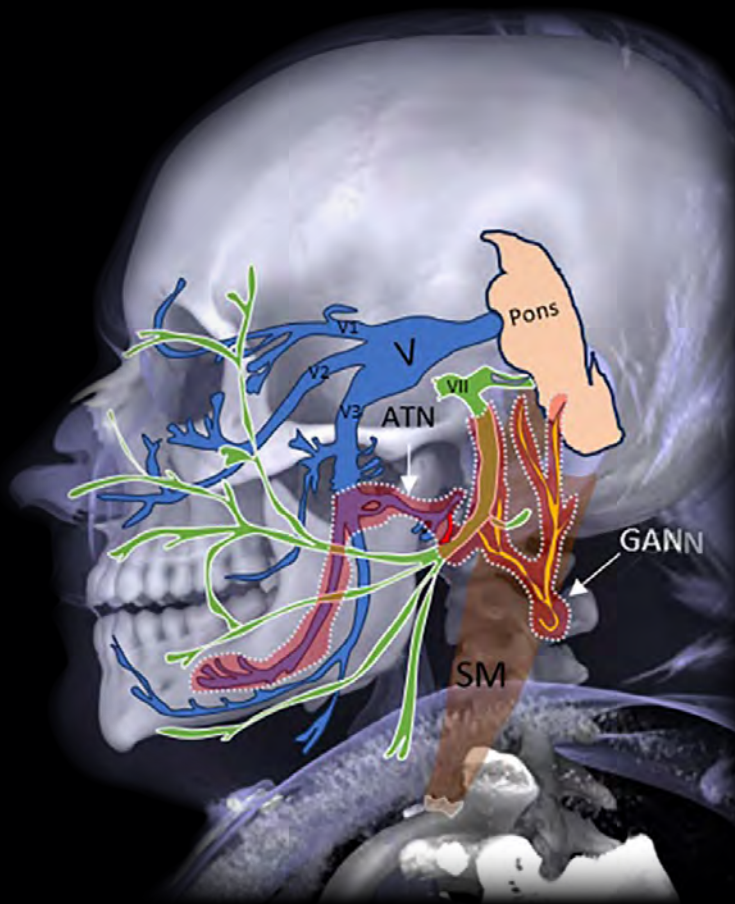


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# AppliedRadiology®

The Journal of Practical Medical Imaging and Management



Tracking the Silent Pathway:  
Imaging the Great Auricular  
Nerve— Insights for  
Radiologists

Artificial Intelligence in Soft  
Tissue Tumor Evaluation in  
View of Radiological Images  
Evaluation: Systematic  
Review and Meta-analysis

Beyond Reconstruction:  
The Next Frontiers in AI  
Imaging Acquisition

A Radiologist at the  
Bedside

Adult Cervical Embryonal  
Rhabdomyosarcoma

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## Tracking the Silent Pathway: Imaging the Great Auricular Nerve—Insights for Radiologists

Osama Raslan, MD

Although often overlooked on imaging, the great auricular nerve can serve as an important pathway for disease spread and a site of diverse pathology. This illustrated review highlights normal imaging anatomy, ultrasound techniques, and a spectrum of clinical entities—including schwannoma, perineural tumor spread, lymphoma, infection, neuralgia, and iatrogenic injury—with an emphasis on recognizing uncommon routes of head and neck cancer extension that can significantly influence diagnosis and patient management. .

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## Artificial Intelligence in Soft Tissue Tumor Evaluation in View of Radiological Images Evaluation: Systematic Review and Meta-Analysis

Razieh Shahnazari, PhD

Can artificial intelligence improve the radiologic evaluation of soft tissue tumors? This systematic review and meta-analysis of 7 studies encompassing more than 1,200 patients found that AI achieved an overall diagnostic accuracy of 82%, with 74% sensitivity and 88% specificity, supporting its potential as a complementary tool for lesion characterization while highlighting the need for prospective clinical validation.

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### Imaging Comes Home: Why More Neurology Practices Are Bringing MRI and PET Onsite



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# A Radiologist at the Bedside

Nina S. Vincoff, MD

Today, for the first time since I finished my internship, I found myself back on an inpatient unit. I had the honor of being invited to shadow our team members on rounds, observing the way they interact with patients, with one another, and with their leaders.

Much has changed in medicine over the past 3 decades. Advances in imaging, therapeutics, and technology are obvious. Even more transformative has been the evolution toward a model of care grounded in partnership, respect, and the active engagement of patients and families.

Today I watched nurses interact with patients with empathy, curiosity, and respect. Conversations began with open-ended questions. Team members ensured that patients understood their care plans and responded directly to their questions and concerns. Colleagues treated one another with professionalism, and leaders were visible and engaged. There was a consistent focus not only on the care being delivered, but also on how it was being experienced.

I do not recall hearing terms such as “shared decision-making,” “patient experience,” or “patient- and family-centered care” during my medical training. Yet today these principles are woven deeply into the fabric of health care delivery.

Just weeks ago, I began my tenure as Chair of the American College of Radiology’s Commission on Patient- and Family-Centered Care. Today I was reminded that patient- and family-centered care is not a program or a committee. It is an approach that places the needs, values, and perspectives of patients and families at the center of every aspect of care.

For radiology, this philosophy has never been more important.

Nearly every patient’s health care journey includes diagnostic imaging. Whether screening for disease, evaluating symptoms, guiding treatment decisions, or monitoring response to therapy, radiology touches patients across the continuum of care. Our specialty may not always have the visibility of bedside medicine, but our reach is broad and profound.

At the end of the morning, I sat down with one of our patient experience leaders to debrief. Together, we considered a simple question: How can we translate the patient-centered principles I observed at the bedside into radiology?

It is a question worth asking.

How do we ensure that patients understand what to expect before an examination? How do we communicate results in ways that inform rather than confuse? How do we design imaging environments that reduce anxiety and improve access? How do we incorporate the patient voice into quality improvement, safety initiatives, and operational decisions?

These questions are not peripheral to our mission. They are central to it. They are questions I look forward to exploring within my department, through my work at the ACR, and within the pages of *Applied Radiology*.

# Tracking the Silent Pathway: Imaging the Great Auricular Nerve—Insights for Radiologists

Osama A. Raslan, MD; Arzu Ozturk, MD; Marwan M. Ali, MD, MBA, FACOG, FACMG; Yasser G. Abdelhafez, MD, PhD; Alireza Paydar, MD; Lamia S. Choudhury, MD; Karleen Meiklejohn, MD; Marianne Abouyared, MD; Andrew C. Birkeland, MD; Arnaud F. Bewley, MD; Kader Karli Oguz, MD; Lotfi Hacein-Bey, MD

## Abstract

We present 2 cases of uncommon perineural tumor spread involving the great auricular nerve (GAN), provide a detailed description of the radiologic anatomy of the nerve in relation to surrounding organs and major nerve connections with a focus on key imaging findings of perineural spread, and describe major conditions that can involve the GAN through a comprehensive review of the literature. The clinical relevance of this work spans from enhanced detection of perineural spread in cutaneous cancers—whose incidence is rising—to improved familiarity with emerging treatment strategies involving the GAN.

**Keywords:** great auricular nerve, perineural tumor spread, head and neck cancer, auriculotemporal nerve, ultrasound imaging

## Introduction and Radiologic Anatomy

The great(er) auricular nerve (GAN) is the largest of the pure sensory superficial branches of the cervical plexus, receiving contributions mainly from the C2 and C3 ventral rami.<sup>1-3</sup> The GAN is most reliably identified—both clinically and radiologically—as it emerges superficially with a

characteristic looping appearance at the posterior border of the sternocleidomastoid muscle (SCM) (Figure 1). It ascends superficially, deep to the cervical fascia overlying the SCM, where it is particularly vulnerable to surgical injury.

To facilitate identification, several anatomical landmarks have been described, including the nerve point of the neck (punctum nervosum), Erb's

point, and McKinney's point. However, for greater anatomical precision, we prefer to use the “great auricular point” (GAP) to describe the optimal location for locating the GAN.

The GAP was consistently identified at approximately one-third the distance from either the mastoid process or the external auditory canal to the clavicular origin of the SCM, and about 1 cm posterior to the external jugular vein (Figure 1).

The GAN then divides into an anterior (facial) branch supplying the skin over the parotid gland and anteroinferior aspect of the auricle, and a posterior (mastoid) branch supplying the skin over the mastoid process and the posteroinferior aspect of the auricle.<sup>2,4,5</sup>

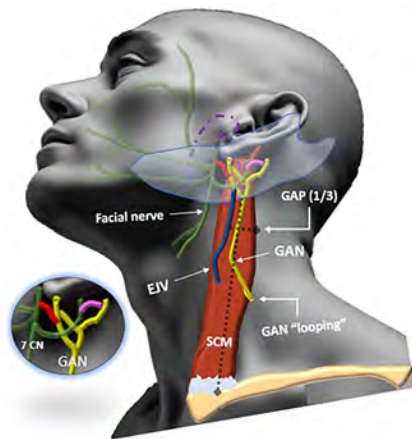
In the parotid gland, the anterior branch connects with the facial nerve (Figure 1, red). Posterior to the ear, the posterior branch connects with both the auricular branch of the vagus nerve and the posterior auricular branch of the facial nerve (Figure 1, pink). These connections

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**Declaration on the use of AI:** The authors of this manuscript declare that the patient image in Figure 1 is artificial intelligence (AI)-generated (magichour.ai); the remainder of the illustration was created by Osama Raslan, MD. No generative AI or AI-assisted technologies were used to generate content, ideas, or theories. We utilized AI solely to ensure anonymity in Figure 1 without compromising image quality or detail. This use was under strict human oversight and control. After the application of AI technologies, the authors carefully reviewed and edited the manuscript to ensure its accuracy and coherence.

**Figure 1.** Illustration of the great auricular nerve (GAN) (yellow), showing its characteristic “looping” at the posterior border of the sternocleidomastoid muscle (SCM) (GAN looping). The nerve ascends superficially on the surface of the SCM, deep to the cervical fascia, approximately 1 cm posterior to the external jugular vein (EJV). It then divides into anterior (facial) and posterior (mastoid) branches, which supply the skin over the parotid gland (purple dotted outline) and the auricle, respectively (light blue shaded area). The anterior branch connects with the facial nerve (green), and the posterior branch connects with the auricular branch of the vagus nerve (not shown) and the posterior auricular branch of the facial nerve (pink) (zoomed insert). The great auricular point (GAP) is identified at one-third the distance from the mastoid process or external auditory canal to the clavicular origin of the SCM (black dotted lines). (Subject image is artificial intelligence-generated (magichour.ai); remainder of the drawing is by Osama Raslan, MD; used with permission.)

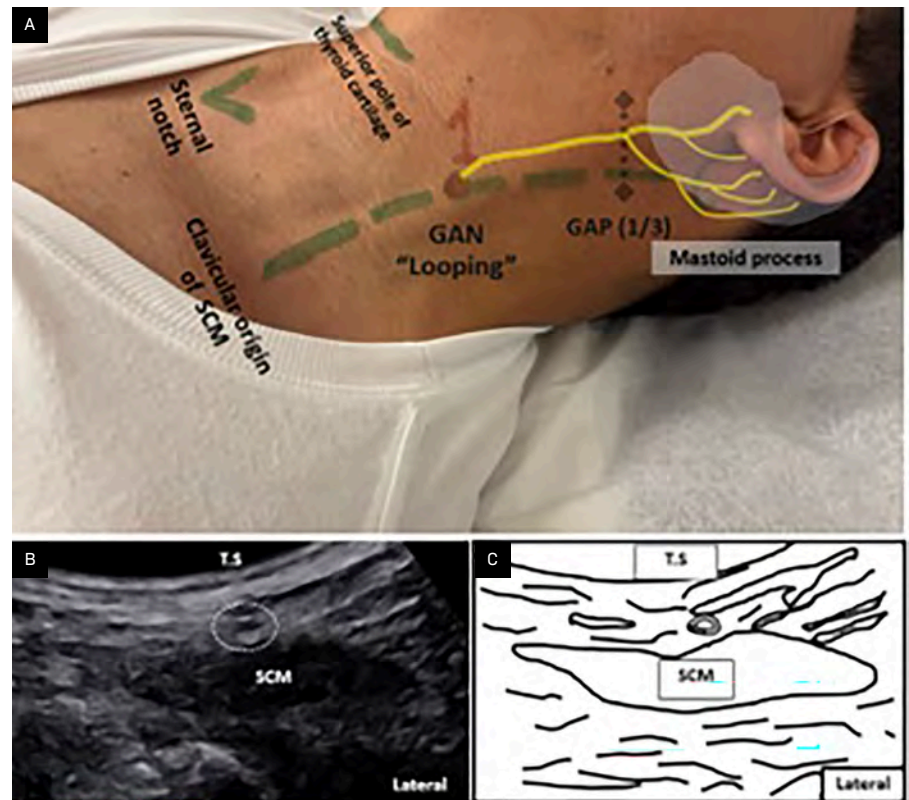


serve as conduits for perineural tumor spread (PNS) between the GAN, the facial nerve, upper cervical nerve roots (C2 and C3), and the vagus nerve.<sup>2,3,5-17</sup>

## US Imaging of the GAN

The GAN can be readily visualized using high-resolution US (HRUS) and is frequently identified in US-guided GAN nerve blocks.<sup>18-22</sup> Lieba-Samal et al were able to consistently visualize the GAN with an 18-MHz HRUS probe throughout its course, both in anatomical specimens

**Figure 2.** US of the greater auricular nerve (GAN). (A) With the patient in a supine or seated position and the head turned to the opposite side, identify key landmarks: the superior pole of the thyroid cartilage, the sternal notch, the clavicular origin of the sternocleidomastoid muscle (SCM), and its insertion at the mastoid process. The GAN emerges superficially at the “GAN-looping” point along the posterolateral border of the SCM and runs over the surface of the SCM to supply the skin over the lower auricle, parotid gland, and mastoid region (shaded white). The GAN can typically be found at approximately one-third the distance between the mastoid process (or external auditory canal) and the clavicular origin of the SCM. (B, C) Using a high-frequency superficial US probe (7-13 MHz) and these anatomical landmarks, the GAN (circled) appears as a small hypoechoic structure running longitudinally over the SCM and curving under its posterolateral border to join the superficial cervical plexus.<sup>18-23</sup>



and in vivo.<sup>21</sup> Reddy et al also used a 15-7-MHz hockey-stick transducer for GAN identification.<sup>20</sup>

The GAN is identified using the anatomical landmarks illustrated in Figure 2. A linear HRUS transducer is positioned at the GAN looping point, located at the level of the thyroid cartilage along the posterolateral border of the SCM. The normal GAN appears just superficial to the SCM as a small, rounded hypoechoic structure with internal linear hyperechoic fascicles, best visualized on longitudinal scans. When followed inferiorly, the GAN courses deep to the SCM to join the

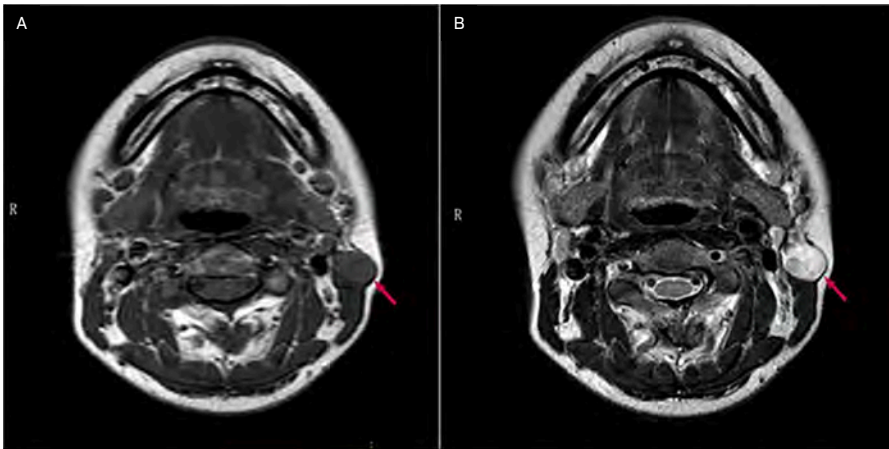
superficial cervical plexus. Tracing the nerve superiorly along the SCM reveals its bifurcation point.<sup>18</sup>

## Pathological Conditions of the GAN

### Schwannoma

Schwannoma of the GAN is extremely rare, with <10 cases reported in the literature.<sup>1,24-26</sup> The lesions are often diagnostically challenging to the clinicians as they usually present as a slowly growing asymptomatic unilateral neck lump with broad

**Figure 3.** A 29-year-old woman presented with a slowly growing mass on the left side of the neck. MRI demonstrated a well-defined, rounded lesion situated on the superficial surface of the sternocleidomastoid muscle (SCM). The mass exhibited intermediate signal intensity on T1-weighted imaging (A) and inhomogeneous hyperintensity on T2-weighted imaging (B), with clearly defined margins (red arrow). The location of the lesion over the SCM and its imaging characteristics are suggestive of a great auricular nerve schwannoma. (Images reproduced with permission from Xu and Sun.)<sup>24</sup>



differential considerations, including lymphadenopathy, and sebaceous cyst, among others, with schwannoma often finally diagnosed intraoperatively during an excisional biopsy, putting the surgeons at litigation risk due to the ensuing permanent sensory disturbance.<sup>24</sup> In their literature review, Oh et al highlighted the striking similarities in the presentation and clinical course of the 4 reported GAN schwannomas, with a median age of 49 years at presentation, a male:female ratio of 3:1, presentation as an asymptomatic neck lump, and an imaging of a well-defined benign-looking inhomogeneous lesion on the surface of the SCM or along the course of GAN (Figure 3).<sup>1</sup> To our knowledge, no cases of primary malignant GAN nerve sheath tumors have been reported in the literature as of July 14, 2025.

### Perineural Tumor Spread

PNS is a well-described phenomenon of head and neck cancer by which there is retrograde or antegrade extension of the tumor from the primary site along the nerve tissues.<sup>27</sup> It is an important finding indicating a worse prognosis, increased recurrence rate, and decreased 5-year survival by up to 30%.<sup>27</sup> PNS along the cranial nerves is a relatively well-known

and well-described phenomenon in the literature<sup>28</sup>; however, only a few articles described PNS along the spinal nerves, and to our knowledge, <15 articles have described PNS along the GAN.<sup>2,13-17,29-31</sup> As PNS can be asymptomatic, radiologists are often the ones who alert clinicians to the presence of GAN PNS, underscoring the importance of radiologists being familiar with this rare but significant tumor extension. Such awareness can help avoid delayed or misdiagnosis, as seen in our first case.

### Case 1

An 83-year-old man with a history of left jawline squamous cell carcinoma, treated by Mohs resection 3 months prior, presented with persistent pain at the surgical site and a 10-day history of slurred speech. Neurological workup and imaging were negative for stroke. Clinical examination revealed tenderness over the scar. PET/CT showed no recurrence but noted mildly increased FDG uptake in a presumed dilated left posterior auricular vein, likely inflammatory (phlebitis/thrombophlebitis) (Figure 4). MRA was inconclusive; venous Doppler supported superficial thrombophlebitis.

Despite treatment, symptoms progressed to left ear numbness, chin pain, facial droop, and incomplete eye closure, consistent with Bell's palsy and trigeminal neuralgia; managed with prednisone, valacyclovir, carbamazepine, and eyelid weight. The patient later developed periauricular/parotid swelling; CT and MRI revealed that the presumed thrombophlebitis was, in fact, PNS along the greater auricular nerve, with invasion of the left SCM and intraspinal extension through the left C2-C3 neural foramen. Imaging also identified a metastatic left parotid mass with additional perineural spread along the facial nerve (CN VII), mandibular division of the trigeminal nerve (V3), and the auriculotemporal nerve (Figure 5).

### Case 2

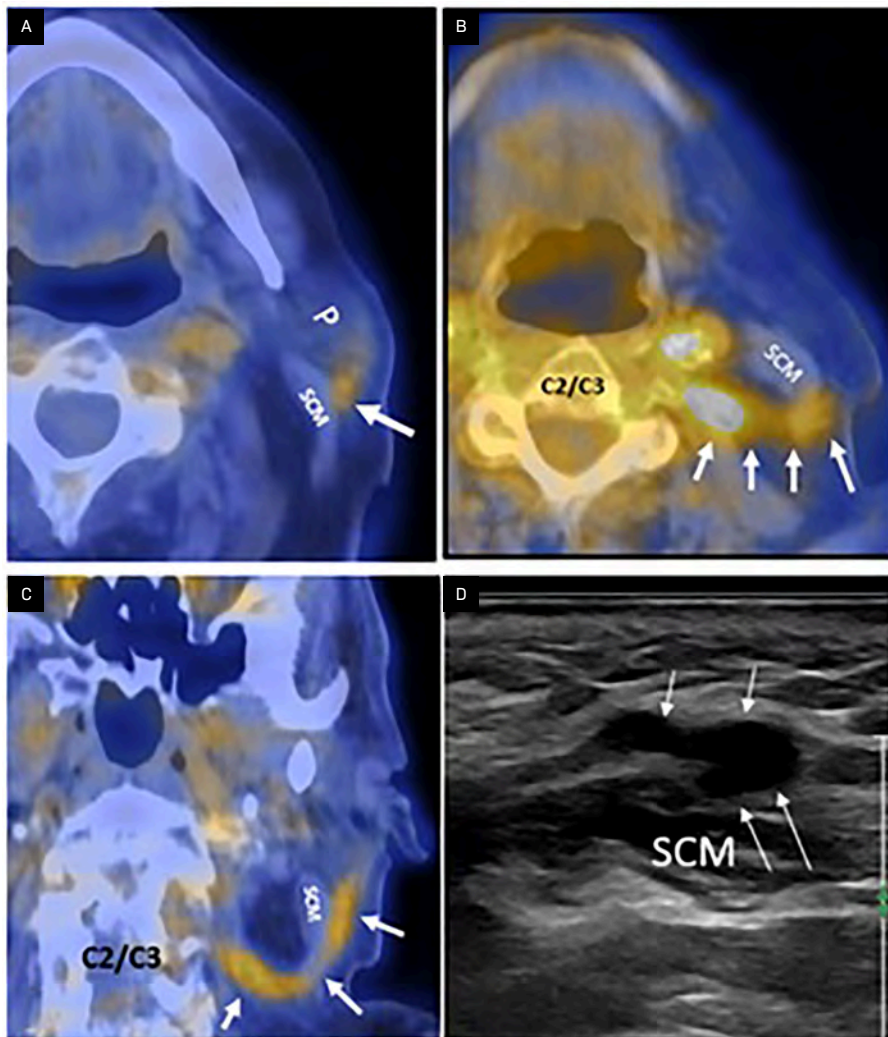
This case involves an 81-year-old male patient with a pathologically confirmed ulcerative cutaneous squamous cell carcinoma of the right cheek, demonstrating the same distinct pattern of perineural extension (Figure 6).

These 2 cases highlight a distinct pattern of perineural spread in which cutaneous malignancies near the parotid gland invade the GAN, extend along its connection to the facial nerve (CN VII), and subsequently spread via the auriculotemporal nerve to the mandibular division (V3) of the trigeminal nerve. Radiologists should be aware of this uncommon pathway and actively evaluate its presence in appropriate clinical contexts.

### Lymphoma

On our extensive literature search, only one case of low-grade GAN lymphoma was reported by Duvall et al in a 56-year-old woman with a history of lung sarcoidosis, presenting with intermittent pain involving the GAN distribution. MRI showed an enhancing soft tissue lesion in the superficial right parotid gland directly inferior to the ear pinna, suspecting sarcoidosis; however, the surgeon noted a visible enlargement of the GAN

**Figure 4.** Axial FDG PET/CT images (A, B) at the level of the parotid gland demonstrate hypermetabolic tumor recurrence (arrows) on the surface of the parotid gland (P), extending inferiorly along the surface of the sternocleidomastoid muscle (SCM) (A), with a characteristic “looping point” at the posterior border of the SCM (B). Coronal oblique FDG PET/CT (C) shows a hypermetabolic, thickened left great auricular nerve (GAN) tumor (arrows) extending retrogradely from the parotid region inferiorly along the SCM surface, followed by the characteristic cranial loop beneath the SCM and ascension along the GAN toward the C2-3 neural exit foramen. (D) US demonstrates perineural spread involving the left GAN and its branches on the SCM surface (arrow). The lesion was misinterpreted as a superficial venous structure due to lack of familiarity, deep hypoechogenicity from high tumor cellularity, and the branching pattern along the nerve.



intraoperatively, with surgical pathology revealing low-grade lymphoma.<sup>32</sup>

### Leprosy

*Mycobacterium leprae* has a propensity to involve Schwann cells and grows best in cool temperatures; hence, its great predilection for the superficially located peripheral nerves, most commonly the ulnar and peroneal nerves, with approximately 21 reports describing lepromatous GAN involvement.<sup>33-35</sup>

The disease is common in the tropics and subtropics, mainly in India and Brazil; however, in the United States, it is more commonly associated with contact with armadillos.<sup>35,36</sup> The patients usually present with cord-like swelling along the course of the GPN with corresponding sensory loss.

GAN enlargement can be clinically misdiagnosed as a thrombosed vessel, lymphadenopathy, IgG4-related disease, peripheral nerve sheath tumor, or PNS.

US imaging typically shows a hypoechoic, fusiform lesion, and CT/MRI will show an enhancing cord-like lesion following the course of the GPN. Imaging may also reveal the development of nerve abscesses requiring prompt surgical decompression to avoid irreversible damage.<sup>35</sup>

### Tuberculosis (TB)

Warpe et al described an unusual case of cervical tuberculous granulomatous lymphadenopathy with tuberculous granulomas involving the adjacent GAN in a 69-year-old woman presenting with painful tubular neck swelling. Neck ultrasonography and CT again misdiagnosed the GAN involvement as a thrombosed retro-mandibular/external jugular vein precluding FNA cytology, and the lesion was finally accurately diagnosed by surgical pathology. Neuropathy in patients with tuberculosis is more commonly iatrogenic from the antituberculous medications; however, this case highlights the possibility of a primary tuberculous.<sup>37</sup>

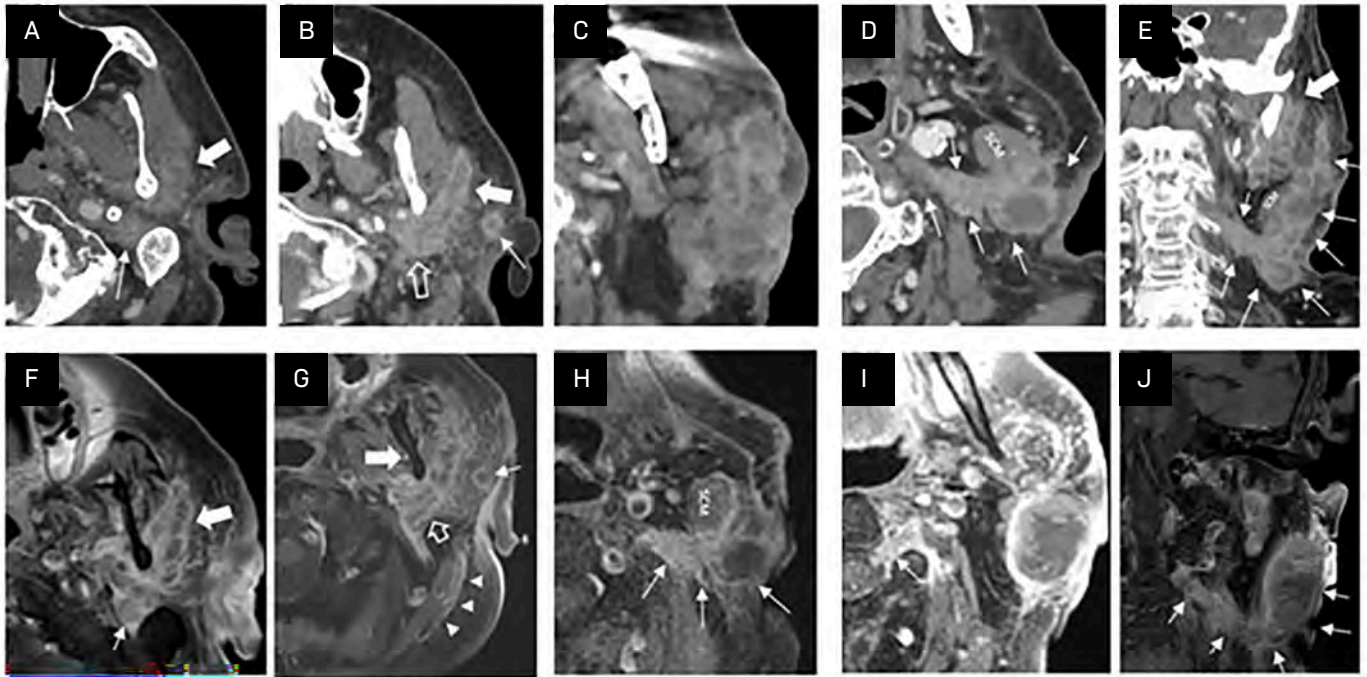
### Krabbe's Disease

Krabbe's disease is an autosomal-recessive lysosomal storage disorder that impairs myelin turnover, affecting both the central and peripheral nervous systems, including all cranial nerves—most notably the optic nerve. In addition to the well-documented intracranial findings of Krabbe's disease of nonenhancing symmetric areas of T2 prolongation within the periventricular white matter, and spinal findings of abnormal enhancement of the lumbosacral nerve roots,<sup>38,39</sup> Markes et al described a 13-year-old female patient with Krabbe's disease who presented with bilateral GAN hypertrophy in addition to the distal lower extremity weakness and sensory loss.<sup>40</sup>

### IgG4-Related Disease

IgG4-related disease is a systemic idiopathic fibroinflammatory condition rich in IgG4+ plasma cells affecting many organs, with predilection to the orbits, salivary and thyroid glands in the head neck region.<sup>41</sup> In our extensive literature

**Figure 5.** Axial (A-D) and coronal (E) contrast-enhanced CT, along with axial (G-J) and coronal (K) fat-saturated contrast-enhanced MRI images of the neck (arranged from superior to inferior), demonstrate extensive perineural tumor spread involving multiple cranial and cervical nerves. (A, G) Invasion of the facial nerve is evident at the stylomastoid foramen (thin arrow) and within the parotid gland (thick arrow). (B, H) Tumor extension is seen along the auriculotemporal branch toward the mandibular division of the trigeminal nerve (V3) (open arrow), with corresponding enhancement of V3 at the mandibular foramen on MRI (thick arrow in H). Invasion of the anterior branch of the great auricular nerve (GAN) is also noted (thin arrow). (C-D, I-J) Inferior sections reveal a confluent perineural mass along the GAN, with complete infiltration of the sternocleidomastoid muscle (SCM). The mass demonstrates the characteristic looping at the posterior border of the SCM (D, I) and ascends retrogradely through the C2-C3 neural foramen into the spinal canal (thin arrows in D-E and J-K).



search, 2 cases of IgG4-related GAN perineural disease have been reported, with one presenting as a palpable neck mass and resected as an enlarged lymph node only to discover a pathologically proven GAN IgG4-related disease with preferential epineurium involvement, and the second discovered intraoperatively during open cervical lymph node dissection.<sup>42</sup> Both cases also had orbital IgG4 disease and postoperatively were responsive to steroid treatment and subsequently suffered sensory loss.<sup>42</sup>

### Great Auricular Neuralgia

GAN *neuralgia* is described as unilateral brief stabbing pain of abrupt onset and termination, in the distribution of the GAN, which is commonly provoked by neck rotation and may remit and relapse like other craniocervical neuralgias. It is often confused with GAN *neuropathy*, which is usually a continuous or near-continuous pain, and commonly

described as a burning, paresthesia, or dysesthesia and often accompanied by reduced or absent sensation somewhere within the GAN distribution.<sup>22,32,43-46</sup>

GAN *neuralgia* can be either idiopathic or secondary to an underlying etiology; hence, imaging using US, CT, or MRI is warranted to evaluate for secondary causes such as inflammation, neoplasm, trauma, or iatrogenic injury, especially with a history of primary malignancy or worsening symptoms.<sup>32</sup>

### Traumatic/Iatrogenic Injury and GAN Sacrifice

Anatomically, the GAN is most vulnerable for traumatic and iatrogenic injury as it emerges from the posterior border of the SCM and runs in the superficial fascia of the SCM.<sup>5,32,47,48</sup> GAN is the most injured nerve with face lift with a complication rate of 6-7%.<sup>5,48</sup> Injury of the GAN has also been described following mandibular condylar

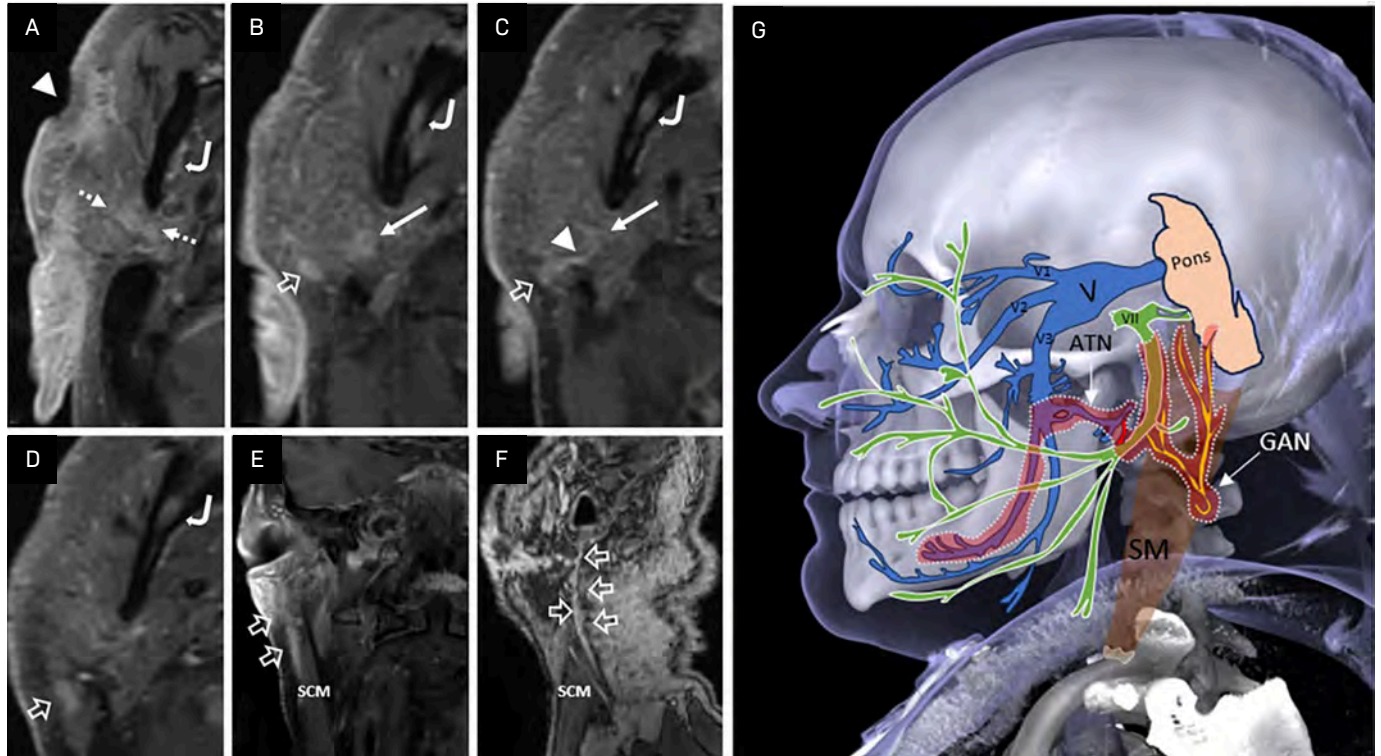
fractures,<sup>49,50</sup> carotid endarterectomy,<sup>49,51,52</sup> pacemaker placement,<sup>43</sup> parotidectomy or submandibulectomy,<sup>47</sup> cervical lymph node dissection, and shoulder arthroscopy.<sup>53</sup> GAN is also frequently sacrificed during parotidectomy.<sup>54</sup> GAN injury can lead to pure anesthesia, paresthesias, and even painful neuromas, and can lead to vexing functional impairments during shaving, combing hair, wearing earrings, and using the telephone. However, some authors also found that the quality of life in such patients was progressively less affected after 1 year.<sup>5,55-57</sup>

## Targeted GAN Interventions

### GAN Nerve Grafting<sup>58</sup>

Since its description by Alberti in 1962<sup>59</sup> and owing to its proximity to the surgical field, easier harvesting using constant surgical landmarks, and its

**Figure 6.** Axial (A-D, superior to inferior), coronal (E) post-contrast fat-suppressed T1-weighted images, and post-contrast oblique sagittal 3D FSPGR T1-weighted (F) MR images of the neck in an 81-year-old male patient. The images demonstrate a pathologically confirmed ulcerated cutaneous squamous cell carcinoma of the right cheek (arrowhead), with perineural invasion of the stylomastoid segment of the right facial nerve (long white arrow). The tumor extends to involve the right auriculotemporal nerve (ATN) (thick dashed arrow, A), the inferior alveolar branch of the trigeminal nerve (V3) (curved arrow, A-D), and the greater auricular nerve (GAN) (empty white arrow, B-F). Note the enhancing anterior branch of the GAN in panel (C), which connects to the facial nerve. (G) A diagrammatic representation illustrates a contiguous perineural tumor spread, highlighted by orange shading. The spread extends from the stylomastoid segment of the facial nerve (cranial nerve VII, green) through the ATN (blue) to the trigeminal nerve (cranial nerve V), including invasion of the inferior alveolar branch of the mandibular division (V3, blue). Additionally, tumor extension is depicted from the facial nerve to the GAN (yellow) via its anterior division connection.



similar diameter to the facial nerve, the GAN has become the nerve graft donor of choice for reconstructing injured facial nerves and has also been used for inferior alveolar nerve grafting.<sup>58</sup>

In their review of 128 patients of published GAN-Facial nerve grafting, Werner et al found that facial nerve tumors were the leading cause for grafting (72%) and that the outcome was mostly successful, with most (65%) patients regaining facial nerve function to House-Brackmann grade III (defined as moderate deficits).<sup>58</sup>

### Nerve Blocks and Neuromodulation

GAN block was classically accomplished via superficial cervical plexus block using large volumes of local anesthetics; however, Jeon et al described one of the earliest cases of highly selective US-guided

GAN block using smaller volume of local anesthetics and steroids in a 25-year-old man presenting with GAN neuralgia resistant to medications.

In addition, Elahi et al were able to demonstrate excellent pain relief not only on the ipsilateral but also on the contralateral side following GAN neuromodulation for a 32-year-old woman complaining of chronic, intractable headache, adding GAN neuromodulation as a viable treatment option for patients with medically refractory primary chronic headache.<sup>60</sup>

### Conclusion

GAN is an often-overlooked site of pathology, reflecting a significant gap in radiologic awareness. This article

reviews the radiologic anatomy, imaging techniques, and spectrum of GAN-related lesions, with a focus on a distinct pattern of perineural spread. Specifically, cutaneous malignancies adjacent to the parotid gland that invade the GAN can result in locoregional extension through both the facial nerve (CN VII) and the auriculotemporal nerve to the mandibular division (V3) of the trigeminal nerve. Increased awareness of this uncommon route will result in improved diagnostic accuracy, more appropriate and earlier patient-specific management, and better outcomes.

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# Artificial Intelligence in Soft Tissue Tumor Evaluation in View of Radiological Images Evaluation: Systematic Review and Meta-Analysis

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## Abstract

**Introduction:** In the field of oncological radiography imaging, artificial intelligence (AI) plays pivotal role, aiding both diagnosis and treatment. While computer-aided diagnosis has been employed in cancer imaging previously, it has shown limited clinical value; however, AI-based models are now routinely part of body organ imaging and are clinically used in many circumstances. The present study aimed to evaluate the diagnostic accuracy of AI in soft tissue tumor evaluation in view of radiological images evaluation.

**Methodology:** The present systematic review and meta-analysis included seven cohort studies of international databases, PubMed, Scopus, Web of Science, and Embase, from January 1, 2015, to May 10, 2025, using keywords aligned with the study objective. The statistical analysis was performed with Stata/MPv17 as fixed effect models.

**Results:** The accuracy of AI in soft tissue tumor assessment based on radiological images was 82% (ES = 0.82; 95% CI 0.68-0.96). The sensitivity and specificity of AI in soft tissue tumor assessment based on radiological images were 74%, and 88%, respectively.

**Conclusion:** AI tools related to imaging with high accuracy, sensitivity, and acceptable specificity can take positive steps toward helping in the diagnosis of soft tissue tumors.

**Keywords:** oncological radiography, artificial intelligence, imaging, cancer, soft tissue tumor

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## Introduction

Soft tissue tumors are a wide class of lesions that occur in nonepithelial, mainly mesenchymal, extraskeletal tissues such as blood vessels, muscles, tendons, fat, peripheral nerves, and fibrous tissue. The incidence of benign tumors is significantly higher than that of malignant tumors. However, rare benign tumors are more common in children.<sup>1,2</sup> These tumors are

classified according to their genotypic origin and phenotypic variation. Most soft tissue tumors are multifactorial in origin (environmental and genetic factors).<sup>3</sup> According to the World Health Organization (WHO 2020) report, soft tissue tumors fall into 11 categories.<sup>4</sup> Fibroblastic and fibrohistiocytic tumors are the most common benign soft tissue tumors after fatty neoplasms. Rhabdomyosarcoma, Ewing sarcoma, and synovial sarcoma are common in children, while liposarcoma, leiomyosarcoma, and undifferentiated pleomorphic sarcoma are the most common sarcomas in adults. Soft tissue sarcomas occur most frequently in the extremities (75%), followed by the trunk wall and retroperitoneum.<sup>4,5</sup>

The use of radiological imaging is of great importance for the evaluation and detection of soft tissue tumors; with the advances made in imaging methods, the presentation of data has increased significantly, which also requires a higher level of expertise to interpret the output data. Therefore, the workload of radiologists has increased, and, on the other hand, due to the complexity of the analysis, there is a need to update their knowledge; as a result, the creation of intelligent systems and algorithms can be a good helper for automatic analysis of images with higher accuracy and speed, and lead to accurate identification of soft tissue tumors with minimal interpretation errors.<sup>6</sup>

By analyzing medical data, artificial intelligence (AI) can aid in the understanding and timely diagnosis of disease.<sup>7</sup> It can also be used to diagnose the type of cancer and determine the appropriate treatment. In addition, AI can be useful in predicting and preventing side effects, as well as assessing a patient's response to various treatments.<sup>8</sup> AI has also recently gained popularity in medical image analysis. Medical imaging assessment with AI has been approved by the US Food and Drug

Administration for radiology.<sup>9</sup> However, there is insufficient evidence in the assessment of radiological images of soft tissue tumors, and further research is needed to confirm the evidence.<sup>10</sup>

Considering the importance of the subject and helping to reduce the workload of radiologists, diagnose soft tissue tumors early, with greater accuracy and speed, and help in the treatment process of patients, the present study aimed to evaluate the diagnostic accuracy of AI in soft tissue tumor evaluation in view of radiological images evaluation.

## Method

### Search and Study Selection

A comprehensive search was conducted using keywords relevant to the study objective in the international databases PubMed, Scopus, Web of Science, and Embase, covering the period from January 1, 2010, to May 25, 2025. All retrieved articles were imported into EndNote software. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

The PubMed search strategy included Medical Subject Headings (MeSH) related to soft tissue conditions, such as *Soft Tissue Neoplasms*, *Sarcoma*, *Soft Tissue Infections*, *Neoplasms*, *Connective and Soft Tissue*, *Therapy*, *Soft Tissue*, and *Soft Tissue Injuries*. It also incorporated specific subheadings for *Soft Tissue Neoplasms*, including complications, diagnosis, diagnostic imaging, etiology, prevention and control, radiation therapy, rehabilitation, surgery, and therapy.

These terms were combined with imaging-related MeSH terms, including *Radiology*, *Radiography*, *Radiation Oncology*, and the subheading *diagnostic imaging*, as well as the subheading *diagnosis*. The strategy further included

**Table 1. PICO Process in Selecting Studies**

| PICO STRATEGY          |                                                                       |
|------------------------|-----------------------------------------------------------------------|
| Patient/population (P) | Soft-tissue                                                           |
| Intervention (I)       | Radiology-based artificial intelligence                               |
| Comparison (C)         | Not defined                                                           |
| Outcomes (O)           | Diagnostic accuracy, diagnostic imaging, sensitivity, and specificity |

*Artificial Intelligence and Sensitivity and Specificity* as MeSH terms.

Additional diagnostic-related terms, such as *Diagnosis* and *Diagnostic Imaging*, were included, along with terms related to accuracy and advanced imaging techniques, including *Data Accuracy* and *Radiotherapy*, *Image-Guided*.

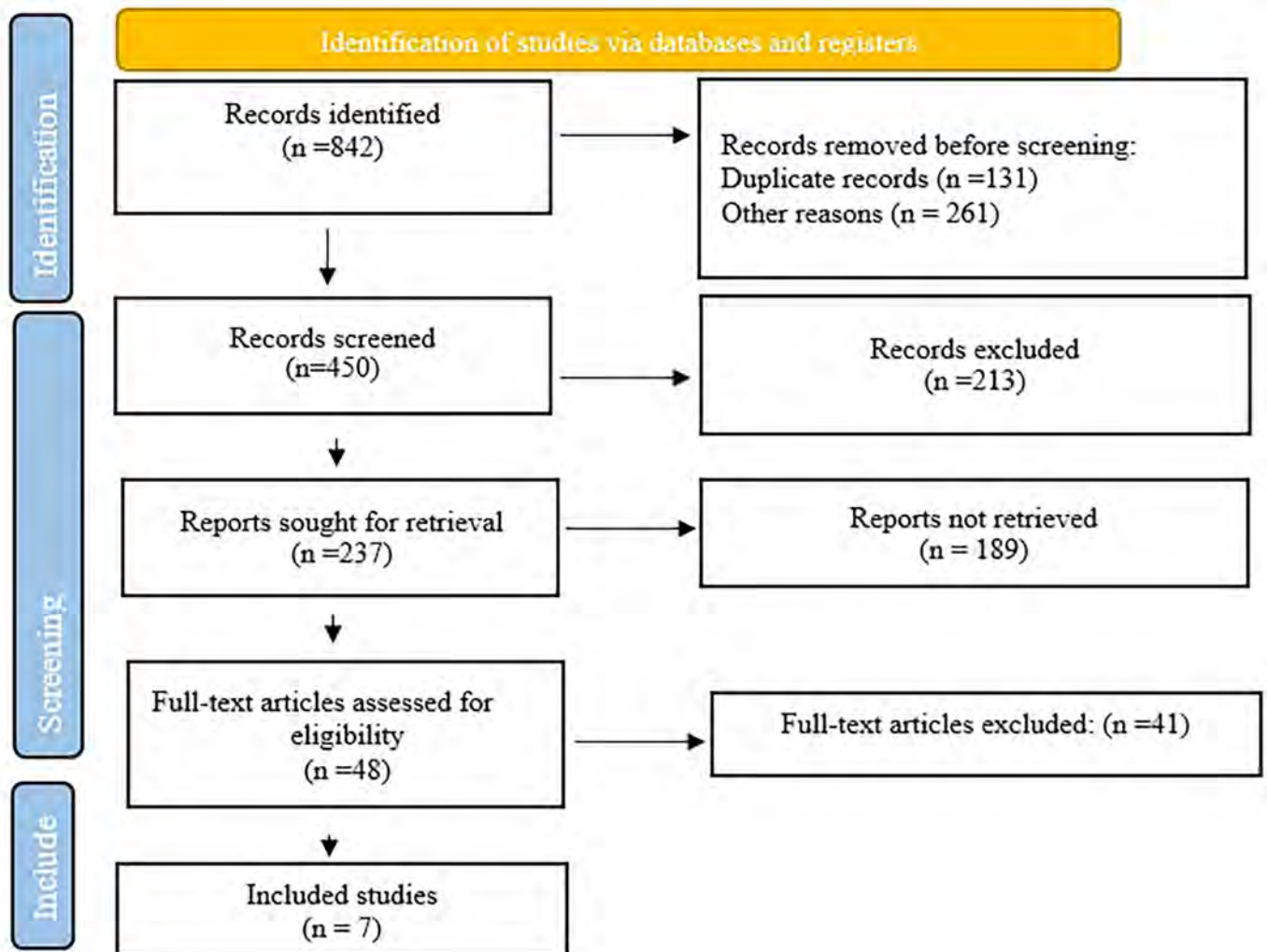
### Eligibility Criteria

The inclusion criteria were based on the PICO strategy (Table 1). Only human studies published in English were included. Studies evaluating AI applications in radiology were considered, including both prospective and retrospective designs, as well as randomized controlled trials.

The exclusion criteria included case studies of specific cancers and case reports, as well as studies exploring alternative diagnostic methods outside the scope of this review. Studies with incomplete or atypical data reporting were also excluded. Additionally, review articles, laboratory studies, animal studies, letters to the editor, conference papers, and studies without available full text were excluded.

### Data Extraction

A predesigned table was used to extract data from the included studies by two independent, blinded authors. In cases of discrepancies, a third author reviewed and resolved them through discussion. A final

**Figure 1.** Flowchart of Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 and selection of studies.

summary was then prepared based on the collected data.

The data extraction table included the following variables: study name (first author), year of publication, study design, number of participants, and outcomes.

### Quality Assessment

Quality assessment was conducted using the Newcastle-Ottawa Scale (NOS),<sup>11</sup> which evaluates studies across three domains: selection, comparability, and outcome. Studies with scores greater than seven on the NOS were considered high quality.

For randomized controlled trials, the risk of bias was assessed using the

Cochrane Risk of Bias tool (RoB 2), which is the recommended instrument for evaluating bias in randomized trials included in Cochrane Reviews.

### Statistical Analysis

The statistical analysis was performed with Stata/MP.v17 as random effect models. Effect size was calculated with 95% CI and the RMEL method.

### Results

A systematic review of the literature yielded 842 articles that met the search criteria. Based on the exclusion criteria, 392 articles were excluded based on

irrelevant or duplicate titles. Abstracts of articles that did not meet the inclusion criteria were removed from a total of 213 screened articles ( $n = 450$ ). 2 independent, blinded authors reviewed the full texts of 48 articles and screened them for inclusion and exclusion criteria. Only 7 articles met the inclusion criteria and were selected for consideration in this study (Figure 1).

### Characteristics of Included Studies

A total of 1230 patients from 7 studies were included in the analysis, comprising 5 retrospective studies and 2 prospective studies. Additional characteristics of the included studies are summarized in Table 2.

**Table 2. Main Characteristics of the Included Studies**

| STUDY                               | STUDY DESIGN  | NUMBER OF PARTICIPANTS | INTERVENTION                                         | ACCURACY | SENSITIVITY | SPECIFICITY |
|-------------------------------------|---------------|------------------------|------------------------------------------------------|----------|-------------|-------------|
| Guo et al <sup>12</sup>             | Retrospective | 185                    | Deep learning on MR images                           | 0.84     | 0.83        | 0.79        |
| Dong et al <sup>13</sup>            | Prospective   | 300                    | Machine learning model on endoscopic ultrasonography | 0.91     | 0.90        | 0.93        |
| <sup>1</sup> Ye et al <sup>14</sup> | Retrospective | 53                     | Deep learning on multiparametric MRIs                | 0.78     | 0.75        | 0.88        |
| Arthur et al <sup>15</sup>          | Retrospective | 89                     | Machine learning mode on CT                          | 0.84     | 0.92        | 0.91        |
| Liang et al <sup>16</sup>           | Retrospective | 126                    | Deep learning on MR images                           | 0.89     | 0.47        | 0.97        |
| Kang et al <sup>17</sup>            | Prospective   | 388                    | Machine learning mode on CT                          | 0.81     | 0.72        | 0.86        |
| Xie et al <sup>18</sup>             | Retrospective | 89                     | Machine learning model, radiographs                  | 0.68     | 0.57        | 0.91        |

**Table 3. Newcastle-Ottawa Scale Assessment of Cohort Included Studies**

|                            | SELECTION                            |                                |                           |                                               | COMPARABILITY | OUTCOME               |                     | TOTAL |
|----------------------------|--------------------------------------|--------------------------------|---------------------------|-----------------------------------------------|---------------|-----------------------|---------------------|-------|
|                            | REPRESENTATIVENESS OF EXPOSED COHORT | SELECTION OF NONEXPOSED COHORT | ASCERTAINMENT OF EXPOSURE | OUTCOME NOT PRESENT AT THE START OF THE STUDY |               | ASSESSMENT OF OUTCOME | LENGTH OF FOLLOW-UP |       |
| Guo et al <sup>12</sup>    | *                                    | *                              | *                         | *                                             | **            | *                     | -                   | 7     |
| Dong et al <sup>13</sup>   | *                                    | *                              | *                         | *                                             | **            | *                     | -                   | 7     |
| Ye et al <sup>14</sup>     | *                                    | *                              | *                         | *                                             | **            | *                     | -                   | 7     |
| Arthur et al <sup>15</sup> | *                                    | *                              | *                         | *                                             | **            | *                     | -                   | 7     |
| Liang et al <sup>16</sup>  | *                                    | *                              | *                         | *                                             | *             | *                     | -                   | 6     |
| Kang et al <sup>17</sup>   | *                                    | *                              | *                         | *                                             | *             | *                     | -                   | 6     |
| Xie et al <sup>18</sup>    | *                                    | *                              | **                        | *                                             | **            | *                     | -                   | 8     |

### Bias Assessment

Fivestudies received a score of 7-8/9 (low risk of bias) and 2 studies had moderate risk of bias (Table 3).

### Diagnostic Accuracy

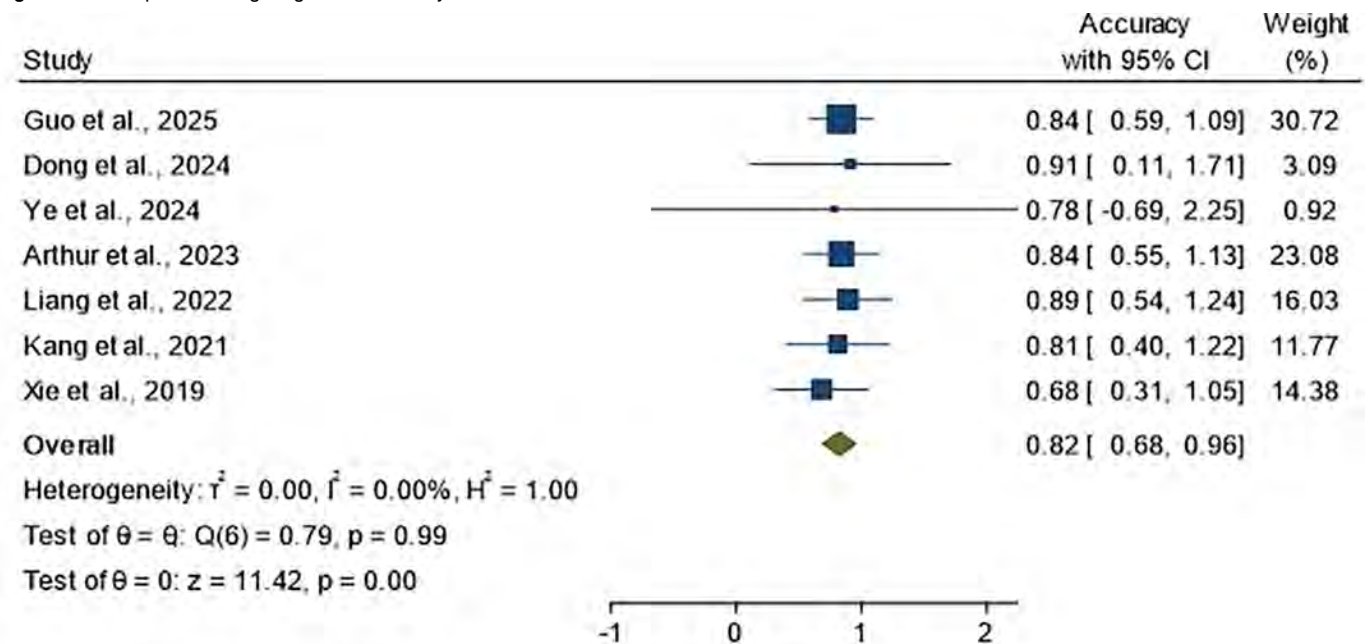
The overall diagnostic accuracy of AI in the assessment of soft tissue tumors based on radiological images was 82% (ES=0.82; 95% CI 0.68-0.96) (Figure 2). The sensitivity and specificity were 74% (ES=0.74; 95% CI 0.58-0.89) and 88% (ES=0.88; 95% CI 0.74-1.02), respectively (Figures 3, 4).

### Discussion

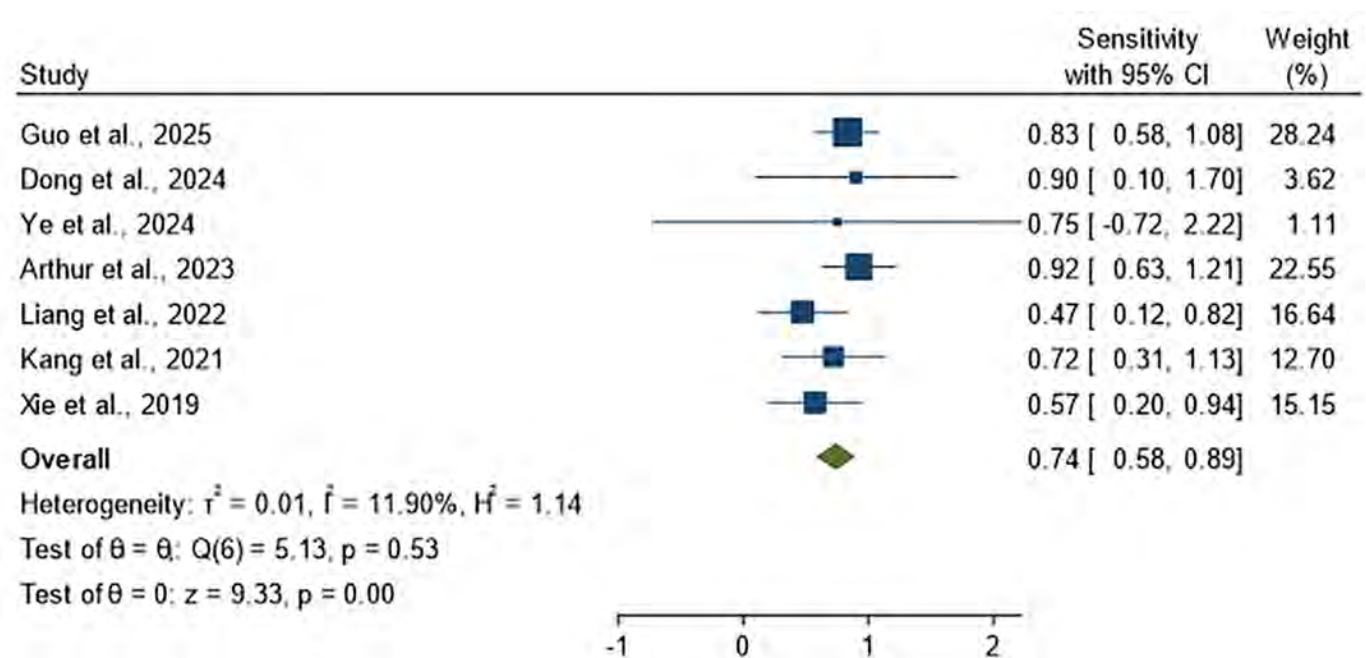
Despite advances in research and available evidence, soft tissue tumors remain a significant clinical challenge. Due to their low prevalence, many pathologists and physicians have limited experience with these lesions, which can lead to delays in diagnosis. Late diagnosis is particularly problematic, as advanced or inoperable tumors are more difficult to treat, and overall response rates remain low, ranging from 12% to

24%.<sup>19</sup> Therefore, improving diagnostic accuracy and adopting novel methods is of critical importance.

The diagnosis of benign and malignant soft tissue lesions still relies heavily on imaging techniques. The final diagnosis is often achieved through tissue sampling and histopathological interpretation, even though some clinical and imaging features may often help narrow the differential diagnosis. Although malignant tumors are usually larger, a significant percentage of soft tissue malignancies arise from small

**Figure 2.** Forest plot showing diagnostic accuracy.

#### Random-effects REML model

**Figure 3.** Forest plot showing sensitivity of artificial intelligence in soft tissue tumor assessment based on radiological images.

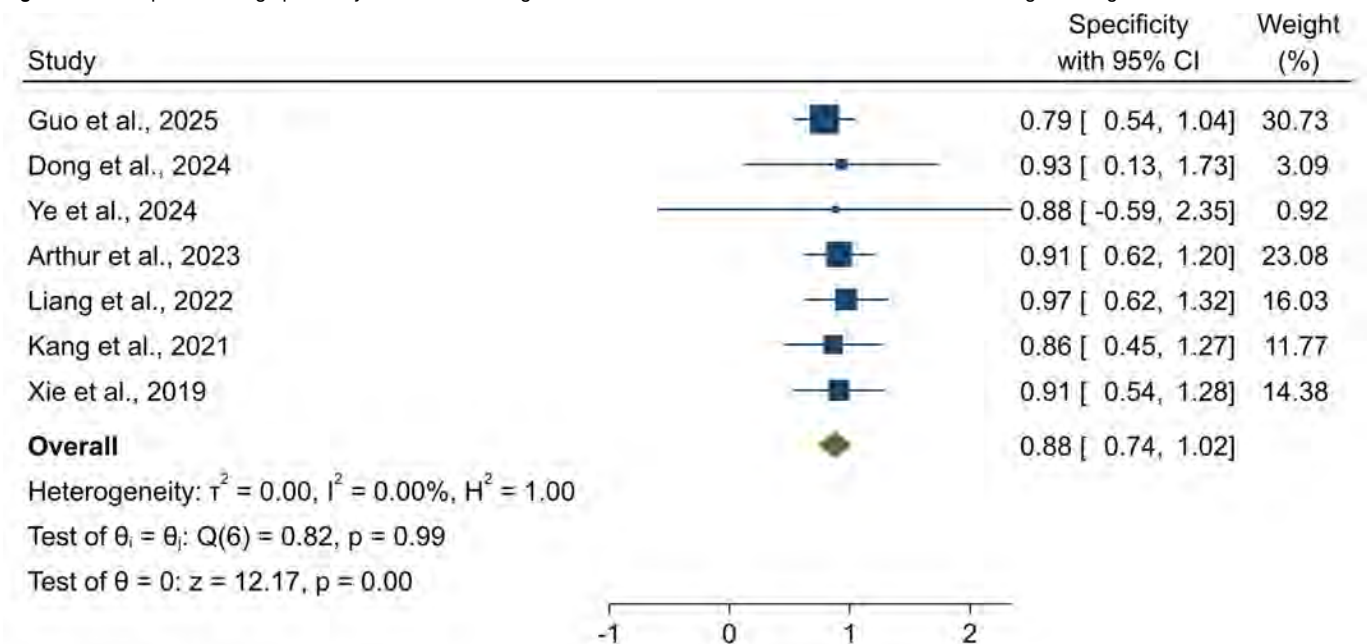
#### Random-effects REML model

soft tissue masses. During surgery, these small masses are more likely to be missed or removed less frequently.<sup>20</sup> Before tissue sampling, some imaging modalities, primarily contrast-enhanced MRI, may help narrow down the differential

considerations, even though histology is still the gold standard for diagnosis. The ability of conventional imaging modalities to accurately distinguish benign and malignant soft tissue tumors, however, has inherent limitations.<sup>21</sup>

AI has emerged as a tool that can assist radiologists with making timely, accurate interpretations of images, potentially improving patient survival and quality of life.<sup>22</sup> According to research, AI can be diagnostically comparable

**Figure 4.** Forest plot showing specificity of artificial intelligence in soft tissue tumor assessment based on radiological images.



#### Random-effects REML model

to human interpreting radiologists in a limited number of cases. Due to the complex biomechanical interactions between different anatomical structures, it is difficult for AI researchers to develop reliable algorithms in the face of multiple potential scanning angles and positional changes. Furthermore, complex preprocessing is often required to improve and standardize image quality before AI operations due to field strength, image noise, and acquisition parameter variability.<sup>23,24</sup>

In the present meta-analysis, AI demonstrated a diagnostic accuracy of 82%, with a sensitivity of 74% and specificity of 88% in the evaluation of soft tissue tumors using radiological images. These findings suggest that AI has considerable potential as a supportive diagnostic tool, enabling faster and reasonably accurate clinical decision-making.

Consistent with the results of the present study, Sudjai et al examining the results of machine learning for distinguishing between ALTs/WDL, observed that AI had high accuracy (88%) in separating muscle lipomas from ALT/WDL, and the performance of this model was

comparable to two radiologists with 7-22 years of experience.<sup>25</sup> Cay et al reported that AI could predict malignancy in lipomatous masses with a sensitivity of 96.8% and a specificity of 93.72%.<sup>26</sup> Fradet et al analyzed MRI results with AI and showed that the AI model could predict malignancy in lipomatous neoplasms with a diagnostic accuracy of 80%,<sup>27</sup> while another study found an accuracy of 88% using a radiomics-based nomogram for detecting malignancy in soft tissue masses.<sup>28</sup>

Heterogeneity among the studies was negligible, indicating that the findings of the present study provide relatively strong evidence. However, most of the included studies were cohort in design, and randomized trials are needed to provide stronger evidence by comparing diagnostic results by AI and radiologists. Despite these limitations, the findings support the integration of AI into radiological workflows as a complementary diagnostic tool.

Although there are encouraging trends in use, there are also a number of barriers and limitations to adoption. Even if AI implementations are validated, achieving high diagnostic accuracy is

essential. In order to maximize future applications in daily practice, practicing radiologists should strive to gain a comprehensive understanding of the use cases and challenges associated with implementing AI in prospective clinical workflows. Variability in the way AI applications are implemented is a significant barrier to their use. Neural networks require extensive and often complex training and refinement steps to mimic human cognition. Performance can also be significantly affected by changes in implementation strategies. Standardization supports generalizability and repeatability, increasing diagnostic confidence in potential applications.

#### Conclusion

Based on the findings of this study, AI demonstrates high diagnostic accuracy, sensitivity, and acceptable specificity in the imaging-based evaluation of soft tissue tumors. AI has the potential to facilitate earlier diagnosis and improve patient prognosis and treatment outcomes. However, the integration of AI into

clinical practice remains challenging, and further research is needed to enhance its clinical applicability, address ethical considerations, and optimize its role in radiology workflows.

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# Beyond Reconstruction: The Next Frontiers in AI Imaging Acquisition

Thomas Campbell Arnold, PhD; Ajit Shankaranarayanan, PhD; Suzie Bash, MD; Lawrence Tanenbaum, MD

Deep learning reconstruction (DLR) is a transformative technology that is rapidly becoming the standard of care across clinical practices. Faster scans, lower noise, and sharper images are no longer a competitive edge, but a baseline expectation. The question now is no longer whether artificial intelligence (AI) can accelerate acquisition, but whether it can make acquisition itself smarter.

The next frontier in acquisition AI is emerging across 3 principles: Acquire less. Acquire smarter. Acquire anywhere. Together, these principles reflect a broadening scope, from AI as a tool for image enhancement to AI as a system for workflow orchestration. As AI becomes more deeply embedded within imaging systems, scanners are evolving from passive hardware into intelligent, adaptive platforms.

The most efficient scan is the one that never needs to be acquired. DLR has already substantially shortened MRI and PET exam times, but there are limits to how much faster conventional acquisition can become. Another path to efficiency is not simply to accelerate scanning, but extracting greater value from the data already collected. This is the promise of image synthesis.

By leveraging information from a limited range of already acquired sequences, AI can infer tissue contrast characteristics to *synthetically* generate images, making additional acquisitions unnecessary (Figure 1).<sup>1</sup>

In practice, this approach can substantially shorten total exam times by reducing the number of series that must be routinely acquired on the scanner. By synthesizing missing information, these tools can also reduce the need for patients to return for additional scanning due to incomplete or motion-degraded studies (Figure 2).

AI tools can also extract information that was previously impractical or undesirable to acquire. DLR is widely used to reduce radiation dose in CT and PET. Additionally, now deep learning can synthesize a CT-like image from a spine MRI (Figure 3), and for many use cases avoid an additional scan and radiation exposure, which is particularly beneficial for pediatric patients.<sup>2</sup> This technology has high fracture sensitivity, which is useful as MRI reports often miss spondylolysis,<sup>4</sup> resulting in significant delays in specialist evaluation.

With image synthesis, the goal is not simply faster scanning, but more efficient

use of the information already available. AI tools capable of deriving monochromatic, monoenergetic spectral information from a conventional polychromatic CT study are also becoming increasingly prevalent. These techniques can routinely boost the visibility of contrast-enhancing lesions and, in some cases, salvage suboptimal vascular studies by increasing iodine conspicuity.

Synthetic acquisition represents only one component of the AI-enabled opportunity. Traditionally, imaging studies consist of sequences prescribed in advance. Fixed protocols are one of MRI's hidden inefficiencies, consuming valuable scanner time acquiring sequences that are ultimately unnecessary, or omitting needed sequences and resulting in patient recalls.

Ideally, AI can make acquisition more responsive to real-time context by suggesting subsequent imaging steps based on what it has already identified. Rather than relying solely on protocols derived from limited clinical history, AI can detect relevant findings while the patient is still on the table and recommend protocol modifications in real time (Figure 4). For example, a routine brain MRI could be automatically redirected toward a dedicated internal auditory canal or pituitary protocol, thereby increasing diagnostic yield and avoiding the need for a callback.

In some cases, AI could determine that no further imaging is required because the sequences already acquired indicated a low likelihood of clinically significant pathology. Conversely, AI could alert imaging teams about the potential

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**Figure 1.** Example of an artificial intelligence algorithm that generates a synthetic STIR sequence from sagittal T1-weighted and T2-weighted spine MRI. The synthetic STIR image shows comparable depiction of vertebral pathology and edema to the acquired STIR image.



**Figure 2.** When a sequence is degraded by patient motion (right), information from other sequences acquired during the same exam can be used to synthesize a replacement image, eliminating the need for rescanning.



value of adding contrast injection when unexpected findings are detected, while reducing overreliance on routine contrast when it's unlikely to provide additional diagnostic value.

AI can also detect urgent findings in real-time and prioritize workflows through integration with PACS. In practical terms, fewer recalls, fewer repeat scans, and better technologist leverage translate directly into improved throughput and greater scanner efficiency. Additionally, AI can communicate urgent findings and

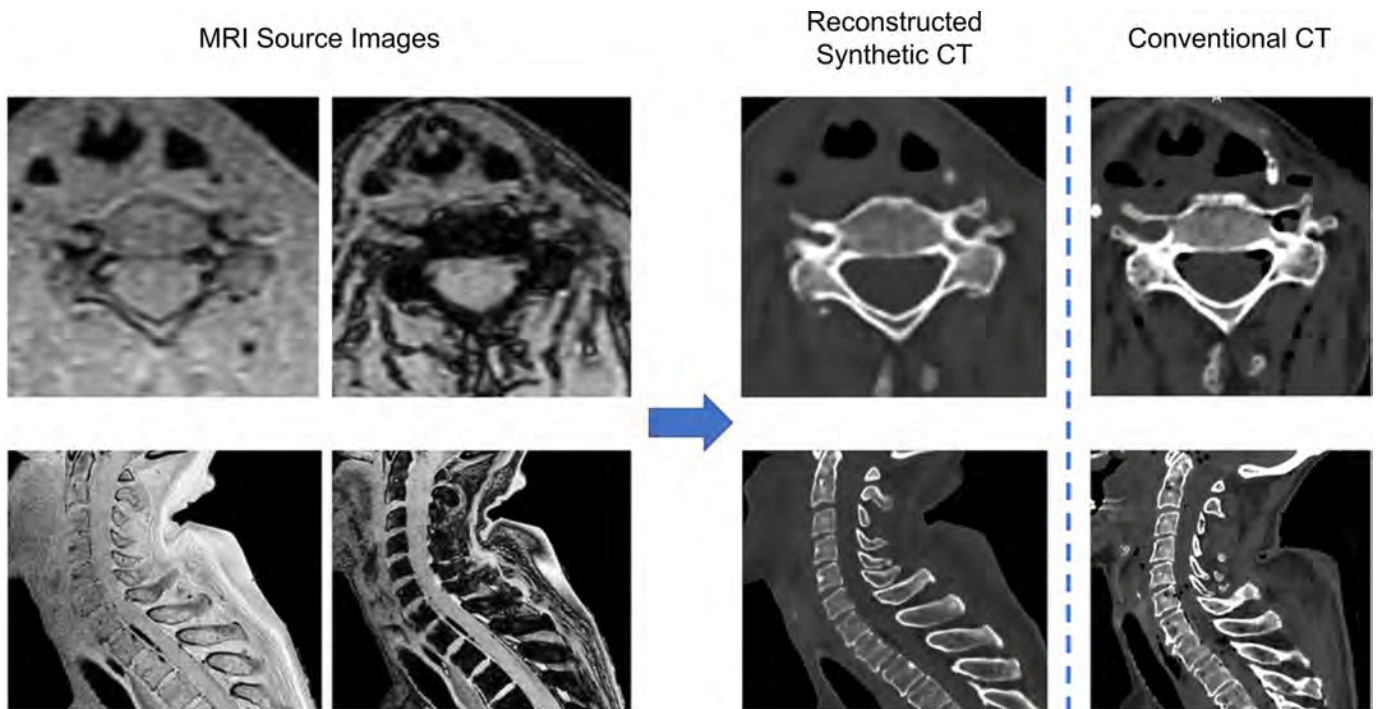
key images to the care team through Health Insurance Portability and Accountability Act-compliant mobile applications before formal radiologist interpretation. In acute ischemic stroke, these technologies have been associated with reductions of up to 87 minutes from emergency department arrival to thrombectomy,<sup>5</sup> with resultant shorter hospital stays and significant improvements in patient outcomes.

Even optimized protocols still depend on technologists to execute them. As imaging volumes rise, the availability of skilled

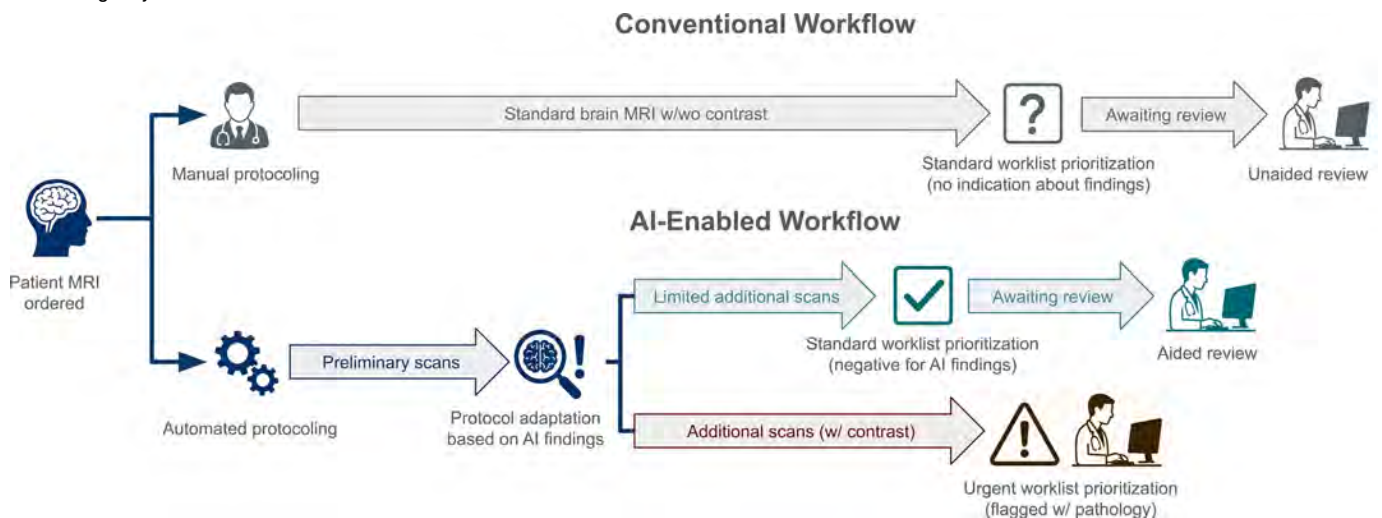
personnel remains one of radiology's most significant operational challenges. Companies are increasingly applying AI to automate complex acquisitions, such as cardiac MRI, enabling sites to offer advanced studies that might otherwise require specialized technologist expertise and distributing enterprise capabilities to better match scanner capacity and patient needs.

In addition, it is becoming increasingly challenging for even experienced technologists to tailor examinations as

**Figure 3.** Examples of conventional CT and MRI-based synthetic CT images. Synthetic CT can provide CT-like anatomical information for surgical planning while avoiding additional ionizing radiation exposure, particularly in pediatric patients. Reprinted under Creative Commons license 4.0 from the *Journal of Neurosurgery: Spine*.<sup>2</sup>



**Figure 4.** Conventional radiology workflows rely on manual protocol selection, fixed imaging protocols, and static worklists (top). Artificial intelligence-enabled workflows (bottom) can automate protocoling, adapt imaging sessions based on preliminary findings, and prioritize worklists according to clinical urgency.



acquisition speeds continue to increase, especially with rising demands from simultaneous, remote scanning. This is where AI-enabled operational tools provide substantial value. Real-time

scan monitoring, technologist decision support, and automated quality control can reduce the number of expert decisions required per exam while also reducing sequence repeats and patient call-backs.

MRI has been the clearest example of AI-driven transformation in acquisition, largely because its historically longer scan times made inefficiencies easier to identify. However, every imaging

modality stands to benefit as AI expands beyond reconstruction and into workflow orchestration and operational decision-making. The long-term implication is not merely more efficient imaging, but progressively more autonomous imaging systems, with scanners increasingly capable of adapting examinations with minimal human intervention.

The next competitive advantage in radiology will not be faster scans; it will be smarter examinations.

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# Finding Joy in Our Daily Radiology Job

Juan D. Guerrero-Calderon, MD

Completing our training and starting our jobs may feel like the climax of our career. After years of studying and passing tests, we are finally done. The first 3-6 months as practicing radiologists are an exciting period of adaptation, in which we build up our confidence as independent practitioners of image-guided procedures and final signers of our reports.

But soon, the thrill of the initial stage has passed, our certifying exam is behind us, and we settle into our new, daily routine. Suddenly we may find ourselves feeling unsettled, wondering how to find joy and purpose in our daily work.

The medical education system trains us to feel accomplishment by successfully passing from one stage of schooling to the next. We immerse ourselves in passing board exams and applying to college, medical school, residency, and fellowship. Our limbic system becomes accustomed to the continuous cycle of examinations, from SAT, to MCAT, to USMLE, to Core exams. Once we've passed these milestones and become radiologists, we may surprise ourselves by missing the dopamine surges of grades and evaluations. The daily routine of our work, despite the diagnostic challenges, may feel more robotic and less fulfilling than we imagined.

As new attendings, we soon face other realities. Joining the radiology workforce opens our eyes to aspects of healthcare economics that we may not have appreciated during training. Staffing shortages result in higher imaging volumes than we expected. Meeting RVU targets and other productivity metrics feels at odds with the way we envisioned our careers in medicine.

We may be surprised, so early in our careers, to already feel disillusioned or even feelings of burnout. So, how do we address these feelings and find joy in our work?

Our new attending salary, after years of medical student tuition and low-paying training programs, may provide an initial sense of

satisfaction, but it is quickly fleeting. Psychologists describe this phenomenon as the hedonic treadmill model. Positive or negative life events temporarily affect our happiness. But those effects fade over time and we return to baseline.<sup>1</sup>

Maintaining the joy we experience in our daily work requires more than material rewards; it requires satisfying our personal sense of purpose. We must balance short-lived experiences linked to "hedonic well-being" with longer-term practices linked to "eudaimonic well-being," the sense of meaning that results from realizing one's potential.<sup>2</sup> In other words, we must remind ourselves of the reasons we became physicians and keep that fire burning through mindful reflection and intentional action.

As a form of meditation, mindfulness has been found to have a positive and direct association with eudaimonic well-being.<sup>3</sup> Mindfulness is the practice of maintaining a state of heightened, non-judgmental awareness of one's thoughts, emotions, or experiences,<sup>4</sup> which may reduce stress, depression, and anxiety.<sup>5</sup>

Amidst the stress of high volumes of work, we can focus our awareness on the ways our work can elevate patient care. Every single image we interpret and procedure we perform has an impact on patient outcomes. Even when we are not directly interacting with patients or clinicians, our work plays a central role on the care team.<sup>6</sup>

Outside the workplace, we can find well-being through our interactions with family and friends and by prioritizing our personal health. We may reconnect to our purpose as physicians by getting out of the darkness of our reading room and involving ourselves in medical/radiological societies, global health organizations, or patient advocacy.

Sometimes, the solution to burnout can be taking a sabbatical. Owen and Owen were early-career radiologists who took an unpaid 6-month sabbatical to travel around the world with their 3 children of ages 10, 12, and 14. They describe returning to their academic

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radiology jobs with a “new appreciation for how good our lives are and how lucky we are to have fulfilling careers.”<sup>7</sup>

Finally, if the culture of our practice no longer aligns with our purpose, it may be time to find a better fit and to know we are not alone in making that decision. Radiologist turnover rates were 61.2% higher in the 2020-2022 period versus 2013. Turnover rates were higher for female radiologists, those in metropolitan areas, and those with fewer years of practice.<sup>8</sup>

Burnout rates have been substantial even among the most resilient physicians.<sup>9</sup> Whatever strategies we ultimately choose to help us find joy, our first step should be an acknowledgment that our feelings are common and do not reflect personal failure. The next step is recognition that joy is possible, and that the pathway to finding it will be different for every individual.

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# Nontraumatic Medial Orbital Blowout Fracture

Chad Jones, MD; Asif Bhimani, MD

## Case Summary

A healthy adult presented with progressive left eye swelling, left eye pain, and bloody mucus following forceful nose blowing. The physical exam was remarkable for significant edema and tenderness to palpation of the left upper eyelid and mild discomfort with upward gaze. Extraocular movements were intact. The exam was negative for skin erythema/ecchymosis, scleral erythema, subconjunctival hemorrhage, hypopyon/hyphema, and eye discharge.

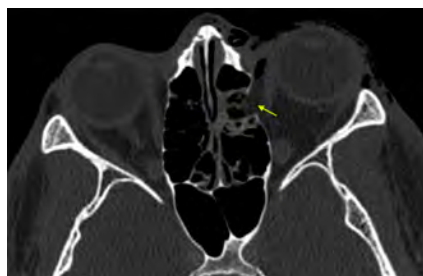
## Imaging Findings

Contrast-enhanced thin-slice CT of the maxillofacial bones demonstrated a left medial orbital wall fracture with herniation of fat (Figure 1). There was mild left proptosis without evidence of extraocular muscle entrapment (Figure 2). A moderate amount of orbital and periorbital emphysema was visualized that tracked to the contralateral side (Figure 3).

## Diagnosis

Nontraumatic medial orbital wall blowout fracture

**Figure 1.** Axial bone window CT demonstrating a left medial orbital wall blowout fracture with herniation of orbital fat (arrow) and mild left proptosis. No extraocular muscle entrapment is seen.



**Figure 2.** Coronal bone window CT with redemonstrated fracture defect in the left medial orbital wall with herniation of intraconal fat (yellow arrow). The left medial rectus is contained within the orbit (red arrow).



**Figure 3.** Axial lung window CT reveals left-sided orbital emphysema, which is seen tracking from the fracture defect along the medial orbital wall to the left preseptal space (yellow arrow). Air tracks to the contralateral orbit through the anterior nasal subcutaneous tissues (red arrow).



fractures are defined as those limited to the internal orbit, while impure orbital fractures involve the orbital rim and require realignment prior to surgical reconstruction.<sup>1</sup> The majority of pure internal orbital fractures are blowout fractures involving the orbital floor or medial orbital wall.<sup>1</sup> The mechanism of these fractures is most commonly secondary to direct trauma, whereby the increase in intraorbital pressure overcomes the structural integrity of the orbital bones.

Orbital blowout fracture in the absence of trauma, as presented here, is rare. A review of the literature reveals just a few other cases of orbital blowout fractures from nose blowing<sup>2-7</sup>; however, the fractures in this case occurred at the orbital floor rather than at the medial orbital wall. A similar case of atraumatic medial orbital wall fracture was found in our review,<sup>8</sup> but in that case the orbital emphysema was unilateral.

We believe our case is a unique presentation where the less-common

## Discussion

The orbit is a complex anatomic structure, and recognizing fracture patterns in this region is crucial to guide proper management. Pure orbital

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atraumatic medial orbital fracture caused orbital emphysema, which tracked from the side of injury to the contralateral orbit.

Increased intrasinus pressure would ordinarily be expected to cause a blow-in fracture, displacing the bone fragment into the intraconal space. In all the reviewed cases of blowout fractures, including ours, the fragment was displaced into the sinus. We hypothesize that these types of fractures initially occur as blow-in fractures secondary to increased intrasinus pressure. However, once sinus pressure is normalized, the pressure gradient is reversed, and the fracture fragment is displaced into the sinus, giving the appearance of a blowout fracture.

Most reported cases of atraumatic orbital blowout fracture did not require surgical intervention. Only antibiotic prophylaxis was necessary to protect against sinus pathogens, which may enter the orbit through the fracture defect.

Owing to a large fracture defect causing significant risk of hypophthalmos, orbital floor reconstruction was performed in one reviewed case.<sup>4</sup> While no cases of atraumatic medial orbital wall fractures requiring surgical intervention were found, scrutinizing the medial rectus muscle, medial canthal ligament, and the lacrimal duct system to evaluate for emergent pathology is important. Injury

to these structures can present clinically as restricted and painful ocular abduction, diplopia, and enophthalmos, all of which may warrant surgical exploration.<sup>9</sup>

Moreover, while most cases of orbital emphysema resolve spontaneously, rapidly increasing burden of emphysema can lead to acute orbital compartment syndrome, leading to permanent vision loss from optic nerve stretching or vascular compromise. Short-term follow-up and strict return precautions should be implemented in these cases to prevent these adverse patient outcomes.

## Conclusion

While orbital blowout fractures and orbital emphysema are most commonly caused by direct trauma, these entities should not be ruled out in atraumatic patients. Those with chronic sinusitis/rhinitis or congenitally thin sinus bones are at increased risk of barotrauma-induced fracture. Awareness of atraumatic orbital fractures can reduce unnecessary medical investigations and potentially shorten hospitalization. A careful examination of the orbital bones and surrounding structures with dedicated thin-slice orbital CT should always be performed in the presence of clinical signs of orbital injury.

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# Adult Cervical Embryonal Rhabdomyosarcoma

M. Grant Liska, MD; Se Yeon Seo, MS; Yi Yeon Seo, MS; Jamie Marko, MD

## Case Summary

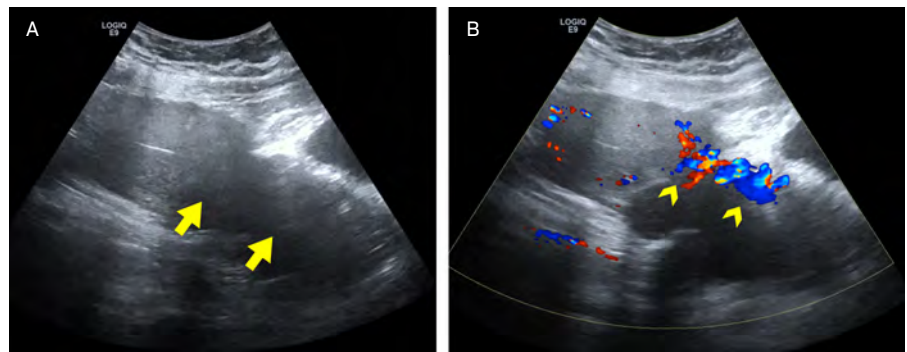
An adult patient presented with complaints of irregular vaginal bleeding with pelvic fullness and pain. Physical examination demonstrated a friable endovaginal soft-tissue mass, clinically presumed to be uterine prolapse.

The patient underwent a total abdominal hysterectomy and bilateral oophorectomy. Surgical pathology revealed cervical and uterine myoinvasion with no evidence of metastatic disease, consistent with stage IC according to the International Federation of Gynecology and Obstetrics (FIGO) Staging System for Adenosarcoma of Uterine Corpus, an unofficial staging system in this case. Following gross-total resection, the patient underwent four cycles of systemic chemotherapy, and the most recent postoperative imaging showed no evidence of disease recurrence.

## Imaging Findings

Initial imaging with transabdominal US demonstrated an amorphous hypoechoic endocervical mass with significant vascularity (Figure 1). A follow-up MRI revealed a 9.0 cm lobular T1 hypointense, T2 hyperintense mass originating from the upper cervix/lower uterine segment

**Figure 1.** (A) Grayscale transabdominal US image in the sagittal plane reveals a poorly defined, hypoechoic mass (arrows) with posterior shadowing in the cervix. (B) Color Doppler image demonstrates significant vascularity (arrowheads).



border and protruding into the vaginal cavity (Figure 2). The mass demonstrated heterogeneous enhancement on T1 post-contrast images (Figure 2), as well as significant diffusion restriction (not shown). There was no convincing evidence of local invasion. On preoperative CT images, the mass appeared as an ill-defined hypoattenuating region causing cervical canal dilation and filling of the vaginal cavity (Figure 3).

## Diagnosis

Cervical embryonal rhabdomyosarcoma (ERMS), stage IC.

Differential considerations include uterine prolapse, pedunculated cervical

leiomyoma, endometrial polyp, cervical adenoma malignum, and other primary cervical malignancies.

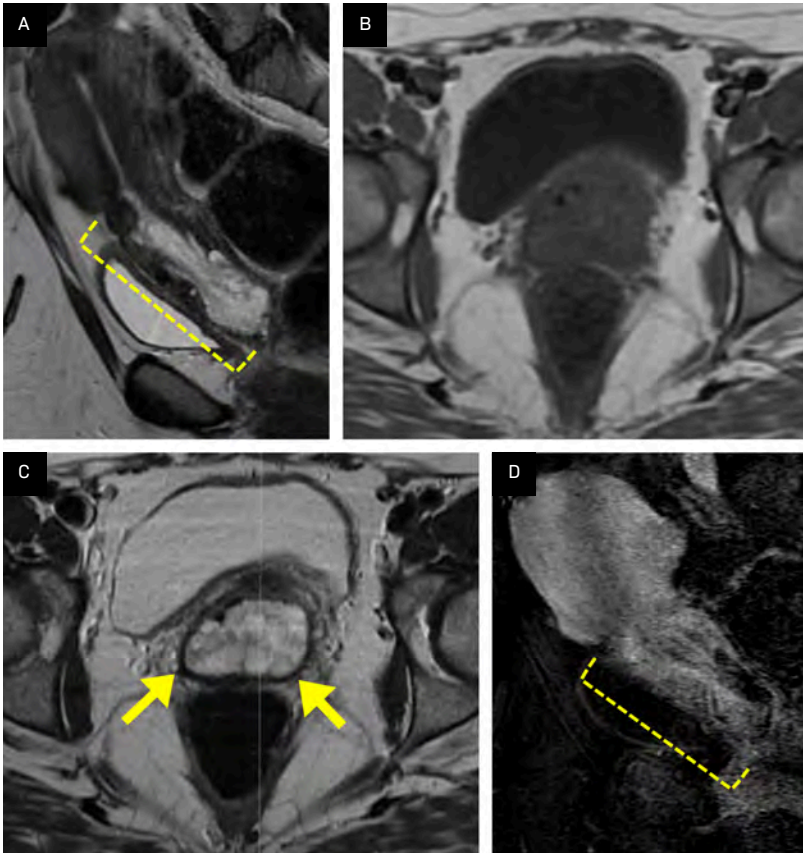
## Discussion

Rhabdomyosarcoma is a malignant mesenchymal tumor characterized by the presence of rhabdomyoblasts, immature skeletal muscle cells that fail to fully differentiate.<sup>1</sup> Among the various histological subtypes, ERMS is the most prevalent, accounting for roughly 50% of cases and affecting the genitourinary tract in 18-22% of cases.<sup>2</sup> ERMS typically affects infants, particularly in the vaginal area.<sup>3</sup> Cervical ERMS is a rare form of the disease, more commonly seen in adolescents during the 2nd decade of life.<sup>4</sup> Presentations of this entity in adulthood are even less common and are linked to somatic mutations in the DICER1 gene. Germline mutations in the DICER1 gene are frequently seen in pediatric patients with ERMS, which is associated with a number of other solid tumors.<sup>5</sup>

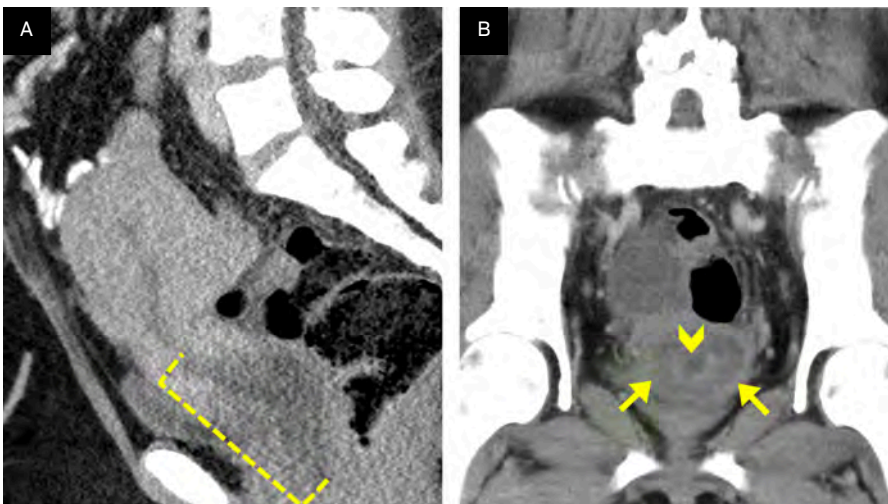
**Affiliations:** Department of Radiology, Walter Reed National Military Medical Center, Bethesda, Maryland (Grant Liska); Nova Southeastern University Dr. Kiran C. Patel College of Osteopathic Medicine, Clearwater, Florida (SY Seo, YY Seo); American College of Radiology Institute for Radiologic Pathology, Silver Spring, Maryland (Marko).

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**Figure 2.** (A) Sagittal T2 sequence demonstrates a high water-content mass (bracket) protruding from the endocervical canal into the vaginal cavity. (B, C) Axial images show a T1 hypointense, T2 hyperintense mass with a thin rim of vaginal tissue (arrows). (D) T1 post-contrast subtraction images reveal heterogeneous contrast enhancement of the mass (bracket).



**Figure 3.** (A) Sagittal contrast-enhanced CT images demonstrate the low-density endocervical mass (bracket) with extension into the vaginal cavity. (B) Coronal images demonstrate the endocervical component of the mass (arrowhead) with surrounding dilated cervical tissue (arrows).



Cervical ERMS tumors in adults tend to be quite large at diagnosis, likely owing to their similar appearance to more common, benign entities such as uterine prolapse, endocervical fibroids, and cervical polyps on pelvic exam and US. Distinctive imaging features of this entity are helpful in making the correct diagnosis, with tumors having high water content (hypoattenuating on CT, T2 hyperintense on MRI) and often assuming a polypoid morphology likened to a bunch of grapes (sarcoma botryoides).<sup>5,6</sup> These features are not pathognomonic, though, and ultimately, tissue sampling is necessary for a definitive diagnosis.

There is no official classification of cervical ERMS; however, based on the largest study of cervical ERMS, the FIGO uterine adenosarcoma staging system was found to be superior to the uterine corpus sarcoma staging system for predicting survival.<sup>5,7</sup> Using this system, this patient's disease was classified as stage IC owing to surgical pathology's demonstration of greater than 50% myometrial/cervical invasion without extrauterine extension or metastatic disease.

Treatment guidelines are based on data from pediatric populations but have demonstrated similar efficacy in case reports of adult patients with cervical ERMS.<sup>8</sup> The prognosis for localized ERMS, including cervical cases, is generally favorable, particularly when early diagnosis and an aggressive surgical approach are achieved.<sup>3-5,9,10</sup> Following gross total resection, this patient underwent 4 cycles of vincristine, actinomycin, and cyclophosphamide therapy, with no imaging evidence of disease recurrence to date.

## Conclusion

ERMS is a malignancy typically seen in children. Infrequently, this tumor can occur in the cervix of adolescents and, even more rarely, present as an adult

cervical cancer. Familiarity with this entity and its distinctive imaging features on MRI is critical to accurate, timely diagnosis in the adult population.

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# Lemierre Syndrome with Intracranial Extension Through the Foramen Ovale

Jason Paek, MD; James Bai, MD

## Abstract

Lemierre syndrome is a rare, potentially life-threatening infection characterized by septic thrombophlebitis of the internal jugular vein following an oropharyngeal infection, most commonly caused by *Fusobacterium necrophorum*. Intracranial complications are uncommon and typically result from retrograde venous thrombophlebitis or hematogenous spread. We report a rare case of a patient in her 20s with *F. necrophorum* bacteremia, septic pulmonary emboli, and thrombosis of the right internal jugular vein, complicated by contiguous intracranial extension through the skull base foramen ovale into the middle cranial fossa. This case illustrates an unusual route of intracranial extension of Lemierre syndrome through the skull base foramen ovale. Early recognition, appropriate antimicrobial therapy, and multimodal management are critical to prevent neurological and systemic complications.

**Keywords:** Lemierre syndrome, *Fusobacterium necrophorum*, intracranial extension, foramen ovale, internal jugular vein thrombosis, septic thrombophlebitis, parapharyngeal space, skull base infection, MRI

## Case Summary

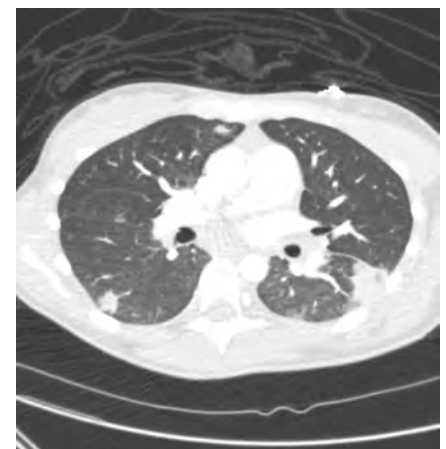
A previously healthy young adult presented with a 1-week history of right-sided neck pain, trismus, pleuritic chest pain radiating to the back, shortness of breath, and fever. On admission, the patient was febrile and tachypneic. Initial chest radiography showed multifocal airspace opacities. Laboratory results include leukocytosis (13,900/ $\mu$ L), elevated lactate (2.4 mmol/L), thrombocytopenia (51,000/ $\mu$ L), and respiratory alkalosis (arterial pH 7.46, PaO<sub>2</sub> 51 mm Hg, PCO<sub>2</sub> 30 mm Hg).

## Imaging Findings

Contrast-enhanced CT of the chest demonstrated multiple bilateral cavitating/consolidative lesions in the lungs consistent with septic pulmonary emboli (Figure 1). Contrast-enhanced CT of the neck demonstrated multi-spacial infection with phlegmon and inflammatory changes involving the right masticator, pharyngeal mucosal, and parapharyngeal spaces. CTA of the neck confirmed right internal jugular vein (IJV) thrombosis (Figure 2).

Brain MRI and MR venography demonstrated a small abscess in the

**Figure 1.** Axial chest CT demonstrating multiple bilateral cavitating and consolidative lung lesions, consistent with septic emboli.

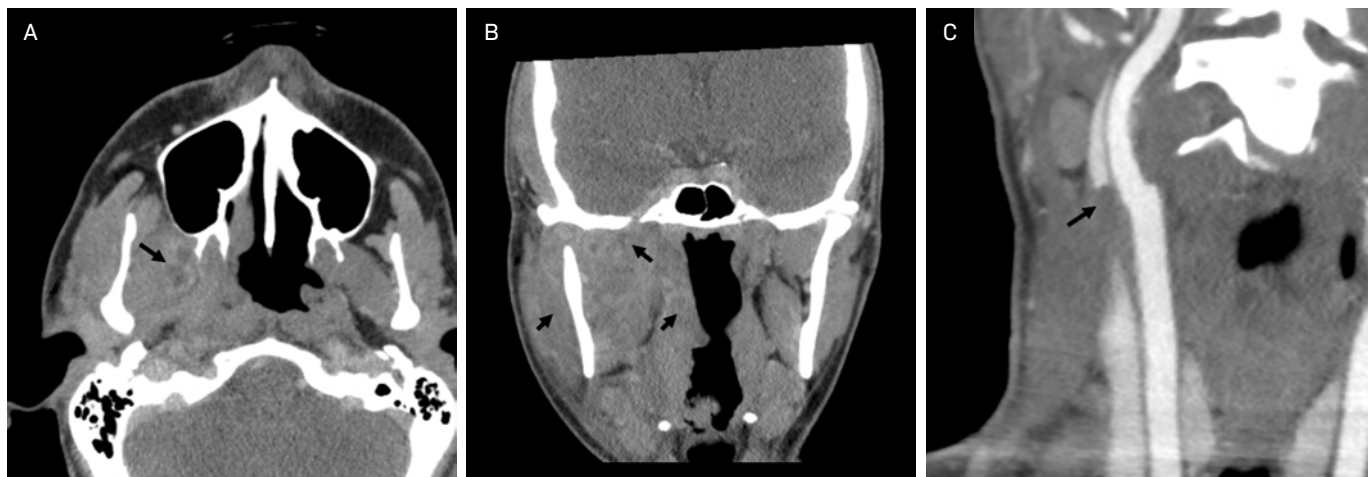


right parapharyngeal space and epidural involvement along the right middle cranial fossa with contiguous extension through the foramen ovale (Figure 3),

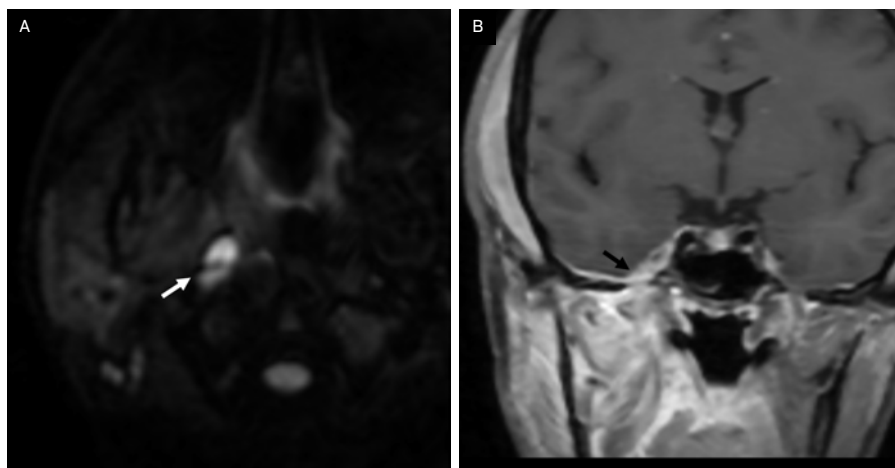
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**Figure 2.** Axial (A) and coronal (B) CT neck demonstrating phlegmon and inflammatory changes involving the right masticator space, right pharyngeal mucosal space, and right parapharyngeal space (black arrows). CT angiogram (C) curved reformat showed filling defect of the right internal jugular vein (black arrow).



**Figure 3.** Axial diffusion-weighted MRI (A) revealing a small collection with restricted diffusion in the right parapharyngeal space (white arrow), compatible with an abscess. Coronal post-contrast T1-weighted imaging (B) demonstrating epidural extension along the right middle cranial fossa through the foramen ovale (black arrow).



but no cavernous or dural venous sinus thrombosis.

Blood cultures grew *Fusobacterium necrophorum*.

The patient was treated with intravenous ceftriaxone and metronidazole; their hospital course was complicated by septic shock requiring transient vasopressor support, acute hypoxemic respiratory failure, and acute kidney injury, all of which resolved with supportive medical management. The patient also developed a pleural empyema, which was managed

with chest tube placement, resulting in subsequent improvement and resolution. At 1-month follow-up, repeat CT of the maxillofacial region and chest demonstrated resolution of the neck phlegmon and cavitary/consolidative pulmonary lesions.

## Diagnosis

Lemierre syndrome with intracranial epidural extension through the foramen ovale

## Discussion

Lemierre syndrome is a rare, potentially fatal complication of oropharyngeal infection, classically defined as septic thrombophlebitis of the IJV secondary to *F. necrophorum* bacteremia. The syndrome primarily affects adolescents and young adults but has been reported across all age groups.<sup>1</sup>

The disease typically begins with a primary oropharyngeal infection (eg, tonsillitis, peritonsillar abscess, dental infection, or mastoiditis), followed by spread to the parapharyngeal space and subsequent IJV thrombophlebitis. The condition may disseminate through septic embolization, hematogenous spread, or contiguous extension to adjacent structures, including the mediastinum, lungs, or, rarely, the intracranial compartment.<sup>2</sup>

Intracranial complications (cerebral abscess, meningitis, epidural/subdural empyema, cavernous or dural venous sinus thrombosis) are uncommon; only a few dozen cases in the are documented in the literature compared with many more with pulmonary or systemic septic emboli.<sup>1,3-6</sup> Knowledge comes mainly from case reports/series and narrative reviews rather than from large cohort studies.

Intracranial extension of Lemierre syndrome may occur via several routes, including retrograde thrombophlebitis into the dural venous sinuses; septic embolization to brain parenchyma; contiguous extension through skull base foramina; and hematogenous dissemination.<sup>3</sup> This case illustrates direct contiguous spread through the foramen ovale, a pathway seldom reported in the literature. The foramen ovale is a skull opening through which the mandibular nerve (cranial nerve V3), lesser petrosal nerve, accessory meningeal artery, and emissary vein exit the skull and enter the masticator space. This creates a direct communication between the intracranial cavity and the masticator space, allowing for the transmission of disease. In our case, the neck infection was centered in the right masticator space extending through the foramen ovale to the intracranial cavity (Figure 5).

Neuroimaging plays a crucial role in detection. Contrast-enhanced MRI and MR venography are the most sensitive modalities for identifying epidural extension, venous thrombosis, or abscess formation. Early imaging should be pursued in any patient with Lemierre syndrome who exhibits neurologic symptoms, severe headache, or cranial nerve deficits.

Management requires prompt intravenous antibiotic therapy targeting anaerobic organisms. Recommended regimens include a beta-lactam/beta-lactamase inhibitor combination or a third-generation cephalosporin plus metronidazole.<sup>1</sup> The role of anticoagulation remains controversial and is generally reserved for extensive or propagating thrombosis.<sup>7</sup> Previous case reports of Lemierre syndrome with intracranial extension have described multiple brain abscesses and epidural empyema, highlighting the need for central nervous system-penetrating antibiotics and neurosurgical drainage in select patients.<sup>4</sup>

## Conclusion

This case demonstrates a rare instance of Lemierre syndrome with contiguous intracranial extension through the foramen ovale, rather than through the more typical embolic or hematogenous spread. Awareness of atypical routes of spread is important, as delayed recognition may lead to neurological complications. Prompt imaging evaluation and early initiation of broad-spectrum antibiotics remain the cornerstones of management.

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# Embolization of Intercostal Artery Pseudoaneurysm Secondary to Active Tuberculosis

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## Abstract

We present a novel case of embolization for a patient presenting with chronic episodes of hemoptysis, found to have a pseudoaneurysm arising from a branch of the L5 intercostal artery secondary to active tuberculosis (TB). The expectant management for pseudoaneurysm in this location would be radiological intervention for identifying and embolizing the pseudoaneurysm. This case is unique given its atypical location and several feeder branches, making the treatment approach more challenging. In addition, a concomitant pseudoaneurysm with active TB predisposes the patient to multiple etiologies for hemoptysis that make management further complicated. Ultimately, the patient was treated with acute coil embolization of the pseudoaneurysm and placed on a prolonged course of the RIPE (Rifampin, Isoniazid, Pyrazinamide, and Ethambutol) regimen for active TB, resulting in resolving hemoptysis and overall clinical improvement. The patient's case and the details of our intervention with relevant imaging are discussed throughout the report, as well as a brief overview of management for hemoptysis secondary to pseudoaneurysms.

**Keywords:** hemoptysis, RIPE, pseudoaneurysm, tuberculosis, embolization

## Case Summary

A middle-aged adult presented with a 2-month history of fever, chills, and night sweats, along with a recent episode of hemoptysis consisting of 150 mL of bright red blood. The patient experienced one episode of hemoptysis 2 months prior but did not seek medical attention. The physical exam was significant for rhonchi breath sounds, with multiple episodes of small volume (<10 mL) hemoptysis in the setting of hemodynamic stability.

Labs were significant for anemia, lactic acidosis, elevated liver function tests, and electrolyte abnormalities.

## Imaging Findings

Chest radiography revealed prominent patchy airspace opacities and right apical and basilar airspace opacities in the left upper lobe, raising concerns for multifocal pneumonia. Subsequent chest CTA revealed a small (<1 cm) cavitory lesion in the right upper lobe and a 2 cm

**Figure 1.** Axial CTA chest lung windows demonstrating thick-walled cavitation of the lower left lung apical segment.

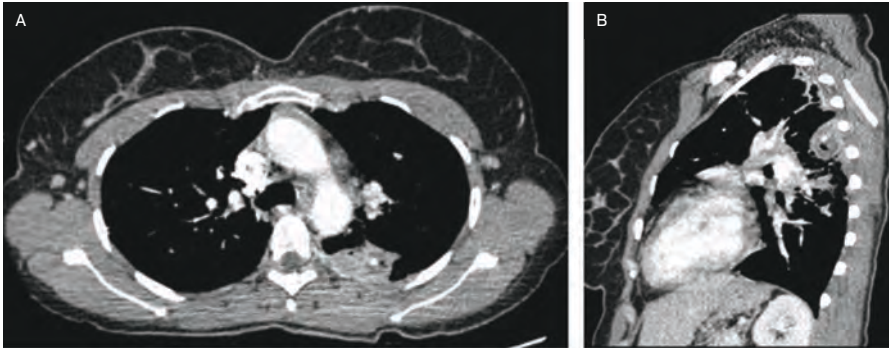


× 1.7 cm × 2.2 cm cavitating consolidative mass in the apical segment of the left lower lobe (Figure 1). The lesion contained high attenuation fluid, along with a discrete, 4 mm, rounded high-attenuation focus matching the attenuation of the arterial vasculature, raising concern for a pseudoaneurysm (PSA) (Figure 2).

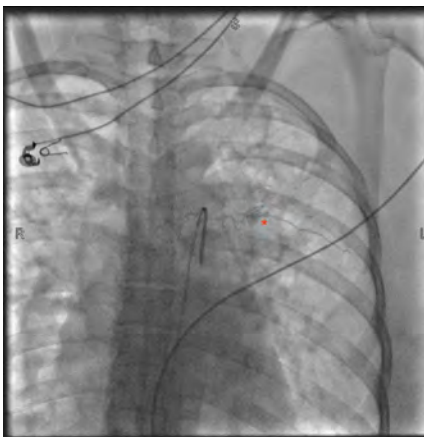
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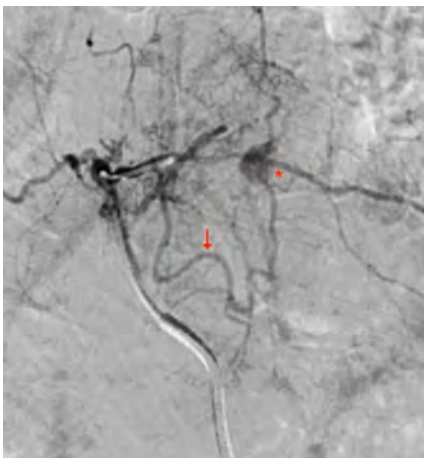
**Figure 2.** CTA Chest, mediastinal window. (A) Axial view demonstrating a lesion with an internal 6 mm nodular focus of high attenuation. (B) Sagittal view demonstrating a pleural-based lesion with both a focus of air and a nodular focus of high attenuation.



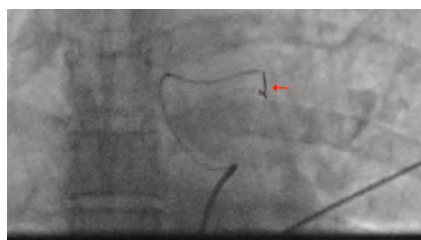
**Figure 3.** Descending thoracic aortogram demonstrating a T5 intercostal pseudoaneurysm marked by the red asterisk.



**Figure 4.** Selective T5 intercostal arteriogram. The pseudoaneurysm (red asterisk) is visualized, with the main (red arrow) and multiple secondary feeding vessels arising from the T5 proximal intercostal artery.



**Figure 5.** Super-selective 2 mm x 1 cm Ruby microcoil (red arrow) deployment within the inferiorly projecting feeder branch.



The patient had a positive QuantiFERON and PCR test showing pan-sensitive mycobacterial tuberculosis (TB). Acid-fast Bacillus (ABF) smear was negative 3 times, indicating the patient was not actively contagious. The patient was placed on a RIPE regimen with pyridoxine 50 mg daily, tranexamic acid nebulizers Q8, and underwent urgent interventional radiology (IR) embolization.

The patient underwent urgent arterial embolization utilizing a right femoral arterial approach. Arch aortogram was performed with subsequent bronchial artery angiograms. While attempting to identify the bronchial artery, the left T5 intercostal artery was opacified and inadvertently demonstrated a possible pseudoaneurysm (Figure 3). A digital roadmap image allowed for successful coaxial catheterization of the intercostal artery using a microcatheter. Hand injection identified the pseudoaneurysm and arteriogram identified a prominent feeder branch from the left intercostal

artery that provided direct supply to the pseudoaneurysm (Figure 4). The feeder branch was super-selectively coil embolized with a 2 mm x 1 cm Ruby microcoil (Figure 5). Post-embolization angiograms showed delayed but persistent filling of the pseudoaneurysm with smaller caliber collateral branches from the intercostal artery. After unsuccessful attempts at selectively catheterizing the other feeder branches, it was decided against embolizing the proximal T5 intercostal artery.

## Diagnosis

Intercostal PSA secondary to active TB. Differential diagnoses include Rasmussen Aneurysm, septic emboli, and vasculitis.

## Discussion

Pulmonary TB remains a significant global health concern as its incidence continues to rise despite efforts to reduce transmission rates. The current incidence rate in the United States is 2.9 per 100,000, which marks an increase compared with previous years.<sup>1</sup> Massive hemoptysis, a life-threatening complication of TB, occurs in about 8% of infected individuals.<sup>2</sup> While no clear consensus exists on the definition of massive hemoptysis, the condition is generally diagnosed when a patient has expectorated from > 100 mL of blood in 24 hours.

In TB infections, hemoptysis typically arises from the rupture of friable small vessels secondary to inflammation, PSA of the intercostal arteries, or the development of a Rasmussen's aneurysm, a distinct pulmonary artery PSA within or adjacent to a tuberculous cavity.<sup>2-5</sup> While the rate of PSA is rare, it carries a mortality rate of over 38%.<sup>3</sup> Any of these vascular complications can progress to massive hemoptysis, and IR is frequently called on to intervene. There are no clear guidelines regarding embolization of PSAs; unique

pitfalls may affect clinical outcomes even in cases of technical success. Roughly 90% of patients with hemoptysis experience bleeding resulting from the high-pressure bronchial circulation, with the other 10% experiencing bleeds from the aorta or nonbronchial circulation and the low-pressure pulmonary artery system.<sup>6</sup>

Most cases of life-threatening hemoptysis arise from the high-pressure systemic circulation; therefore, embolization strategies typically first target the bronchial arteries. However, non-bronchial systemic arteries (NBSAs)—including variable collateral supply from the intercostal, internal mammary, phrenic, or subclavian branches—are frequently overlooked sources of bleeding and represent major contributors to early rebleeding, particularly in the setting of chronic inflammatory or pleural disease.<sup>6</sup> Pre-procedure multidetector CTA is essential for identifying enlarged bronchial arteries and ectopic NBSA feeders, allowing for accurate procedural planning and selective catheterization.<sup>6</sup> In addition, the anatomic location of parenchymal cavitation can help predict the responsible systemic feeder, as posteriorly located cavitary disease often correlates with involvement of the corresponding intercostal artery.<sup>6</sup>

Bronchial artery embolization is typically performed using particles  $\geq 300\text{--}355\text{ }\mu\text{m}$ , with larger particles favored in the presence of arteriovenous shunting and careful attention paid to avoidance of spinal arterial branches.<sup>6</sup> Embolization of NBSAs frequently requires super-selective catheter positioning and, when the risk of non-target embolization is high, the use of controlled embolic agents such as coils.<sup>7</sup> Hemoptysis stemming from pulmonary arterial lesions (eg, Rasmussen PSA) requires targeted pulmonary artery embolization, often combined with systemic treatment. With respect to intercostal artery PSAs, there remains no clear consensus regarding optimal embolic agent selection. Successful reports in the literature have used microcoils with or without glue, alcohol, and/or Gelfoam.<sup>4,5,7-10</sup> In our

case, we utilized microcoils to reduce the risk of nontarget embolization. Of note, severe cases warrant consideration of thoracotomy.

A potential complication of intercostal artery embolization is spinal cord injury. The artery of Adamkiewicz, which supplies the anterior spinal artery of the thoracic and lumbar spinal cord segments, should be carefully sought and avoided to prevent infarction and the development of long-term neurological complications. Radicular branches from the proximal intercostal arteries should also be avoided for similar reasons. Therefore, selective embolization should be employed. Bleeding sources close to the radicular orifices are typically treated with coils to limit inadvertent embolization.<sup>7,10</sup>

Numerous collateral pathways supplying intercostal artery PSAs may represent a source of treatment failure and, when identified, should ideally be embolized.<sup>4,9</sup> As demonstrated in our case, the PSA was supplied by multiple feeder branches, with post-embolization angiography showing delayed yet persistent filling.<sup>9</sup> Another contributor to treatment failure is the coagulopathy that can accompany massive hemoptysis, such that technically successful embolization may not immediately translate into clinical hemostasis, resulting in persistent postprocedural bleeding.<sup>6</sup> In our case, we were able to acutely stabilize and improve the patient's hemoptysis. The condition progressively resolved over several weeks with medical management, including an anti-tuberculous regimen. This emphasizes the importance of a multidisciplinary approach and longitudinal care in complex cases.

## Conclusion

In cases of hemoptysis, IR is frequently called upon to intervene and prevent rapid patient deterioration. Preprocedural CTA is vital for diagnosis and mapping. While the bronchial arteries are common culprits, recognition of nonbronchial sources is crucial to increasing the chance of technical success and positive patient

outcomes. Medical management also plays a key role throughout the patient's stay, highlighting the importance of taking a multidisciplinary approach to complex cases. Our coil embolization is one of only a few reported in the literature, with no consensus for the best embolic to use in these cases. Our success in this study warrants further research into how to best embolize and manage rare yet life-threatening PSAs.

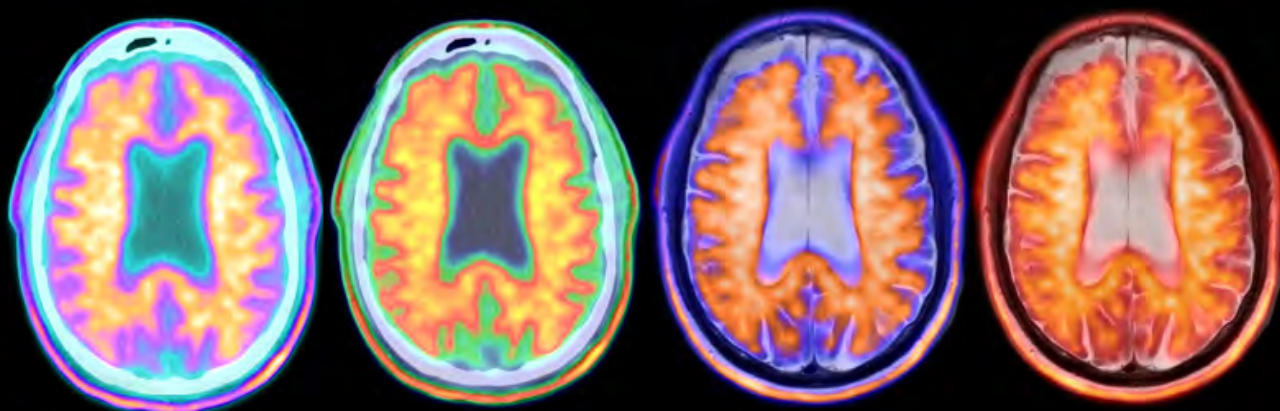
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# AppliedRadiology®

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## Imaging Comes Home: Why More Neurology Practices Are Bringing MRI and PET Onsite



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# Imaging Comes Home: Why More Neurology Practices Are Bringing MRI and PET Onsite

## Executive Summary

Neurology care is entering a transformative era, driven by breakthrough anti-amyloid therapies for Alzheimer disease (AD), growing disease burden, and evolving economic incentives.

Advanced MRI and PET scans, now central to the diagnosis, treatment selection, and safety monitoring of AD, provide anatomical, functional, and quantitative information that clinicians can use alongside clinical evaluation, laboratory findings, and other assessments to support patient management decisions.

These shifts are occurring amid increasing pressure on neurology practices. An aging population living longer with chronic conditions means higher patient volumes, while the rise in biomarker-based disease definitions puts strain on already overburdened hospital-based radiology systems.

Meanwhile, payer policies continue to incentivize the migration of imaging from hospitals to lower-cost outpatient settings. In this environment, integrating onsite imaging allows neurology practices to expand capacity, shorten wait times, improve patient experience, standardize protocols, enable immediate results, and diversify revenue streams.

New technologies and evolving delivery models—including more accessible, easy-to-site MRI and PET/CT systems, AI workflows, flexible financing solutions, and alternate siting options such as mobile units, all supported by manufacturers like Siemens Healthineers, have lowered barriers to entry, making advanced imaging accessible to private practices of all sizes. Increasingly, these capabilities are being offered as fully integrated, turnkey solutions that combine equipment, implementation, staffing, and operational support, enabling practices of all sizes to deploy advanced imaging quickly and with reduced administrative burden.

### Quick Facts

**Neurology is rapidly evolving** due to new Alzheimer therapies and rising demand from aging populations.

**MRI and PET scans are essential,** but reliance on overburdened hospital imaging causes treatment delays and inconsistency.

**Onsite imaging is more accessible,** improving efficiency, care, and revenue for outpatient practices.

**Important Safety Information:** MRI provides images to be interpreted by physicians; it is not indicated to determine disease stage or prognosis.

## The Role of Imaging in Alzheimer Disease

The introduction of two first-in-class therapies for Alzheimer disease (AD), lecanemab (Leqembi) and donanemab (Kisunla), marks a historic turning point in clinical neuroscience. For the first time, clinicians can offer patients disease-modifying treatments rather than only palliative care for this devastating ailment. These therapies require extensive use of advanced diagnostic imaging tools to support clinician assessment of amyloid pathology, patient evaluation workflows, treatment planning considerations, safety surveillance, and longitudinal disease management.

## Diagnosis and Biomarker Confirmation

Clinical evaluation of patients with suspected AD is increasingly supported by biomarker evidence, including amyloid PET imaging or cerebrospinal fluid analysis.<sup>1</sup> Amyloid deposition may begin years to decades before the onset of clinical symptoms,<sup>1</sup> although in clinical practice amyloid PET imaging may be used as part of the clinical workup in patients presenting with cognitive impairment.

**Important Safety Information:** Disease-modifying therapy (DMT) in Alzheimer disease is associated with risks. Refer to the prescribing information for the specific DMT for information regarding adverse reactions, contraindications, warnings, and precautions.

## Imaging Findings and Disease Characterization

Clinicians are increasingly interested in identifying imaging and biomarker patterns associated with earlier disease presentation (low-tau burden), as clinical trials show that these individuals derive the greatest benefit from emerging therapies. Quantitative MRI may provide volumetric and structural information that can support clinician assessment of neurodegenerative patterns associated with earlier or



*Imaging now plays a critical role across the entire Alzheimer's disease continuum. In the past year alone, RadNet performed approximately 7,000 amyloid PETs and 339,000 brain MRIs, underscoring the expanding role of advanced imaging in Alzheimer's care. This represents a cumulative 7,189% increase in amyloid PET volumes and a 25% increase in MRI brain volumes over the past two years.*

—Suzie Bash, MD, Neuroradiologist at RadNet

later disease presentation. When a dementia other than AD is suspected, clinicians may order FDG PET to screen for an alternative diagnosis.

### Treatment Monitoring and Safety

Once clinicians confirm a diagnosis of AD and that the patient meets MRI eligibility criteria, treatment may begin. Patients then undergo periodic MRI surveillance for amyloid-related imaging abnormalities (ARIA), a known safety risk associated with anti-amyloid therapy. If imaging findings consistent with ARIA are detected, clinicians may pursue more frequent MRI monitoring until ARIA-E (edema) has resolved and ARIA-H (hemorrhage) has stabilized.

## The Changing Landscape of Neurology Care

### Growing Treatment Burden

Anti-amyloid therapies arrive at a time when neurology already faces mounting patient volumes, driven largely by aging populations and longer life expectancies. A 2021 study found that since 1990, the global burden of neurological disease—measured in disability-adjusted life years (DALYs)—has increased by 18%.<sup>2</sup> More recent analysis suggests that neurological disorders now affect approximately 1 in 2 people in the United States.<sup>3</sup> While mortality related to neurological disease has declined, this trend also means patients are living longer (about 10%) with chronic

conditions.<sup>3</sup> Alzheimer disease, the most common neurodegenerative condition worldwide, currently affects an estimated 7 million people in the U.S.,<sup>3</sup> a number projected to approach 13 million by 2050.<sup>1</sup>

### Market and Policy Drivers

Economic factors further reinforce neurology's growing reliance on imaging. In pursuit of cost savings, payers continue to push imaging services away from hospitals and into outpatient settings, a trend known as “outmigration” that shows no sign of slowing.<sup>4</sup> The rise of high-deductible insurance plans and price transparency laws have driven many patients to seek more economical alternatives to high-cost hospital scans. Meanwhile, federal policymakers remain committed to advancing value-based care payment models. For example, Guiding an Improved Dementia Experience (GUIDE), a model program from CMS, extends Medicare coverage to support longitudinal, coordinated dementia care through interdisciplinary service “partners” such as community-based organizations and other non-acute care settings.<sup>5</sup>

## Why Onsite Imaging Matters

### Access and Patient Experience

Demand for neurological imaging is outstripping capacity, creating significant access challenges for patients.<sup>4</sup> Long wait times for imaging

can exacerbate the burden of uncertainty and anxiety that patients with neurodegenerative disorders already experience in relation to their condition. By offering imaging technology in a single location, neurologists can expect to expand capacity, reduce patient wait times for scans, and spare patients the inconvenience of traveling to offsite radiology departments. Ideally, an integrated model reduces appointments, streamlines care, and eases patient and caregiver worry.

### Clinical and Operational Efficiencies

Control over imaging referrals significantly influences diagnostic quality and downstream clinical decisions. Neurologists who directly generate imaging orders or oversee workflows add substantial value by ensuring clear communication of clinical context and protocol specifications. Referrals from non-dementia specialists (e.g., internal medicine or family practice physicians) can lead to protocol variability or ambiguity in imaging results. Direct neurologist-driven ordering maintains protocol consistency, which is especially critical in the era of anti-amyloid therapies. Uniform dementia imaging protocols across timepoints are essential—particularly for blood-sensitive sequences (e.g.,

**Over 7 million Americans are living with Alzheimer disease.**

**By 2050, this number is projected to rise to nearly 13 million.**

<https://www.alz.org/alzheimers-dementia/facts-figures#quickFacts>

GRE vs. SWI)—since even minor variations can affect professional assessments of safety and patient eligibility.

ARIA surveillance relies on direct comparison with prior exams, making imaging continuity vital. Integrated care models that combine



*The rule of thumb used to be eight neurologists per scanner, but new economics and shared models have changed that.*

—Joseph V. Fritz, PhD, Former CEO of DENT Neurological Institute, Founder of NeuroNet

clinical evaluation and imaging in one facility reduce care fragmentation and support consistent review of findings associated with ARIA.

Neurologist control over imaging pathways relies on collaboration with trusted neuroradiologists, enabling timely, accurate interpretations and prompt bidirectional communication to guide management. In anti-amyloid therapy—where ARIA may require suspending infusions—swift response to new findings reassures clinicians and patients. Timely results also mitigate malpractice risk amid radiology backlogs.<sup>6</sup>

## Financial and Strategic Considerations

### What to Analyze Before You Invest

Determining whether sufficient patient volume exists to support an investment in imaging technology depends largely on an office's geographic location and referral environment. The assessment process usually begins informally, perhaps by surveying patients about scan wait times or by speaking with colleagues at nearby health systems to gauge radiology backlogs and unmet demand.

When considering modalities such as PET, access to radiopharmaceuticals is a critical additional consideration. PET imaging depends on short-lived radiotracers (e.g., FDG), which require reliable, timely delivery from regional cyclotrons or radiopharmacies. Practices must evaluate proximity to suppliers, delivery schedules, regulatory handling requirements, and contingency plans for supply disruptions. Limited radiopharma-

ceutical availability or logistical constraints can significantly impact scheduling flexibility, throughput, and overall financial viability.

Ultimately, practices seriously considering onsite imaging must move beyond anecdotal evidence and develop a formal pro forma financial statement. This is typically paired with a feasibility analysis that integrates economic modeling, market research, and detailed local assessment. Key inputs include demand tied to relevant clinical drivers—such as multiple sclerosis (MS), headache and dementia—as well as population demographics, consumer utilization trends, market share and competitive dynamics, referral pathways, and reimbursement benchmarks.

The resulting analysis is not only critical for internal decision making, but also serves as a foundational document for securing the bank loans typically needed to finance imaging systems. As a result, practices almost always contract with healthcare management consultants to build out a pro forma. In addition to their invaluable market expertise, consultants play a pivotal role in negotiating payer contracts, an often highly localized process that depends on insider knowledge, direct engagement, and personal relationships.

### Revenue and Ancillary Opportunities

Compared with other medical specialties, neurologists' salaries generally fall in the lower-middle range. This is largely because neurology emphasizes cognitive and

## Onsite Imaging Feasibility Checklist

- ☐ High local neuroimaging volume
- ☐ Enough neurologists, subspecialists in the mix
- ☐ Enough space to house equipment
- ☐ Creditworthiness, including personal loan guarantees
- ☐ Sufficient workforce potential
- ☐ Knowledge of reimbursement benchmarks
- ☐ A trusted vendor partner
- ☐ A trusted group of neuroradiologists for imaging interpretation

consultative care, while higher-paid specialties, such as orthopedics, radiology, and cardiology, focus on procedural services that receive greater reimbursement. Further, neurologists generate limited ancillary revenue, because the diagnostic tests they typically order (e.g., EEGs, nerve conduction studies, LPs) are not highly compensated.

Consequently, some industry observers view onsite imaging as a strategy to offset overhead costs by establishing new ancillary revenue streams, while simultaneously enhancing the quality and efficiency of patient care.

### Practice Size and Economics

The internal configuration of a practice's clinicians also comes into play. Historically, clinics were thought to need 8 to 10 neurologists to generate enough imaging volume to justify investing in diagnostic imaging equipment. A standard MRI unit, for instance, typically requires approximately 3,000 to 4,000 scans per year to turn a profit<sup>7</sup> (although this figure varies widely depending on local reimbursement rates).

Based on national imaging volumes and workforce data, the average general neurologist orders about 500 scans annually.<sup>8,9</sup>

However, that calculus is shifting. Subspecialists, especially those focusing on headache and MS, often order many more MRI scans per year. For example, a typical MS subspecialist might order as many as 1,200 scans a year.<sup>10</sup> As a result, a practice staffed with one general neurologist and two or three high-volume subspecialists may generate sufficient MRI volume to justify the cost of in-office imaging equipment.

Practices evaluating the financial feasibility of in-office MRI often begin with a simple contribution-margin framework. The average technical component (TC) revenue can be estimated from a weighted average of local payer fee schedules. Subtracting the variable cost of a scan (such as supplies or contrast) from the TC yields the per-scan contribution margin. Profitability ultimately depends on whether the contribution margin, multiplied by projected annual MRI volume, exceeds the fixed costs associated with equipment, facility space, and staffing.<sup>11</sup>

## Regulatory and Reimbursement Landscape

### Stark Law and Compliance

Onsite imaging requires compliance with the Physician Self-Referral Law, commonly referred to as the Stark Law, as well as its In-Office Ancillary Services Exception (IOASE) rules. Practices must also implement appropriate training and receive accreditation from a recognized organization such as the American College of Radiology. In addition, many states require a Certificate of Need (CON) to establish imaging services, although CON requirements vary significantly by state.

Beginning with the introduction of Stark II in the mid-1990s,

### DENT Neurologic Institute: A Physician-led Imaging Model

In an era of increasing hospital consolidation, the physician-run DENT Neurologic Institute in Buffalo, New York, stands out for preserving independence through control of neuroimaging and agile governance.

Founded more than 60 years ago, DENT has grown into one of the world's largest outpatient neuroimaging centers, with approximately 100 providers across 26 clinics.

Owned and operated exclusively by physicians, DENT's streamlined structure enables rapid adoption of new technologies, leadership in clinical trials, and swift responses to clinical and business needs.

Despite operating in a low-reimbursement region, the practice maintains profitability through high patient volumes across multiple subspecialties and an open-access model that allows new patients to be seen within 72 hours.

Its integrated infusion services program, supported by bulk purchasing through NeuroNet, further strengthens operational efficiency.

NeuroNet also connects DENT with a national network of practices, leveraging shared data from more than 4.5 million patients to support ongoing research initiatives.

neurological imaging and interpretation started moving away from neurology and toward radiology departments in hospitals. At the time, payers and policymakers were concerned that private practice self-referrals might lead to over-utilization and cost overruns. Since the Stark Law exempted hospitals from its self-referral prohibition, it seemed to make more sense that imaging should occur primarily in hospital settings.<sup>12</sup>

In recent years, however, this dynamic has changed. Declining reimbursement rates for diagnostic imaging have reduced hospitals' financial incentives to retain exclusive control over these services. In fact, many hospital systems now recognize the economic and clinical advantages of transitioning neurological imaging to outpatient settings.<sup>13</sup> Consequently, procedural challenges facing practices seeking to establish outpatient imaging centers have become less arduous.

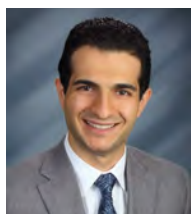
Compliance with Stark and state self-referral laws varies by jurisdiction and requires careful structuring with healthcare regulatory counsel.

However, thousands of physician groups across the United States successfully operate onsite imaging under the federal In-Office Ancillary Services exception.

The Stark Law's most important guidelines are straightforward and easy to understand. First, physician salaries and compensation can never be tied to scan volume. Any imaging-generated revenue must be distributed equally within the practice, with no hint of a per-scan payment structure. Second, patients must be informed, in writing, that they retain the option of receiving their scans at other, specifically named, imaging facilities nearby. If these provisions are followed meticulously, neurologists with competent legal representation should expect little trouble complying with the Stark Law.

### Payer Policies

The Centers for Medicare and Medicaid Services (CMS) has encouraged the migration of diagnostic imaging procedures to lower-cost outpatient facilities, mainly through the implementation and expansion



*It's not onsite [remote scan interpretation], but it feels onsite, because we and our reading radiologists have conferences every two weeks where we go over interesting images or interesting cases.*

—Mani Nezhad, MD, Neurologist at Link Neurosciences Institute

### **Building Reading Care Teams: The Link Neuroscience Institute in California**

An ideal onsite imaging model brings neurologists and neuroradiologists together in a collaborative, co-located environment, working as a unified team. Nevertheless, a shortage of in-house radiology expertise does not necessarily preclude onsite imaging. With strong communication and coordinated teamwork, neurology practices can successfully outsource remote scan reporting. The Link Neuroscience Institute in California, partners with RadNet for neuroradiology services. While this approach requires ongoing collaboration, such as frequent provider messaging and twice-monthly, practice-wide video conferences, it has proven effective in maintaining consistent workflows and delivering high-quality patient care.

of site-neutral payment policies. These policies reduce or eliminate reimbursement disparities that previously favored hospital outpatient departments over freestanding facilities, a trend that is expected to continue. In July 2025, the CMS solicited feedback on further expanding site-neutral policies to include additional services, such as diagnostic imaging services without contrast.

Outpatient imaging can also benefit from bundling opportunities. Under the Medicare Physician Fee Schedule (MPFS) and similar commercial structures, onsite imaging allows neurologists to bill for both the professional component (PC, interpretation) and technical component (TC, equipment/use), often as a global code. This “bundling” of PC and TC into one claim represents a key opportunity, as it captures higher total reimbursement compared to hospital settings, where the TC is billed separately by the facility.

As with other medical procedures, prior authorizations (PAs) continue to proliferate for imaging approvals.

While increased PAs add to administrative burden, they constitute an advantage in at least one sense: Payers' authorizations strengthen a practice's defense against any potential Stark Law legal challenges.

### **Radiology Access management (RAM) Considerations**

Beyond these federal and state frameworks, practices must also address Radiology Access Management (RAM) licensing requirements. RAM programs—implemented by many commercial payers—govern prior authorization, site-of-service restrictions, and utilization management for advanced imaging such as MRI, CT, and PET. These programs often require practices to use designated clinical decision support tools, adhere to evidence-based appropriateness criteria, and obtain payer approval before performing certain studies. Compliance with RAM protocols can influence workflow, scheduling, and revenue cycle operations, and may favor lower-cost outpatient or office-based imaging settings over hospital-based care.

## **Operational Readiness and Implementation**

### **Staffing Solutions**

Amid persistent workforce shortages, recruiting and retaining qualified technologists remains one of the most significant operational hurdles for practices considering onsite imaging. Clinics have adopted a range of strategies to mitigate staffing constraints and maintain service continuity, including:

- Early engagement with radiologic technology students, often prior to graduation—a tactic that has proven especially effective for freestanding clinics, which typically face fewer onboarding and credentialing barriers than hospital-based systems
- Hybrid staffing and shared-services models, frequently in partnership with third-party providers, to provide coverage flexibility and reduce dependence on full-time hires
- Expanded use of teleradiology and remote work arrangements, enabling practices to access a broader talent pool while maintaining clinical throughput
- Vendor partnerships that include training and temporary staffing programs, such as [Siemens Healthineers' FlexForce® Tech](#), which allow practices to address short-term staffing gaps while creating pathways to transition contract technologists into permanent roles
- Adoption of AI-enabled workflow automation, which reduces manual tasks, improves efficiency, and helps offset staffing limitations without compromising quality of care

### **Partnership Models**

When neurologists rely entirely on external imaging providers, they

often relinquish control over key aspects of imaging management, including protocol standardization, scheduling prioritization, and timely access to imaging data critical for clinical decision-making. In competitive markets, external imaging providers may also capture downstream referrals for related services such as infusion therapies or clinical trials.

As a result, even smaller or growing practices should recognize that there are strategies available to retain more control over imaging services. Several partnership and access models can help practices expand imaging capabilities without assuming the full financial burden of equipment ownership:

- **Co-located imaging:** Joint ventures, management agreements, or collaborative arrangements with imaging centers, radiology groups, or technology contractors can provide access to imaging while mitigating the financial risks associated with sole ownership.
- **Leasing:** Leasing offers a flexible alternative to purchasing expensive imaging equipment, with structured payments spread over time and options often tailored to medical practices. “Block” leasing—where two or more practices share access to equipment—combines the benefits of structured payments with co-located imaging. However, this approach may involve additional regulatory considerations and potential payer restrictions related to shared ownership arrangements.
- **Mobile solutions:** Mobile imaging units provide a lower-commitment option that avoids the high cost, space requirements, and infrastructure demands of fixed installations. Typically housed in trailers or coaches, these scanners visit clinics on designated days, allowing

practices to offer onsite imaging access to patients.

- **Turnkey solutions:** Full-service, turnkey models offered through third-party partners enable practices to deploy imaging capabilities without managing day-to-day operations. These arrangements typically bundle equipment, site planning, staffing, workflow management, maintenance, and revenue cycle support into a single integrated solution. Turnkey models are particularly well suited for practices seeking rapid implementation, minimal operational burden, and a predictable cost structure, especially when internal administrative or technical resources are limited.
- **Industry support:** Imaging manufacturers such as Siemens Healthineers can assist practices during the planning process with demographic analysis, referral pathway evaluation, bank financing guidance, reimbursement benchmarking, pro forma development, and other early-stage planning tasks.

## Emerging Technologies in Neuroimaging

### Streamlined Imaging

Access to neuroimaging remains limited in remote, rural, and underserved regions. In response, manufacturers have introduced a new generation of scanning systems designed to be more affordable and compact, with reduced siting requirements and lower operating costs. Many of these systems also incorporate cloud-based quantification tools intended to enhance workflow consistency and image analysis, as well as deep-learning AI designed to shorten scan times, all of which may improve efficiency and the overall patient experience.

## Practice Readiness Checklist for Onsite Neuroimaging

- ☐ **Patient-Centric Care Model**  
Build an imaging model aligned with neurologic workflows and patient care pathways.
- ☐ **Regulatory Readiness**  
Ensure compliance with the Stark Law and related regulations with guidance from a qualified healthcare attorney.
- ☐ **Flexible Adoption Pathways**  
Lower barriers to entry through partnership models and scalable, low-field imaging technologies.
- ☐ **Data-Driven Feasibility Assessment**  
Evaluate onsite imaging viability using local demand, reimbursement benchmarks, and financial modeling—not rules of thumb.
- ☐ **Strategic Industry Partnerships**  
Partner with manufacturers for support in planning, financing, training, and implementation.
- ☐ **Integrated Care Team Collaboration**  
Foster close collaboration between neurologists and neuroradiologists to ensure protocol consistency and timely interpretation.

The MAGNETOM Flow MRI system from Siemens Healthineers illustrate this shift. Its dry-cool technology allows for elimination of a quench pipe, resulting in simplified infrastructure and siting requirements, and it can be safely installed in a standard examination room with a smaller footprint than most MRI systems. The system requires minimal liquid helium, significantly reducing operational costs, and is designed to be simple enough for a trained medical assistant to operate, helping to lower staffing expenses.

As disease-modifying therapies expand, demand for amyloid and tau PET imaging is expected to rise significantly, particularly in centers that manage large volumes of patients with memory disorders. Growing demand for early AD screening has also increased interest in hybrid imaging systems. PET/CT provides a less invasive

### Simplified MRI infrastructure

- Total scanner weight less than 3.7 tons
- Minimum siting requirement 269 sq ft
- Transportation height below 80 inches  
– fits through existing hallways and doors

269 sq ft

&lt; 80 in

With its compact footprint, the Siemens MAGNETOM Flow MRI can accommodate reduced siting requirements and operational costs.

alternative to cerebrospinal fluid assessment for evaluating amyloid pathology. Emerging hybrid PET/MRI systems enable clinicians to combine amyloid PET biomarker assessment with baseline MRI<sup>†</sup> screening for structural abnormalities, infarcts, or preexisting hemorrhages, as well as the capability for quantitative volumetric analysis—effectively consolidating two clinical visits into a single examination.

## Conclusion

The arrival of disease-modifying therapies for AD, rising patient volumes, and imaging outmigration are reshaping how neurologic care is delivered.

Onsite imaging allows neurology practices to expand capacity, reduce wait times, and improve the patient experience. It may support greater protocol consistency for longitudinal imaging workflows, including imaging associated with ARIA surveillance, while restoring clinician control over increasingly complex patient management pathways.

Flexible partnership models, including co-located arrangements, leasing structures, mobile solutions, and turnkey offerings, are lowering barriers to entry and allowing practices of varying sizes to adopt imaging capabilities in ways that align with their clinical, operational, and financial goals. Practices that strategically integrate imaging through ownership or partnership will be positioned to deliver high-quality, patient-centered care while maintaining autonomy in an increasingly complex and competitive health-care environment.

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*An SEP is something we can't see, or don't see, or our brain doesn't let us see, because we think that it's somebody else's problem. That's what SEP means. Somebody Else's Problem. The brain just edits it out, it's like a blind spot.*

—Douglas Adams, in *Life, the Universe, and Everything*



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## Queue Anxiety (Somebody Else's Problem)

C. Douglas Phillips, MD, FACR

Queue anxiety. This particular form mostly strikes division directors, chairs, and those of us who are not yet accustomed to the “shift work” paradigm of so many modern radiology departments.

I guess you know what I mean, but let us set the stage: Outpatient venue. You sit down to read, coffee in hand, power up, and are greeted with the worklist.

*The worklist.*

You and your colleagues hit it. You dictate, you talk to clinicians and patients, nurses, an occasional administrative type, and to your colleagues. The scanners are busy; work is getting cranked out and more CTs, MRs, and other studies hit that list, and it is ... *a battle royale.*

The list wants to flourish, to be fruitful and multiply and divide. You want to kill it.

*It's growing!* Someone went to lunch/a conference/a dentist's appointment.

*It's shrinking!* Someone got back/the late person came in/the residents went to a conference.

Sometimes, the list grows in a dramatic fashion. How cranked do you get when the techs forget to finalize 5-10 studies, and then do them all at once? *Whutttt?! I'm sure it has shortened my life.*

But the worst anxiety for me is the growth at the end of the day. You've been keeping up. The list was stable. But then, the end of the day starts to appear, and the list is growing. Whoa, growing a lot. *Damn, how did we get 30 studies behind?*

And there you are, imagining several things.

First, your next day. *Do I really want to come in tomorrow 50-60 back?* Next, you're thinking about your colleagues. *Will they think I'm slacking off? Will something that needs attention go unaddressed for the day?*

The movement to shift work is an odd one, I'll just state for the public record. But, with the young 'uns being schooled in this fashion, it's worth thinking about the queue issue. So, your shift is ending, and the list has exploded; this has just become, to borrow from Douglas Adams, somebody else's problem, or an SEP. Go ahead. Ask me how I feel about this.

Go ahead. I dare you.

Okay. You asked.

I don't get it. Seems a bit unusual for me to look at an expanding list and just pack up and go home. But, if the big hand on Mickey points to the ceiling and his little hand is on the 5, I am free to go. For the first 30 years of my career, that expanding list would have been the indication that the planned events for the evening are going to happen without me, and it looks like take-out for dinner again.

But times have changed. Hey, maybe this is all good. Maybe handing that list off to someone else is a good idea. Yeah ...sure. I'll just have a larger list tomorrow.

Keep doing that good work. Mahalo.