women younger than age 30 years, pregnant or lactating
   - Suspicious findings → biopsy > diagnostic mammography or DBT
   - Probably benign findings → US short term follow-up
   - Negative findings → clinical follow up, DM or DBT rarely helpful

3. US or DM or DBT initially for women aged 30 to 39 years → next steps as above

4. Any highly suspicious breast mass detected by imaging should have core biopsy, irrespective of palpable findings.

5. Any highly suspicious breast mass detected by palpation should be biopsied, irrespective of imaging findings.

References:
Screening mammography allows the detection of early, clinically occult cancers. Most lesions detected on screening mammograms are benign. Lesions that are concerning include masses, focal asymmetries, architectural distortion and grouped calcifications. Diagnostic mammography and/or ultrasound is necessary for further evaluation.

**Summary Recommendations**

- **Architectural distortion seen on screening mammogram** → diagnostic mammogram
- **Mass (indistinct, obscured or microlobulated margins) seen on screening mammogram** → diagnostic mammogram and then ultrasound
- **Mass (circumscribed without suspicious features) seen on screening mammogram** → ultrasound (diagnostic mammogram may also be needed)
- **Multiple bilateral nonsuspicious masses seen on screening mammogram** → return to screening mammography
- **Multiple bilateral masses seen on screening mammogram with dominant or suspicious mass** → diagnostic mammogram and ultrasound
- **Focal asymmetry or asymmetry (single-view finding) seen on screening mammogram** → diagnostic mammogram, possibly with ultrasound
- **Grouped calcifications** → diagnostic mammogram with magnification views
Ultrasound

Ultrasound (US) can be used to differentiate cystic from solid masses. Round or oval masses with circumscribed, obscured, indistinct or microlobulated margins can be further investigated with US for more characterization. US is not required for evaluation of suspicious or likely malignant mammographic findings, although it may be used to guide needle biopsy. US can also evaluate architectural distortions found on mammography. Negative US evaluation of suspicious mammographic findings should not dissuade the decision to biopsy.

Magnetic Resonance Imaging

MRI evaluation of nonpalpable noncalcified mammographic lesions is controversial and should not be used when established methods can confidently evaluate a finding. MRI is not indicated for evaluating the majority of mammographic findings. MRI may be used in evaluating asymmetries and questionable architectural distortions when diagnostic mammography is inconclusive and there is no US correlate or definitive target for biopsy.

Biopsy

Final assessment of mammographically detected suspicious lesions should be assigned according to the ACR BI-RADS Atlas. If a lesion is Breast Imaging, Reporting and Data System (BI-RADS) category 4 or 5, a percutaneous core biopsy is warranted, with either mammographic or US guidance. Percutaneous biopsy should be done to shorten the diagnostic process and/or provide a more cost-effective method of diagnosis as compared with excisional biopsy. Percutaneous biopsy of suspicious lesions can provide accurate tissue diagnosis at decreased cost, precluding the need for surgery in specific benign cases and allow definitive single-stage surgical treatment in cases that are as malignant.

References:
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6420 Rockledge Drive, Suite 3100
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