American College of Radiology
ACR Appropriateness Criteria®
Cervical Neck Pain or Cervical Radiculopathy

Variant 1: **New or increasing nontraumatic cervical or neck pain. No "red flags." Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography cervical spine	Usually Appropriate	☢☢
MRI cervical spine without IV contrast	May Be Appropriate (Disagreement)	O
CT cervical spine without IV contrast	May Be Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢

Variant 2: **New or increasing nontraumatic cervical radiculopathy. No "red flags." Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	Usually Appropriate	O
CT cervical spine without IV contrast	May Be Appropriate	☢☢☢
Radiography cervical spine	May Be Appropriate (Disagreement)	☢☢
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢

<u>Variant 3:</u> **Prior cervical spine surgery. New or increasing nontraumatic cervical or neck pain or radiculopathy. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography cervical spine	Usually Appropriate	☢☢
CT cervical spine without IV contrast	Usually Appropriate	☢☢☢
MRI cervical spine without and with IV contrast	May Be Appropriate (Disagreement)	O
MRI cervical spine without IV contrast	May Be Appropriate (Disagreement)	O
CT myelography cervical spine	May Be Appropriate	☢☢☢☢
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
MRI cervical spine with IV contrast	Usually Not Appropriate	O
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢

Variant 4: **Suspicion for infection with new or increasing nontraumatic cervical or neck pain or radiculopathy. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without and with IV contrast	Usually Appropriate	O
CT cervical spine with IV contrast	May Be Appropriate	☢☢☢
MRI cervical spine without IV contrast	May Be Appropriate	O
CT cervical spine without IV contrast	May Be Appropriate (Disagreement)	☢☢☢
MRI cervical spine with IV contrast	May Be Appropriate (Disagreement)	O
Radiography cervical spine	May Be Appropriate (Disagreement)	☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
Gallium scan whole body	Usually Not Appropriate	☢☢☢☢
WBC scan whole body	Usually Not Appropriate	☢☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢

Variant 5: **Known malignancy. New or increasing nontraumatic cervical or neck pain or radiculopathy. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without and with IV contrast	Usually Appropriate	O
MRI cervical spine without IV contrast	Usually Appropriate	O
Radiography cervical spine	May Be Appropriate	☢☢
CT cervical spine with IV contrast	May Be Appropriate (Disagreement)	☢☢☢
CT cervical spine without IV contrast	May Be Appropriate (Disagreement)	☢☢☢
MRI cervical spine with IV contrast	May Be Appropriate (Disagreement)	O
Bone scan whole body with SPECT or SPECT/CT neck	May Be Appropriate	☢☢☢
FDG PET/CT whole body	Usually Not Appropriate	☢☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Fluoride PET/CT whole body	Usually Not Appropriate	☢☢☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢

Variant 6: **Cervicogenic headache and new or increasing nontraumatic cervical or neck pain. No neurologic deficit. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	May Be Appropriate (Disagreement)	O
Radiography cervical spine	May Be Appropriate	☢☢
CT cervical spine without IV contrast	May Be Appropriate	☢☢☢
Facet injection/medial branch block cervical spine	May Be Appropriate	☢☢
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢

Variant 7: **Chronic cervical or neck pain. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography cervical spine	Usually Appropriate	☢☢
MRI cervical spine without IV contrast	May Be Appropriate (Disagreement)	O
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT myelography cervical spine	Usually Not Appropriate	☢☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢

<u>Variant 8:</u> **Chronic cervical or neck pain. No neurologic findings. Radiographs show degenerative changes. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI cervical spine without IV contrast	Usually Appropriate	O
CT cervical spine without IV contrast	May Be Appropriate	☢☢☢
CT myelography cervical spine	May Be Appropriate	☢☢☢☢
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢
MRI cervical spine with IV contrast	Usually Not Appropriate	O
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢

Variant 9: **Chronic cervical or neck pain without or with radiculopathy. Radiographs show ossification in the posterior longitudinal ligament (OPLL). Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
CT cervical spine without IV contrast	Usually Appropriate	☢☢☢
CT myelography cervical spine	May Be Appropriate (Disagreement)	☢☢☢☢
MRI cervical spine without IV contrast	May Be Appropriate (Disagreement)	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
Radiographic myelography cervical spine	Usually Not Appropriate	☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA neck with IV contrast	Usually Not Appropriate	☢☢☢
Discography cervical spine	Usually Not Appropriate	☢☢
Facet injection/medial branch block cervical spine	Usually Not Appropriate	☢☢
MRA neck with IV contrast	Usually Not Appropriate	O
MRA neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
Bone scan whole body with SPECT or SPECT/CT neck	Usually Not Appropriate	☢☢☢

CERVICAL NECK PAIN OR CERVICAL RADICULOPATHY

Expert Panel on Neurological Imaging: Marin A. McDonald, MD, PhD[a]; Claudia F. E. Kirsch, MD[b]; Beejal Y. Amin, MD[c]; Joseph M. Aulino, MD[d]; Angela M. Bell, MD[e]; R. Carter Cassidy, MD[f]; Santanu Chakraborty, MBBS, MSc[g]; Asim F. Choudhri, MD[h]; Seth Gemme, MD[i]; Ryan K. Lee, MD, MRMD, MBA[j]; Michael D. Luttrull, MD[k]; Darlene F. Metter, MD[l]; Toshio Moritani, MD, PhD[m]; Charles Reitman, MD[n]; Lubdha M. Shah, MD[o]; Aseem Sharma, MD[p]; Robert Y. Shih, MD[q]; Laura A. Snyder, MD[r]; Sophia C. Symko, MD, MS[s]; Ralf Thiele, MD[t]; Julie Bykowski, MD.[u]

Summary of Literature Review

Introduction/Background

The physical, psychological, and socioeconomic impact of cervical or neck pain is extensive. In 2010, 16.3 million health care visits to hospitals and physician offices were related primarily to neck pain [1]. The Global Burden of Disease 2010 Study identified neck pain as the fourth leading cause of years lost to disability [2], with most epidemiological studies reporting an annual prevalence ranging between 15% and 50% [3-8]. Although most episodes resolve, nearly 50% of individuals continue to experience ongoing or recurrent pain [9].

The differential diagnosis of cervical or neck pain includes consideration of acute versus chronic, neuropathic versus nonneuropathic [10], and musculoskeletal versus nonmusculoskeletal processes. It is important to acknowledge overlap of symptoms of cervical or neck pain, and cervical radiculopathy with additional conditions and symptoms beyond the scope of this document. Imaging in the setting of spine trauma should be guided by the ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [11]. The presence of a neck mass or lymphadenopathy should be guided by the ACR Appropriateness Criteria® topic on "Neck Mass/Adenopathy" [12]. Neuropathic symptoms should be clarified by examination to exclude myelopathy or plexopathy, guided by the ACR Appropriateness Criteria® topic on "Myelopathy" [13] and ACR Appropriateness Criteria® topic on "Plexopathy" [14], respectively. Evaluation of cervicogenic headache may overlap with symptoms addressed in the ACR Appropriateness Criteria® topic on "Headache" [15]. The presence of clinical signs or symptoms suggesting meningitis, neck soft-tissue infection, or upper respiratory infection should be managed on clinical guidelines separate from this review of cervical neck pain.

Mechanical pain associated with facet joints, intervertebral discs, muscles, or fascia represents the majority of nontraumatic cervical or neck pain, with the acknowledgement that these may result from or accelerate in the setting of prior traumatic injury. Cervical neuropathic pain most commonly includes radicular symptoms from a herniated disc or osteophyte. Additional etiologies include tumor, infection, inflammation, and vascular causes; therefore, consideration of the patient's medical history is critical to accurately guide imaging.

In low back pain, a system of "red flags" was adopted to aid clinicians in triaging patients seeking nonemergent care (see the ACR Appropriateness Criteria® topic on "Low Back Pain" [16]). Although the diagnostic accuracy of red flag symptoms is not validated for the cervical spine, the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders [1] recommended the adoption of a similar system for cervical and neck pain, with red flags of that include trauma, malignancy, prior neck surgery, spinal cord injury, systemic diseases including ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, inflammatory arthritis, and/or suspected infection, history of intravenous drug use, intractable pain despite therapy, or tenderness to palpation over a

[a]Research Author, UC San Diego Health Center, San Diego, California. [b]Panel Chair, Northwell Heath, Zucker Hofstra School of Medicine at Northwell, Manhasset, New York. [c]Loyola University Medical Center, Maywood, Illinois; neurosurgical consultant. [d]Vanderbilt University Medical Center, Nashville, Tennessee. [e]Rush University Medical Center, Chicago, Illinois; American College of Physicians. [f]UK Healthcare Spine and Total Joint Service, Lexington, Kentucky; American Academy of Orthopaedic Surgeons. [g]Ottawa Hospital Research Institute and the Department of Radiology, The University of Ottawa, Ottawa, Ontario, Canada; Canadian Association of Radiologists. [h]Le Bonheur Children's Hospital, University of Tennessee Health Science Center, Memphis, Tennessee. [i]Baystate Medical Center, Springfield, Massachusetts; American College of Emergency Physicians. [j]Einstein Healthcare Network, Philadelphia, Pennsylvania. [k]The Ohio State University Wexner Medical Center, Columbus, Ohio. [l]UT Health San Antonio, San Antonio, Texas. [m]University of Michigan, Ann Arbor, Michigan. [n]Medical University of South Carolina, Charleston, South Carolina; North American Spine Society. [o]University of Utah, Salt Lake City, Utah. [p]Mallinckrodt Institute of Radiology, Saint Louis, Missouri. [q]Walter Reed National Military Medical Center, Bethesda, Maryland. [r]Barrow Neurological Institute, Phoenix, Arizona; neurosurgical consultant. [s]Neuroradiology Consultant, Denver, Colorado. [t]University of Rochester School of Medicine and Dentistry, Rochester, New York, American College of Rheumatology. [u]Specialty Chair, UC San Diego Health Center, San Diego, California.

Reprint requests to: publications@acr.org

vertebral body. Additional proposed red flags include congenital findings, concomitant vascular disease in patients >50 years of age, abnormal labs (erythrocyte sedimentation rate, C-reactive protein level, white blood cell), and neurological deficits [10].

Special Imaging Considerations

CT myelography has supplanted fluoroscopic myelography in most circumstances; however, there may be times when fluoroscopic myelography is also performed prior to CT imaging. For this document, the procedure term "CT myelography" is used to guide referral to the radiologist. The ultimate judgment regarding the appropriateness of any specific procedure—lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage—must be made by the radiologist, with appropriate documentation and coding [17].

Discussion of Procedures by Variant

Variant 1: New or increasing nontraumatic cervical or neck pain. No "red flags." Initial imaging.

Similar to low back pain, many cases of acute (<6 weeks' duration) cervical or neck pain resolve, although nearly 50% of patients may continue to have residual or recurrent episodes of pain up to 1 year after initial presentation [18,19]. Factors associated with poor prognosis include female gender, older age, coexisting psychosocial pathology, and radicular symptoms [1], although the causation versus association of these relationships is not defined.

In absence of red flag symptoms, imaging may not be required at the time of initial presentation [1] as spondylotic changes are commonly identified on radiographs and MRI in patients >30 years of age and correlate poorly with the presence of neck pain [20-23]. Although the diagnostic accuracy of red flag symptoms is not validated for the cervical spine, the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders [1] recommended the adoption of a similar system for cervical and neck pain, with red flags including trauma, malignancy, prior neck surgery, spinal cord injury, systemic diseases—including ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, inflammatory arthritis—suspected infection, history of intravenous drug use, intractable pain despite therapy, or tenderness to palpation over a vertebral body. Additional proposed red flags include congenital findings, concomitant vascular disease in patients >50 years of age, abnormal labs (erythrocyte sedimentation rate, C-reactive protein level, white blood cell), and neurological deficits [10].

CT Cervical Spine

CT offers superior depiction of cortical bone and is more sensitive than radiographs in assessing facet degenerative disease, osteophyte formation, vacuum phenomenon, and joint capsular calcification [24]. Ultra-low-dose techniques are proposed for CT in other regions of the body [25]; however, currently this has not been directly compared to radiographs for evaluation of the neck and cervical spine.

CT Myelography Cervical Spine

In the absence of radiographic abnormalities or neurological symptoms, myelography is not an appropriate first-line imaging test.

CTA Neck

The literature search did not identify any studies regarding the use of CT angiography (CTA) in the evaluation of this clinical presentation.

Percutaneous Interventions

The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

MRA Neck

The literature search did not identify any studies regarding the use of MR angiography (MRA) in the evaluation of this clinical presentation.

MRI Cervical Spine

MRI is the most sensitive test for detecting soft abnormalities associated with neck pain; however, this is characterized by a high rate of abnormalities in asymptomatic individuals [22,23]. As such, MRI is not considered a first-line imaging modality in the setting of acute or worsening uncomplicated neck pain.

Bone Scan Whole Body with SPECT or SPECT/CT Neck
There is no current role for nuclear medicine studies as the initial examination in this scenario. Tc-99m bone scan lacks both resolution and specificity in detecting pathology related to acute or worsening neck pain in the absence of red flag symptoms; most commonly, these will be associated with degenerative spondylosis. A recent retrospective study of patients with nonconclusive MRI or CT findings demonstrated that hybrid single-photon emission computed tomography (SPECT)/CT imaging identified potential pain generators in 92% of cervical spine scans [26]; however, this is not a first-line examination.

Radiography Cervical Spine
Radiographs are widely accessible and useful to diagnose spondylosis, degenerative disc disease, malalignment, or spinal canal stenosis. Flexion/extension radiographs have limited value in degenerative disease [27]. In the absence of red flag symptoms, therapy is rarely altered by radiographic findings [27-29].

Myelography Cervical Spine
In the absence of radiographic abnormalities or neurological symptoms, myelography is not an appropriate first-line imaging test.

Variant 2: New or increasing nontraumatic cervical radiculopathy. No "red flags." Initial imaging.

Cervical radiculopathy is defined as a syndrome of pain or sensorimotor deficits that are due to dysfunction of a cervical spinal nerve, the roots of the nerve, or both. The most common clinical presentation is of the combination of neck pain with pain in one arm accompanied by varying degrees of sensory or motor function loss in the affected nerve-root distribution [30]. Cervical radiculopathy is less prevalent than cervical or neck pain, with one population-based study showing an average annual age-adjusted incidence of 83.2 per 100,000 people [31]. Radiculopathies may result from compressive causes related to narrowing of the neural foramina, such as by facet or uncovertebral joint hypertrophy, or from associated disc bulging or herniation and degenerative spondylosis in the absence of a history of diabetes or red flag symptoms [31]. A recent meta-analysis assessing the positive predictive value of physical examination tests in the setting of a clinical history of cervical radiculopathy concluded there was limited evidence for a correlation between physical examination findings and MRI evidence of cervical nerve root compression [32]. This may be due to a high rate of both false-positive and false-negative findings on MRI in the setting of suspected cervical radiculopathy [33]. Most cases of acute cervical neck pain with radicular symptoms resolve spontaneously or with conservative treatment measures [31,34].

In absence of red flag symptoms, imaging may not be required at time of initial presentation [1] as spondylotic changes are commonly identified on radiographs and MRI in patients >30 years of age and correlate poorly with the presence of neck pain [20-23]. Although the diagnostic accuracy of red flag symptoms is not validated for the cervical spine, the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders [1] recommended the adoption of a similar system for cervical and neck pain, with red flags that include trauma, malignancy, prior neck surgery, spinal cord injury, systemic diseases—including ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, inflammatory arthritis, suspected infection—history of intravenous drug use, intractable pain despite therapy, or tenderness to palpation over a vertebral body. Additional proposed red flags include congenital findings, concomitant vascular disease in patients >50 years of age, abnormal labs (erythrocyte sedimentation rate, C-reactive protein level, white blood cell), and neurological deficits [10].

CT Cervical Spine
CT provides good definition of bony elements and is helpful in the assessment of neuroforaminal stenosis secondary to uncovertebral or facet hypertrophy and is helpful when C6 and C7 are not clearly seen on traditional lateral radiographic views. However, CT is shown to be less sensitive than MRI for evaluation of nerve root compression [35,36].

CT Myelography Cervical Spine
MRI has mostly supplanted CT myelography as a first-line imaging modality for complex cervical radiculopathy [37]. However, studies have shown that CT myelography may prove useful in diagnosing foraminal stenosis, bony lesions, and nerve root compression [38] and can be considered in patients with clinically apparent radiculopathy and contraindication to MRI, or in the setting of equivocal MRI findings.

CTA Neck
The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions
The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

MRA Neck
The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine
MRI has become the preferred method to evaluate the cervical spine in the setting of suspected nerve root impingement [39] because of its superior intrinsic soft-tissue contrast and good spatial resolution. Brown et al [35] in a blinded, retrospective review studied 34 patients with clinically diagnosed cervical radiculopathy who underwent MRI prior to surgery and reported that MRI correctly predicted 88% of the lesions as opposed to 81% for CT myelography, 57% for plain myelography, and 50% for CT. However, as noted previously, degenerative findings on MRI are commonly observed in asymptomatic patients [21,23,40,41]. A prospective study evaluating MRI cervical spine in recent onset cervical radiculopathy found a high rate of both false-positive and false-negative findings [33].

Bone Scan Whole Body with SPECT or SPECT/CT Neck
Tc-99m bone scan lacks both resolution and specificity to detect pathology related to suspected nerve root compression.

Radiography Cervical Spine
Approximately 65% of asymptomatic patients 50 to 59 years of age will have radiographic evidence of significant cervical spine degeneration, regardless of radiculopathy symptoms [42].

Myelography Cervical Spine
CT myelography has supplanted fluoroscopic myelography in most circumstances; however, there may be times when fluoroscopic myelography is also performed prior to CT imaging. The ultimate judgment regarding the appropriateness of any specific procedure, lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage must be made by the radiologist, with appropriate documentation and coding [17].

Variant 3: Prior cervical spine surgery. New or increasing nontraumatic cervical or neck pain or radiculopathy. Initial imaging.

Anterior cervical discectomy and fusion (ACDF) is a common modality for the treatment of radiculopathy and myelopathy that is due to cervical disc disease [43,44]. Potential risks associated with ACDF include pseudoarthrosis [45], acceleration of adjacent segment degeneration [46,47], and complications related to the hardware itself, all of which may manifest as new or increasing nontraumatic neck pain. If infection is suspected, please see Variant 4. Imaging of patients with myelopathy should be guided by the separate ACR Appropriateness Criteria® topic on "Myelopathy" [13].

CT Cervical Spine
Multidetector CT scanning with high-quality multiplanar reformatted images have enhanced the efficacy of CT assessment and imaging findings, particularly around hardware. CT is the most sensitive and specific modality to assess spinal fusion [48-50] and can aid in detecting adjacent segment degeneration [51]. A recent review of 690 patients who underwent ACDF concluded that CT altered the treatment plan in 39% of patients who had persistent symptoms and altered the treatment plan for 60% of patients with persistent symptoms and abnormal radiographs or MRI. Furthermore, recent advances in dual-energy CT has shown promise to reduce beam-hardening metal artifact, which may improve the evaluation of hardware complications and adjacent segment degeneration in postoperative patients with new or worsening neck pain [52]. Whether imaging is informative for changes to improve outcome remains to be established. In one study, half of the symptomatic cohort did not have postoperative CT, and the majority recovered with 2 years of conservative therapy [53].

CT Myelography Cervical Spine
CT myelography is not the first-line test of choice for complex cervical radiculopathy [37]. However, it can be considered in patients with radiculopathy, particularly if MRI is nondiagnostic related to hardware artifact.

CTA Neck

The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions

The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

MRA Neck

The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine

Metal artifact may limit assessment of the cervical hardware and complications related to position or integrity. There continues to be emerging techniques for metal artifact reduction, which is beyond the scope of this document [54]. MRI is the most sensitive imaging test for detecting soft-tissue abnormalities associated with neck pain but is characterized by a high rate of abnormalities in asymptomatic individuals [22,23]. Most cervical discectomies are performed by an anterior approach without transgression of the epidural space; therefore, epidural scar or granulation tissue formation is minimal, and contrast-enhanced imaging is not routinely used after ACDF [55]. Gadolinium-enhanced MRI may have a role in the setting of neck pain and prior posterior-approach cervical fusion/decompressive procedures, although the majority of the literature to date evaluates the use of gadolinium-based contrast in the differentiation of recurrent disc herniations (a potentially actionable finding) from epidural scar in the setting of lumbar spine surgery [56,57].

Bone Scan Whole Body with SPECT or SPECT/CT Neck

There is no current role for nuclear medicine studies as the initial examination in this scenario. The role of Tc-99m bone scan in the setting of new or worsening neck pain in the postsurgical patient is limited, as radionuclide scans may remain positive for a year or more in the region of the operative bed [58]. SPECT/CT may offer diagnostic information in the setting of suspected pseudoarthrosis or equivocal CT or MRI findings [59].

Radiography Cervical Spine

Initial radiographic evaluation, including anteroposterior and lateral views, is useful to assess hardware integrity and detect adjacent segment disease, which may contribute to symptoms [60,61]. The addition of flexion/extension radiographs may be considered to improve detection of vertebral body nonunion or pseudoarthrosis [62] and may supplement conventional views following ACDF [63], cervical disc implantation, or posterior cervical fixation [64-66].

Myelography Cervical Spine

CT myelography has supplanted fluoroscopic myelography in most circumstances; however, there may be times when fluoroscopic myelography is also performed prior to CT imaging. The ultimate judgment regarding the appropriateness of any specific procedure, lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage must be made by the radiologist, with appropriate documentation and coding [17].

Variant 4: Suspicion for infection with new or increasing nontraumatic cervical or neck pain or radiculopathy. Initial imaging.

The coexistence of fever, leukocytosis, elevated erythrocyte sedimentation rate, or C-reactive protein levels or history of immunosuppression, immunocompromised, diabetes, long-term steroid use, renal or liver failure, or drug use raise the concern for infection as a cause for neck pain [67]. The incidence of spinal infection is 0.2 to 2 cases per 100,000 per year [68,69], including involvement of the marrow, disc, paraspinal soft tissues, epidural space, meninges, spinal cord, or nerve roots. Potential infectious etiologies include hematogenous disease spread, extension from a contiguous infection of the prevertebral or paravertebral structures, or prior surgery or trauma. The presence of clinical signs or symptoms suggesting meningitis or anterior neck infection should be managed based on clinical guidelines separate from this review of neck pain. Imaging of patients with myelopathy related to suspected spinal infection should be guided by the separate ACR Appropriateness Criteria® topic on "Myelopathy" [13].

CT Cervical Spine
CT with and without contrast is superior to radiography for the detection of erosive changes, loss of fat planes, and paraspinal edema and fluid collections [69]. CT scanning also offers potential advantages in identifying the presence of gas within an abscess, the lack of gas within the disc space, or a sequestrum within the spinal canal [70]. CT with contrast is complementary to MRI.

CT Myelography Cervical Spine
The literature search did not identify any studies regarding the use of CT myelography in the evaluation of this clinical presentation.

CTA Neck
The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions
The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

FDG-PET/CT Skull Base to Mid-Thigh
PET using the tracer fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)/CT is the scintigraphic procedure of choice for spinal osteomyelitis [71-73].

Gallium-67 Scan Whole Body
Specificity may be increased by combining Tc-99m methylene diphosphonate (MDP) with gallium-67 citrate [74], and higher sensitivity and resolution can be further achieved with SPECT/CT [75].

Indium-111 WBC Scan Whole Body
Indium-labeled leucocytes have a low sensitivity in spinal infections (osteomyelitis and discitis). In these clinical scenarios, leucocytes are generally not used because of a reported 40% false-negative rate, which is manifested as normal uptake or photopenia. In the past, the preferred radionuclide imaging for spinal osteomyelitis was a combination of bone and gallium scans.

MRA Neck
The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine
MRI with and without contrast is considered the best modality for demonstrating spinal infections, with a sensitivity of 96%, specificity of 92%, and accuracy of 94% [68,69,76]. While bone marrow edema can be detected on noncontrast examinations [68,77-79], the addition of contrast improves detection and characterization of leptomeningeal involvement or the development of an epidural or paraspinal abscess [79,80].

Bone Scan Whole Body with SPECT or SPECT/CT Neck
Three-phase Tc-99m MDP scintigraphy is sensitive (90%) but not specific (78%) [76] for the identification of suspect cervical spine osteomyelitis.

Radiography Cervical Spine
Radiographs lack sensitivity and specificity in the setting of discitis or osteomyelitis, as 30% to 40% of the vertebral bone must be destroyed before lytic changes can be identified [81,82]. Because of the low sensitivity and specificity, particularly in early phases of spine infection, a negative cervical spine radiograph should not be considered comprehensive imaging in this scenario.

Myelography Cervical Spine
CT myelography has supplanted fluoroscopic myelography in most circumstances; however, there may be times when fluoroscopic myelography is also performed prior to CT imaging. The ultimate judgment regarding the appropriateness of any specific procedure, lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage must be made by the radiologist, with appropriate documentation and coding [17].

Variant 5: Known malignancy. New or increasing nontraumatic cervical or neck pain or radiculopathy. Initial imaging.

Although primary tumors of the spine are uncommon [83], an estimated 10% of cancer patients develop symptomatic spinal metastases during the course of their disease [84], making the spine the most common site of osseous metastatic disease [85]. Suspected spinal metastases are typically diagnosed using cross-sectional imaging with the dual goal of identifying potential metastases and characterizing the extent of malignancy. As such, the choice of imaging modality is often based on both the type of malignancy and the presenting clinical features, especially if referable to pathological fracture, cord compression, or nerve root impingement.

CT Cervical Spine

Because of its high spatial resolution, CT is more sensitive than conventional radiography for the detection of bone metastases and has shown good correlation with nuclear bone scans, particularly if coupled with concurrent CT examinations of the thorax, abdomen, and/or pelvis [86]. CT can help characterize lesions as lytic or blastic and may successfully assess paravertebral or intraspinal extension if intravenous contrast is used [87]. CT is also useful to obtain better structural definition of abnormal findings identified on scintigraphy or MRI [88], such as in the setting of suspected pathologic fracture. However, given that CT is relatively insensitive for tumors restricted to the marrow space, the sensitivity of CT is relatively low in early malignant bone involvement [87,89], and as such, MRI is favored as an initial diagnostic modality.

CT Myelography Cervical Spine

The literature search did not identify any studies regarding the use of CT myelography in the evaluation of this clinical presentation.

CTA Neck

The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Fluoride PET/CT whole body

F-18-sodium fluoride (NaF) PET/CT has become an important tool for detecting and evaluating metastatic bone cancer [90,91] and may be a preferable modality for detecting metastatic bone disease in morbidly obese patients; however, there is currently no evidence supporting the validity of F-18 NaF PET/CT as a first-line test evaluating acute neck pain or radicular symptoms in patients with malignancy.

Percutaneous Interventions

The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

FDG-PET/CT Whole Body

FDG-PET/CT is sensitive for detection of metastatic disease and has been compared to detection rates of bone scans [92,93]. However, resolution of PET scans is limited for assessment of involvement of the spinal cord/meninges and exiting nerve roots, and as such, there is currently no evidence supporting the validity of FDG-PET/CT as a first-line test evaluating acute neck pain or radicular symptoms in patients with malignancy.

MRA Neck

The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine

MRI has high sensitivity and specificity for the detection and discrimination of malignant bone lesions [88], with the addition of contrast to delineate the extent of marrow leptomeningeal, epidural, neuroforminal, and paraspinal involvement. Furthermore, local spread of bone metastases and extension into the spinal canal is better assessed on MRI, particularly in the setting of clinical suspicion for nerve root or cord compression [94].

Bone Scan Whole Body with SPECT or SPECT/CT Neck

Although Tc-99m bone scan is the most commonly used technique for detecting suspected osseous metastasis, it has a high false-positive rate secondary to benign processes with increased bone turnover, such as degenerative osteoarthrosis [95]. The addition of SPECT to the acquisition protocol of bone scintigraphy improves image contrast resolution [96] and, thus, diagnostic accuracy. Furthermore, adding a CT acquisition can increase this diagnostic accuracy with anatomic localization to the SPECT images resulting in SPECT/CT [36].

Radiography Cervical Spine

Conventional radiography still plays an important role in the diagnostic evaluation of bone metastases as pathological changes in cortical bone are detectable by plain radiograph even if they are only a few millimeters wide [97]. Radiographs can also reveal osteolytic lesions at risk for superimposed pathological fracture. However, given that these osteolytic changes may only be detectable after 50% of the bone substance has been destroyed [87], and lesions up to 1 cm may not be detectable, radiographs alone are not sufficient to exclude metastases in the setting of neck pain in a patient with known malignancy.

Myelography Cervical Spine

CT myelography has supplanted fluoroscopic myelography in most circumstances; however, there may be times when fluoroscopic myelography is also performed prior to CT imaging. The ultimate judgment regarding the appropriateness of any specific procedure, lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage must be made by the radiologist, with appropriate documentation and coding [17].

Variant 6: Cervicogenic headache and new or increasing nontraumatic cervical or neck pain. No neurologic deficit. Initial imaging.

Cervicogenic headache is attributed to disorders of the bone, disc, and/or soft-tissue elements of the cervical spine, usually accompanied by neck pain [98]. Potential pain generators include the atlanto-occipital and atlantoaxial joints, C2-3 facet joints, C2-3 intervertebral disc, cervical myofascial trigger points, and the cervical spinal nerves [99]. Suspected cervicogenic headache presents a true diagnostic dilemma secondary to the myriad of structures that may be the causative factor of headache in the setting of neck pain and the absence of definitive radiographic findings, leading to a diagnosis of cervicogenic headache [100]. It is important to remember the possibility of dissection as a source of acute ipsilateral headache and neck pain [101,102], which is addressed in the ACR Appropriateness Criteria® topic on "Headache" [15].

CT Cervical Spine

There is no evidence that medical imaging is diagnostic for the etiologies of cervicogenic headache; however, imaging may lend support to its diagnosis [103]. For example, in a study of 22 symptomatic and 20 control patients, there was no difference in the number of patients with cervical disc bulges or in the distribution of degenerative disc disease within the cervical spine [104].

CT Myelography Cervical Spine

In the absence of radiographic abnormalities or neurological symptoms, CT myelography is not an appropriate first-line imaging test.

CTA Neck

The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions

The International Classification of Headache Disorders include "headache is abolished following diagnostic blockade of a cervical structure or its nerve supply" as part of one of their four causation criteria for cervicogenic headache [98]. However, this is not a first-line diagnostic procedure to be performed without establishing the levels and extent of degenerative changes and is not necessary to make the diagnosis. Recent literature is limited to diagnostic efficacy rather than focusing on treatment outcomes.

MRA Neck

The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine

There is no evidence that medical imaging is diagnostic for the etiologies of cervicogenic headache; however, imaging may lend support to its diagnosis [103]. For example, in a study of 22 symptomatic and 20 control patients, there was no difference in the number of patients with cervical disc bulges or in the distribution of degenerative disc disease within the cervical spine [104].

Bone Scan Whole Body with SPECT or SPECT/CT Neck
The role of Tc-99m bone scan in the setting of chronic neck pain is limited. The addition of SPECT to the acquisition protocol of bone scintigraphy improves image contrast resolution [105], and thus diagnostic accuracy. Some authors have advocated the use of SPECT imaging in identifying the pain source (ie, facet disease) [106]. Furthermore, adding a CT acquisition can increase this diagnostic accuracy with anatomic localization to the SPECT images resulting in SPECT/CT [36].

Radiography Cervical Spine
There is no evidence that medical imaging is diagnostic for the etiologies of cervicogenic headache; however, imaging may lend support to its diagnosis [103]. For example, in a study of 22 symptomatic and 20 control patients, there was no difference in the number of patients with cervical disc bulges or in the distribution of degenerative disc disease within the cervical spine [104].

Myelography Cervical Spine
In the absence of radiographic abnormalities or neurological symptoms, myelography is not an appropriate first-line imaging test.

Variant 7: Chronic cervical or neck pain. Initial imaging.

Up to 50% of patients will continue to have residual or recurrent episodes of neck pain up to 1 year after initial presentation [9]. For some patients, this may overlap with content in the ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [11] related to whiplash-associated disorders.

CT Cervical Spine
CT is not currently recommended as a first-line examination for chronic neck pain in the absence of red flags or neurological symptoms.

CT Myelography Cervical Spine
CT myelography is not an appropriate test for chronic neck pain in the absence of radicular or myelopathic symptoms.

CTA Neck
The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions
The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

MRA Neck
The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine
MRI is the most sensitive test for detecting soft abnormalities associated with neck pain; however, it is characterized by a high rate of abnormalities in asymptomatic individuals [22,23]. As such, MRI is not considered appropriate as a first-line imaging modality in the setting of chronic, uncomplicated neck pain.

Bone Scan Whole Body with SPECT or SPECT/CT Neck
The role of Tc-99m bone scan in the setting of chronic neck pain is limited, though SPECT likely offers benefit over conventional planar imaging. Some authors have advocated SPECT imaging in identifying the pain source (ie, facet disease) [106]; however, is not considered appropriate as a first imaging modality in the setting of chronic, uncomplicated neck pain.

Radiography Cervical Spine
Radiographs may be helpful in clarifying the clinical diagnosis of cervical spondylosis from mechanical, inflammatory, or metabolic processes in patients who otherwise have no red flag symptoms [107]. Radiographically visible degenerative changes, such as disc space narrowing, osteophyte formation, facet, and uncovertebral hypertrophy, are common [108] and may not correlate with symptoms or impact treatment.

Myelography Cervical Spine
Myelography is not an appropriate test for chronic neck pain in the absence of radicular or myelopathic symptoms.

Variant 8: Chronic cervical or neck pain. No neurologic findings. Radiographs show degenerative changes. Next imaging study.

Degenerative changes are commonly identified on radiographs with aging, and patients may present to a new provider with previously performed radiographs. The presence of degenerative changes alone in the setting of chronic, unchanging cervical or neck pain does not require cross-sectional imaging. For some patients, this may overlap with content in the ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [11] related to whiplash-associated disorders.

CT Cervical Spine
Multidetector CT scans with high-quality multiplanar reformatted images have enhanced the efficacy of CT, which offers superior depiction of cortical bone and is more sensitive than radiographs in the assessment of facet degenerative disease, osteophyte formation, vacuum phenomenon, and joint capsular calcification [24].

CT Myelography Cervical Spine
CT myelography is not an appropriate test for chronic neck pain in the absence of radicular or myelopathic symptoms.

CTA Neck
The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions
The use of provocative injections in the cervical spine to identify a pain source is controversial. The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders concluded there was no evidence to support using cervical provocative discography or anesthetic facet or nerve blocks [1]. The use of facet injection as a diagnostic maneuver is limited by frequent anesthetic leakage into adjacent spaces, resulting in false-positive results [109,110].

MRA Neck
The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine
In patients with neck pain without neurologic symptoms, the relevance of specific MRI findings in the cervical spine should be considered in light of expected changes associated with aging. MRI is more sensitive than CT in identifying degenerative cervical disorders [111,112]. However, the presence of degenerative changes should be interpreted with caution. In a small series, Fryer et al [113] found little correlation between the presence of facet arthropathy and the side or level of symptoms in patients with acute, unilateral neck pain. Spondylotic changes on radiographs and MRI are common in patients over 30 years of age and have been shown to correlate poorly with the presence of neck pain [20-23,114,115]. Okada et al [112], in a 10-year longitudinal MRI study, showed that cervical disc degeneration progressed in 85% of patients, though symptoms developed in only 34% of patients. Most significantly, patients developing symptoms showed more frequent progression of disc degeneration on MRI, including anterior compression of the dura and spinal cord, posterior disc protrusion, disc space narrowing, and foraminal stenosis.

Bone Scan Whole Body with SPECT or SPECT/CT Neck
The role of Tc-99m bone scan in the setting of chronic neck pain is limited, though SPECT likely offers benefit over conventional planar imaging. Some authors have advocated the use of SPECT imaging in identifying the pain source (ie, facet disease) [106]. A recent retrospective study of 25 patients with chronic cervical spine pain demonstrated that hybrid SPECT/CT imaging identified potential pain generators in 92% of patients [26], and as such may have a role in secondary workup.

Myelography Cervical Spine
Myelography is not an appropriate test for chronic neck pain in the absence of radicular or myelopathic symptoms. Similar to more recent literature on MRI, asymptomatic degenerative changes have been described on myelograms [116].

Variant 9: Chronic cervical or neck pain without or with radiculopathy. Radiographs show ossification in the posterior longitudinal ligament (OPLL). Next imaging study.

Heterotopic ossification in the posterior longitudinal ligament (OPLL) predisposes the patient to progressive narrowing of the spinal canal and/or abutment of the spinal cord. OPLL commonly presents in the fifth or sixth decade of life with a 2:1 male-to-female ratio. OPLL of the cervical spine is more common than thoracic OPLL, which was confirmed in a survey of 1,058 patients with OPLL, of whom 3.2% demonstrated involvement of the cervical spine and 0.8%, the thoracic spine [117]. Although original estimates of OPLL prevalence were based on lateral radiographs of the spine, more recently reported prevalence rates based on CT report prevalence rates of cervical OPLL between 1.7% in the white United States population and 4.6% in the Korean population [118,119].

CT Cervical Spine

Although radiographs are helpful in the diagnosis of OPLL, particularly in the cervical region, CT is more reliable both in the identification of OPLL and in the evaluation of sequelae related to its diagnosis [120]. CT evaluation can show OPLL type, thickness, length of involved segments, and associated systemic diseases, such as diffuse idiopathic skeletal hyperostosis. The superior spatial resolution of CT helps identify regions of neuroforaminal and spinal canal narrowing and should be considered in any patient presenting with new or worsening radiculopathy in the setting of suspected OPLL.

CT Myelography Cervical Spine

CT myelography performed in flexion and extension has been described to help identify regions of position-dependent cord compression related to cervical spinal stenosis from OPLL [121], although it is not routinely used in clinical practice.

CTA Neck

The literature search did not identify any studies regarding the use of CTA in the evaluation of this clinical presentation.

Percutaneous Interventions

The literature search did not identify any studies regarding the use of cervical facet joint, medial branch blocks, or discography as a first-line test in the evaluation of this clinical presentation.

MRA Neck

The literature search did not identify any studies regarding the use of MRA in the evaluation of this clinical presentation.

MRI Cervical Spine

Detection of OPLL on MRI is limited, with reported sensitivity of 32% to 44.3% [122]. Therefore, the primary utility of MRI in the setting of OPLL is in the assessment of cord abutment/signal changes secondary to spinal canal narrowing. MRI also affords the ability to evaluate the exiting nerve roots in the setting of radiculopathy.

Bone Scan Whole Body with SPECT or SPECT/CT Neck

The literature search did not identify any studies regarding the use of bone scan as a first-line test in the evaluation of this clinical presentation.

Myelography Cervical Spine

CT myelography has supplanted fluoroscopic myelography in most circumstances; however, there may be times when fluoroscopic myelography is also performed prior to CT imaging. The ultimate judgment regarding the appropriateness of any specific procedure, lumbar versus cervical puncture route, amount of contrast, and the extent and modality of imaging coverage must be made by the radiologist, with appropriate documentation and coding [17].

Summary of Recommendations

- **Variant 1:** Radiographs of the cervical spine are usually appropriate for the initial imaging of patients with new or increasing nontraumatic cervical or neck pain and no red flags. The panel did not agree on recommending MRI cervical spine without IV contrast for individuals in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of MRI cervical spine without IV contrast in this patient population is controversial but may be appropriate.

- **Variant 2:** MRI cervical spine without IV contrast is usually appropriate for the initial imaging of patients with new or increasing nontraumatic cervical radiculopathy and no red flags. The panel did not agree on recommending radiographs of the cervical spine in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of radiographs of the cervical spine in this patient population is controversial but may be appropriate.
- **Variant 3:** Radiographs of the cervical spine or CT cervical spine without IV contrast is usually appropriate for the initial imaging of patients with prior cervical spine surgery and with new or increasing nontraumatic cervical or neck pain or radiculopathy. These procedures are equivalent alternatives. The panel did not agree on recommending MRI cervical spine without IV contrast or MRI cervical spine without and with IV contrast in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from these procedures. The use of MRI cervical spine without IV contrast or MRI cervical spine without and with IV contrast in this patient population is controversial but may be appropriate.
- **Variant 4:** MRI cervical spine without and with IV contrast is usually appropriate for the initial imaging of patients with suspicion for infection with new or increasing nontraumatic cervical or neck pain or radiculopathy. The panel did not agree on recommending CT cervical spine without IV contrast, or MRI cervical spine with IV contrast, or radiographs of the cervical spine in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from these procedures. The use of CT cervical spine without IV contrast, or MRI cervical spine with IV contrast, or radiographs of the cervical spine in this patient population is controversial but may be appropriate.
- **Variant 5:** MRI cervical spine without and with IV contrast or MRI cervical spine without IV contrast are usually appropriate for the initial imaging of patients with known malignancy and new or increasing nontraumatic cervical, or neck pain, or radiculopathy. The addition of contrast is preferred for assessment of the leptomeningeals and soft-tissues; however, a noncontrast MRI also provides diagnostic detail. The panel did not agree on recommending CT cervical spine with IV contrast, CT cervical spine without IV contrast, or MRI cervical spine with IV contrast in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from these procedures. The use of CT cervical spine with IV contrast, CT cervical spine without IV contrast, or MRI cervical spine with IV contrast in this patient population is controversial but may be appropriate.
- **Variant 6:** Radiographs of the cervical spine, or CT cervical spine without IV contrast, or facet injection/medial branch block cervical spine may be appropriate for the initial imaging of patients with cervicogenic headache and new or increasing nontraumatic cervical or neck pain and with no neurologic deficit. The panel did not agree on recommending MRI cervical spine without IV contrast in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of MRI cervical spine without IV contrast in this patient population is controversial but may be appropriate.
- **Variant 7:** Radiographs of the cervical spine is usually appropriate for the initial imaging of patients with chronic cervical or neck pain. The panel did not agree on recommending MRI cervical spine without IV contrast in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of MRI cervical spine without IV contrast in this patient population is controversial but may be appropriate.
- **Variant 8:** MRI cervical spine without IV contrast is usually appropriate as the next imaging study for patients with chronic cervical or neck pain with no neurologic findings when radiographs show degenerative changes.
- **Variant 9:** CT cervical spine without IV contrast is usually appropriate as the next imaging study for patients with chronic neck pain without or with radiculopathy and OPLL diagnosed on radiographs. The panel did not agree on recommending CT myelography cervical spine or MRI cervical spine without IV contrast in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from these procedures. The use of CT myelography cervical spine or MRI cervical spine without IV contrast in this patient population is controversial but may be appropriate.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [123].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".

References

1. Nordin M, Carragee EJ, Hogg-Johnson S, et al. Assessment of neck pain and its associated disorders: results of the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. Spine (Phila Pa 1976) 2008;33:S101-22.
2. Murray CJ, Atkinson C, Bhalla K, et al. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. JAMA 2013;310:591-608.
3. Binder AI. Neck pain. BMJ Clin Evid 2008;2008.
4. Fejer R, Kyvik KO, Hartvigsen J. The prevalence of neck pain in the world population: a systematic critical review of the literature. Eur Spine J 2006;15:834-48.
5. Fernandez-de-las-Penas C, Hernandez-Barrera V, Alonso-Blanco C, et al. Prevalence of neck and low back pain in community-dwelling adults in Spain: a population-based national study. Spine (Phila Pa 1976) 2011;36:E213-9.
6. Hogg-Johnson S, van der Velde G, Carroll LJ, et al. The burden and determinants of neck pain in the general population: results of the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. Spine (Phila Pa 1976) 2008;33:S39-51.
7. Son KM, Cho NH, Lim SH, Kim HA. Prevalence and risk factor of neck pain in elderly Korean community residents. J Korean Med Sci 2013;28:680-6.
8. Strine TW, Hootman JM. US national prevalence and correlates of low back and neck pain among adults. Arthritis Rheum 2007;57:656-65.
9. Cohen SP. Epidemiology, diagnosis, and treatment of neck pain. Mayo Clin Proc 2015;90:284-99.
10. Cohen SP, Hooten WM. Advances in the diagnosis and management of neck pain. BMJ 2017;358:j3221.
11. American College of Radiology. ACR Appropriateness Criteria®: Suspected Spine Trauma. Available at: https://acsearch.acr.org/docs/69359/Narrative/. Accessed November 30, 2018.
12. American College of Radiology. ACR Appropriateness Criteria®: Neck Mass/Adenopathy. Available at: https://acsearch.acr.org/docs/69504/Narrative/. Accessed November 30, 2018.
13. Roth CJ, Angevine PD, Aulino JM, et al. ACR Appropriateness Criteria Myelopathy. J Am Coll Radiol 2016;13:38-44.
14. Bykowski J, Aulino JM, Berger KL, et al. ACR Appropriateness Criteria(R) Plexopathy. J Am Coll Radiol 2017;14:S225-S33.
15. American College of Radiology. ACR Appropriateness Criteria®: Headache. Available at: https://acsearch.acr.org/docs/69482/Narrative/. Accessed November 30, 2018.
16. Patel ND, Broderick DF, Burns J, et al. ACR Appropriateness Criteria Low Back Pain. J Am Coll Radiol 2016;13:1069-78.
17. American College of Radiology. ACR–ASNR–SPR Practice Parameter For The Performance Of Myelography And Cisternogaphy. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Myelog-Cisternog.pdf. Accessed November 30, 2018.
18. Vasseljen O, Woodhouse A, Bjorngaard JH, Leivseth L. Natural course of acute neck and low back pain in the general population: the HUNT study. Pain 2013;154:1237-44.

19. Vos CJ, Verhagen AP, Passchier J, Koes BW. Clinical course and prognostic factors in acute neck pain: an inception cohort study in general practice. Pain Med 2008;9:572-80.
20. Brinjikji W, Luetmer PH, Comstock B, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. AJNR Am J Neuroradiol 2015;36:811-6.
21. Lehto IJ, Tertti MO, Komu ME, Paajanen HE, Tuominen J, Kormano MJ. Age-related MRI changes at 0.1 T in cervical discs in asymptomatic subjects. Neuroradiology 1994;36:49-53.
22. Machino M, Yukawa Y, Imagama S, et al. Age-Related and Degenerative Changes in the Osseous Anatomy, Alignment, and Range of Motion of the Cervical Spine: A Comparative Study of Radiographic Data From 1016 Patients With Cervical Spondylotic Myelopathy and 1230 Asymptomatic Subjects. Spine (Phila Pa 1976) 2016;41:476-82.
23. Matsumoto M, Fujimura Y, Suzuki N, et al. MRI of cervical intervertebral discs in asymptomatic subjects. J Bone Joint Surg Br 1998;80:19-24.
24. Kalichman L, Hunter DJ. Lumbar facet joint osteoarthritis: a review. Semin Arthritis Rheum 2007;37:69-80.
25. McLaughlin PD, Ouellette HA, Louis LJ, et al. The emergence of ultra-low--dose computed tomography and the impending obsolescence of the plain radiograph? Can Assoc Radiol J 2013;64:314-8.
26. Matar HE, Navalkissoor S, Berovic M, et al. Is hybrid imaging (SPECT/CT) a useful adjunct in the management of suspected facet joints arthropathy? Int Orthop 2013;37:865-70.
27. White AP, Biswas D, Smart LR, Haims A, Grauer JN. Utility of flexion-extension radiographs in evaluating the degenerative cervical spine. Spine (Phila Pa 1976) 2007;32:975-9.
28. Johnson MJ, Lucas GL. Value of cervical spine radiographs as a screening tool. Clin Orthop Relat Res 1997:102-8.
29. Leichtle UG, Wunschel M, Socci M, Kurze C, Niemeyer T, Leichtle CI. Spine radiography in the evaluation of back and neck pain in an orthopaedic emergency clinic. J Back Musculoskelet Rehabil 2015;28:43-8.
30. Bogduk N. The anatomy and pathophysiology of neck pain. Phys Med Rehabil Clin N Am 2003;14:455-72, v.
31. Radhakrishnan K, Litchy WJ, O'Fallon WM, Kurland LT. Epidemiology of cervical radiculopathy. A population-based study from Rochester, Minnesota, 1976 through 1990. Brain 1994;117 (Pt 2):325-35.
32. Thoomes EJ, van Geest S, van der Windt DA, et al. Value of physical tests in diagnosing cervical radiculopathy: a systematic review. Spine J 2018;18:179-89.
33. Kuijper B, Tans JT, van der Kallen BF, Nollet F, Lycklama ANGJ, de Visser M. Root compression on MRI compared with clinical findings in patients with recent onset cervical radiculopathy. J Neurol Neurosurg Psychiatry 2011;82:561-3.
34. Woods BI, Hilibrand AS. Cervical radiculopathy: epidemiology, etiology, diagnosis, and treatment. J Spinal Disord Tech 2015;28:E251-9.
35. Brown BM, Schwartz RH, Frank E, Blank NK. Preoperative evaluation of cervical radiculopathy and myelopathy by surface-coil MR imaging. AJR Am J Roentgenol 1988;151:1205-12.
36. van Rijn JC, Klemetso N, Reitsma JB, et al. Observer variation in the evaluation of lumbar herniated discs and root compression: spiral CT compared with MRI. Br J Radiol 2006;79:372-7.
37. Modic MT, Masaryk TJ, Ross JS, Mulopulos GP, Bundschuh CV, Bohlman H. Cervical radiculopathy: value of oblique MR imaging. Radiology 1987;163:227-31.
38. Bartlett RJ, Hill CR, Gardiner E. A comparison of T2 and gadolinium enhanced MRI with CT myelography in cervical radiculopathy. Br J Radiol 1998;71:11-9.
39. Abbed KM, Coumans JV. Cervical radiculopathy: pathophysiology, presentation, and clinical evaluation. Neurosurgery 2007;60:S28-34.
40. Boden SD, McCowin PR, Davis DO, Dina TS, Mark AS, Wiesel S. Abnormal magnetic-resonance scans of the cervical spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am 1990;72:1178-84.
41. Mostofi K, Khouzani RK. Reliability of cervical radiculopathy, its congruence between patient history and medical imaging evidence of disc herniation and its role in surgical decision. Eur J Orthop Surg Traumatol 2016;26:805-8.
42. Friedenberg ZB, Miller WT. Degenerative Disc Disease of the Cervical Spine. J Bone Joint Surg Am 1963;45:1171-8.

43. Buchowski JM, Anderson PA, Sekhon L, Riew KD. Cervical disc arthroplasty compared with arthrodesis for the treatment of myelopathy. Surgical technique. J Bone Joint Surg Am 2009;91 Suppl 2:223-32.
44. Rao RD, Currier BL, Albert TJ, et al. Degenerative cervical spondylosis: clinical syndromes, pathogenesis, and management. J Bone Joint Surg Am 2007;89:1360-78.
45. Shriver MF, Lewis DJ, Kshettry VR, Rosenbaum BP, Benzel EC, Mroz TE. Pseudoarthrosis rates in anterior cervical discectomy and fusion: a meta-analysis. Spine J 2015;15:2016-27.
46. Hilibrand AS, Carlson GD, Palumbo MA, Jones PK, Bohlman HH. Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. J Bone Joint Surg Am 1999;81:519-28.
47. Lee JC, Lee SH, Peters C, Riew KD. Adjacent segment pathology requiring reoperation after anterior cervical arthrodesis: the influence of smoking, sex, and number of operated levels. Spine (Phila Pa 1976) 2015;40:E571-7.
48. Buchowski JM, Liu G, Bunmaprasert T, Rose PS, Riew KD. Anterior cervical fusion assessment: surgical exploration versus radiographic evaluation. Spine (Phila Pa 1976) 2008;33:1185-91.
49. Ploumis A, Mehbod A, Garvey T, Gilbert T, Transfeldt E, Wood K. Prospective assessment of cervical fusion status: plain radiographs versus CT-scan. Acta Orthop Belg 2006;72:342-6.
50. Selby MD, Clark SR, Hall DJ, Freeman BJ. Radiologic assessment of spinal fusion. J Am Acad Orthop Surg 2012;20:694-703.
51. Nunley PD, Jawahar A, Cavanaugh DA, Gordon CR, Kerr EJ, 3rd, Utter PA. Symptomatic adjacent segment disease after cervical total disc replacement: re-examining the clinical and radiological evidence with established criteria. Spine J 2013;13:5-12.
52. Pessis E, Campagna R, Sverzut JM, et al. Virtual monochromatic spectral imaging with fast kilovoltage switching: reduction of metal artifacts at CT. Radiographics 2013;33:573-83.
53. Derakhshan A, Lubelski D, Steinmetz MP, Benzel EC, Mroz TE. Utility of Computed Tomography following Anterior Cervical Diskectomy and Fusion. Global Spine J 2015;5:411-6.
54. American College of Radiology. ACR–ASNR–ASSR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Spine. Available at: https://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/CT_Spine.pdf. Accessed November 30, 2018.
55. Ross JS. Magnetic resonance imaging of the postoperative spine. Semin Musculoskelet Radiol 2000;4:281-91.
56. Hueftle MG, Modic MT, Ross JS, et al. Lumbar spine: postoperative MR imaging with Gd-DTPA. Radiology 1988;167:817-24.
57. Ross JS, Masaryk TJ, Schrader M, Gentili A, Bohlman H, Modic MT. MR imaging of the postoperative lumbar spine: assessment with gadopentetate dimeglumine. AJR Am J Roentgenol 1990;155:867-72.
58. Iseda T, Nakano S, Suzuki Y, et al. Radiographic and scintigraphic courses of union in cervical interbody fusion: hydroxyapatite grafts versus iliac bone autografts. J Nucl Med 2000;41:1642-5.
59. Coric D, Branch CL, Jr., Jenkins JD. Revision of anterior cervical pseudoarthrosis with anterior allograft fusion and plating. J Neurosurg 1997;86:969-74.
60. Park JY, Kim KH, Kuh SU, Chin DK, Kim KS, Cho YE. What are the associative factors of adjacent segment degeneration after anterior cervical spine surgery? Comparative study between anterior cervical fusion and arthroplasty with 5-year follow-up MRI and CT. Eur Spine J 2013;22:1078-89.
61. Yi S, Lee DY, Ahn PG, Kim KN, Yoon do H, Shin HC. Radiologically documented adjacent-segment degeneration after cervical arthroplasty: characteristics and review of cases. Surg Neurol 2009;72:325-9; discussion 29.
62. Gruskay JA, Webb ML, Grauer JN. Methods of evaluating lumbar and cervical fusion. Spine J 2014;14:531-9.
63. Ghiselli G, Wharton N, Hipp JA, Wong DA, Jatana S. Prospective analysis of imaging prediction of pseudarthrosis after anterior cervical discectomy and fusion: computed tomography versus flexion-extension motion analysis with intraoperative correlation. Spine (Phila Pa 1976) 2011;36:463-8.
64. Hong JT, Sung JH, Son BC, Lee SW, Park CK. Significance of laminar screw fixation in the subaxial cervical spine. Spine (Phila Pa 1976) 2008;33:1739-43.
65. Hwang IC, Kang DH, Han JW, Park IS, Lee CH, Park SY. Clinical experiences and usefulness of cervical posterior stabilization with polyaxial screw-rod system. J Korean Neurosurg Soc 2007;42:311-6.

66. Ryu WH, Kowalczyk I, Duggal N. Long-term kinematic analysis of cervical spine after single-level implantation of Bryan cervical disc prosthesis. Spine J 2013;13:628-34.
67. Grammatico L, Baron S, Rusch E, et al. Epidemiology of vertebral osteomyelitis (VO) in France: analysis of hospital-discharge data 2002-2003. Epidemiol Infect 2008;136:653-60.
68. Arbelaez A, Restrepo F, Castillo M. Spinal infections: clinical and imaging features. Top Magn Reson Imaging 2014;23:303-14.
69. Tali ET, Oner AY, Koc AM. Pyogenic spinal infections. Neuroimaging Clin N Am 2015;25:193-208.
70. Sans N, Faruch M, Lapegue F, Ponsot A, Chiavassa H, Railhac JJ. Infections of the spinal column--spondylodiscitis. Diagn Interv Imaging 2012;93:520-9.
71. Kouijzer IJE, Scheper H, de Rooy JWJ, et al. The diagnostic value of (18)F-FDG-PET/CT and MRI in suspected vertebral osteomyelitis - a prospective study. Eur J Nucl Med Mol Imaging 2018;45:798-805.
72. Palestro CJ. Radionuclide imaging of osteomyelitis. Semin Nucl Med 2015;45:32-46.
73. Palestro CJ, Torres MA. Radionuclide imaging in orthopedic infections. Semin Nucl Med 1997;27:334-45.
74. Love C, Patel M, Lonner BS, Tomas MB, Palestro CJ. Diagnosing spinal osteomyelitis: a comparison of bone and Ga-67 scintigraphy and magnetic resonance imaging. Clin Nucl Med 2000;25:963-77.
75. Palyo RJ, Sinusas AJ, Liu YH. High-Sensitivity and High-Resolution SPECT/CT Systems Provide Substantial Dose Reduction Without Compromising Quantitative Precision for Assessment of Myocardial Perfusion and Function. J Nucl Med 2016;57:893-9.
76. Modic MT, Feiglin DH, Piraino DW, et al. Vertebral osteomyelitis: assessment using MR. Radiology 1985;157:157-66.
77. Ledermann HP, Schweitzer ME, Morrison WB, Carrino JA. MR imaging findings in spinal infections: rules or myths? Radiology 2003;228:506-14.
78. Mahnken AH, Bucker A, Adam G, Gunther RW. [MRI of osteomyelitis: sensitivity and specificity of STIR sequences in comparison with contrast-enhaned T1 spin echo sequences]. Rofo 2000;172:1016-9.
79. Mahnken AH, Wildberger JE, Adam G, et al. Is there a need for contrast-enhanced T1-weighted MRI of the spine after inconspicuous short tau inversion recovery imaging? Eur Radiol 2005;15:1387-92.
80. Longo M, Granata F, Ricciardi K, Gaeta M, Blandino A. Contrast-enhanced MR imaging with fat suppression in adult-onset septic spondylodiscitis. Eur Radiol 2003;13:626-37.
81. Moore SL, Rafii M. Imaging of musculoskeletal and spinal tuberculosis. Radiol Clin North Am 2001;39:329-42.
82. Varma R, Lander P, Assaf A. Imaging of pyogenic infectious spondylodiskitis. Radiol Clin North Am 2001;39:203-13.
83. Dang L, Liu X, Dang G, et al. Primary tumors of the spine: a review of clinical features in 438 patients. J Neurooncol 2015;121:513-20.
84. Perrin RG, Laxton AW. Metastatic spine disease: epidemiology, pathophysiology, and evaluation of patients. Neurosurg Clin N Am 2004;15:365-73.
85. Wong DA, Fornasier VL, MacNab I. Spinal metastases: the obvious, the occult, and the impostors. Spine (Phila Pa 1976) 1990;15:1-4.
86. Bristow AR, Agrawal A, Evans AJ, et al. Can computerised tomography replace bone scintigraphy in detecting bone metastases from breast cancer? A prospective study. Breast 2008;17:98-103.
87. Buhmann Kirchhoff S, Becker C, Duerr HR, Reiser M, Baur-Melnyk A. Detection of osseous metastases of the spine: comparison of high resolution multi-detector-CT with MRI. Eur J Radiol 2009;69:567-73.
88. Heindel W, Gubitz R, Vieth V, Weckesser M, Schober O, Schafers M. The diagnostic imaging of bone metastases. Dtsch Arztebl Int 2014;111:741-7.
89. Muindi J, Coombes RC, Golding S, Powles TJ, Khan O, Husband J. The role of computed tomography in the detection of bone metastases in breast cancer patients. Br J Radiol 1983;56:233-6.
90. Kulshrestha RK, Vinjamuri S, England A, Nightingale J, Hogg P. The Role of 18F-Sodium Fluoride PET/CT Bone Scans in the Diagnosis of Metastatic Bone Disease from Breast and Prostate Cancer. J Nucl Med Technol 2016;44:217-22.
91. Usmani S, Marafi F, Ahmed N, Esmail A, Al Kandari F, Van den Wyngaert T. Diagnostic Challenge of Staging Metastatic Bone Disease in the Morbidly Obese Patients: A Primary Study Evaluating the Usefulness of 18F-Sodium Fluoride (NaF) PET-CT. Clin Nucl Med 2017;42:829-36.

92. Ak I, Sivrikoz MC, Entok E, Vardareli E. Discordant findings in patients with non-small-cell lung cancer: absolutely normal bone scans versus disseminated bone metastases on positron-emission tomography/computed tomography. Eur J Cardiothorac Surg 2010;37:792-6.
93. Chang CY, Gill CM, Joseph Simeone F, et al. Comparison of the diagnostic accuracy of 99 m-Tc-MDP bone scintigraphy and 18 F-FDG PET/CT for the detection of skeletal metastases. Acta Radiol 2016;57:58-65.
94. Vassiliou V, Chow E, Kardamakis D. *Bone Metastases: A Translational and Clinical Approach*. Netherlands: Springer; 2014.
95. O'Sullivan GJ, Carty FL, Cronin CG. Imaging of bone metastasis: An update. World J Radiol 2015;7:202-11.
96. Groch MW, Erwin WD. SPECT in the year 2000: basic principles. J Nucl Med Technol 2000;28:233-44.
97. Layer G. Skelettmetastasen. In: Stabler A, ed. *Handbuch diagnostische Radiologie*. Berlin: Heidelberg: Springer; 2005:327-38.
98. Headache Classification Committee of the International Headache Society (IHS) The International Classification of Headache Disorders, 3rd edition. Cephalalgia 2018;38:1-211.
99. Bogduk N. The neck and headaches. Neurol Clin 2014;32:471-87.
100. Biondi DM. Cervicogenic headache: a review of diagnostic and treatment strategies. J Am Osteopath Assoc 2005;105:16S-22S.
101. Silbert PL, Mokri B, Schievink WI. Headache and neck pain in spontaneous internal carotid and vertebral artery dissections. Neurology 1995;45:1517-22.
102. Sturzenegger M. Headache and neck pain: the warning symptoms of vertebral artery dissection. Headache 1994;34:187-93.
103. Fredriksen TA, Fougner R, Tangerud A, Sjaastad O. Cervicogenic headache. Radiological investigations concerning head/neck. Cephalalgia 1989;9:139-46.
104. Coskun O, Ucler S, Karakurum B, et al. Magnetic resonance imaging of patients with cervicogenic headache. Cephalalgia 2003;23:842-5.
105. Van den Wyngaert T, Strobel K, Kampen WU, et al. The EANM practice guidelines for bone scintigraphy. Eur J Nucl Med Mol Imaging 2016;43:1723-38.
106. Makki D, Khazim R, Zaidan AA, Ravi K, Toma T. Single photon emission computerized tomography (SPECT) scan-positive facet joints and other spinal structures in a hospital-wide population with spinal pain. Spine J 2010;10:58-62.
107. Binder AI. Cervical spondylosis and neck pain. BMJ 2007;334:527-31.
108. Gore DR, Sepic SB, Gardner GM. Roentgenographic findings of the cervical spine in asymptomatic people. Spine (Phila Pa 1976) 1986;11:521-4.
109. Freedman MK, Overton EA, Saulino MF, Holding MY, Kornbluth ID. Interventions in chronic pain management. 2. Diagnosis of cervical and thoracic pain syndromes. Arch Phys Med Rehabil 2008;89:S41-6.
110. Anderberg L, Annertz M, Brandt L, Saveland H. Selective diagnostic cervical nerve root block--correlation with clinical symptoms and MRI-pathology. Acta Neurochir (Wien) 2004;146:559-65; discussion 65.
111. Boutin RD, Steinbach LS, Finnesey K. MR imaging of degenerative diseases in the cervical spine. Magn Reson Imaging Clin N Am 2000;8:471-90.
112. Okada E, Matsumoto M, Ichihara D, et al. Aging of the cervical spine in healthy volunteers: a 10-year longitudinal magnetic resonance imaging study. Spine (Phila Pa 1976) 2009;34:706-12.
113. Fryer G, Adams JH. Magnetic resonance imaging of subjects with acute unilateral neck pain and restricted motion: a prospective case series. Spine J 2011;11:171-6.
114. Patel TK, Weis JC. Acute neck pain in the ED: Consider longus colli calcific tendinitis vs meningitis. Am J Emerg Med 2017;35:943 e3-43 e4.
115. Urrutia J, Contreras O. Calcium hydroxyapatite crystal deposition with intraosseous penetration involving the posterior aspect of the cervical spine: a previously unreported cause of neck pain. Eur Spine J 2017;26:53-57.
116. Hitselberger WE, Witten RM. Abnormal myelograms in asymptomatic patients. J Neurosurg 1968;28:204-6.

117. Ohtsuka K, Terayama K, Yanagihara M, et al. An epidemiological survey on ossification of ligaments in the cervical and thoracic spine in individuals over 50 years of age. Nihon Seikeigeka Gakkai Zasshi 1986;60:1087-98.
118. Fujimori T, Le H, Hu SS, et al. Ossification of the posterior longitudinal ligament of the cervical spine in 3161 patients: a CT-based study. Spine (Phila Pa 1976) 2015;40:E394-403.
119. Sohn S, Chung CK, Yun TJ, Sohn CH. Epidemiological survey of ossification of the posterior longitudinal ligament in an adult Korean population: three-dimensional computed tomographic observation of 3,240 cases. Calcif Tissue Int 2014;94:613-20.
120. Kudo H, Yokoyama T, Tsushima E, et al. Interobserver and intraobserver reliability of the classification and diagnosis for ossification of the posterior longitudinal ligament of the cervical spine. Eur Spine J 2013;22:205-10.
121. Yoshii T, Yamada T, Hirai T, et al. Dynamic changes in spinal cord compression by cervical ossification of the posterior longitudinal ligament evaluated by kinematic computed tomography myelography. Spine (Phila Pa 1976) 2014;39:113-9.
122. Otake S, Matsuo M, Nishizawa S, Sano A, Kuroda Y. Ossification of the posterior longitudinal ligament: MR evaluation. AJNR Am J Neuroradiol 1992;13:1059-67; discussion 68-70.
123. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf. Accessed November 30, 2018.