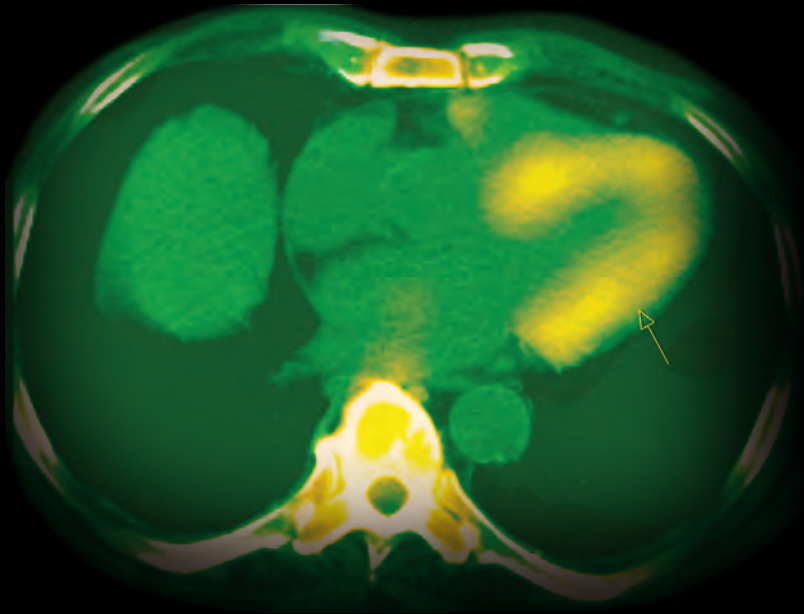


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The Journal of Practical Medical Imaging and Management

**^{99m}Tc-Pyrophosphate
(PYP) Scintigraphy: History,
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REVIEW

99mTc-Pyrophosphate (PYP) Scintigraphy: History, Evolution, and Role in Cardiac Amyloidosis

Faisal Jamal, MD; Jeevika, MBBS; Sagar Kulkarni, MBBS; Snehansh Roy Chaudhary, MD

This review highlights the evolution of 99mTc-PYP scintigraphy from its early use in myocardial infarction imaging to its current role as a highly specific, noninvasive tool for diagnosing transthyretin cardiac amyloidosis (ATTR-CM). The article highlights key advances—including the Perugini grading system and SPECT/CT refinement—and outlines current guidelines emphasizing visual assessment and exclusion of AL amyloidosis. With growing therapeutic options, PYP imaging has become central to early and accurate diagnosis of ATTR-CM.

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Nina S. Vincoff, MD, is the editor-in-chief of *Applied Radiology*. She is the Executive Medical Director of the Radiology Care Division at Prisma Health and Clinical Associate Professor of Radiology at the University of South Carolina School of Medicine Greenville. She can be reached at nina@appliedradiology.com

Leading Change with the Patient at the Center

Nina S. Vincoff, MD

This fall marks the beginning of two new chapters in my professional journey. In September, I began my tenure as Editor-in-Chief of *Applied Radiology*. That same month, after 26 years of practice in New York, I moved to South Carolina to become the Executive Medical Director of Radiology at Prisma Health. Change can be exhilarating, but it can also be unsettling and sometimes scary. It asks us to let go of what is familiar and to trust in what is new. Throughout my career, I have found that keeping a focus on what is best for the patient makes it easier to embrace change and to lead others through it.

Radiology has transformed dramatically since I was a resident. Many of the technologies and tools I use every day as a breast imager—digital mammography, tomosynthesis, computer-aided detection, artificial intelligence, wireless localization, and contrast-enhanced mammography, to name just a few—did not exist when I was in training. Learning to use these tools has been challenging at times, but the reward has always been clear. Each advancement has enabled me to provide higher-quality care for my patients.

As a leader, I have had the privilege of introducing many of these innovations to my teams. Even more importantly, I have challenged the radiologists I work with to expand the way they think about their role in patient care. I believe that the role of the radiologist extends beyond identifying and reporting imaging findings. For a breast imager, that might mean identifying women at increased risk for developing breast cancer and connecting them with preventive services, ensuring that newly diagnosed cancer patients are guided quickly and compassionately to treatment, creating patient-friendly reports that promote shared decision-making, or noting the presence of breast arterial calcification on mammography to alert women that they may be at higher risk for heart disease. For some radiologists, this expanded, patient-facing role felt uncomfortable at first, but the reward for our patients ultimately eased the decision to embrace change.

Leading change successfully requires empathy, communication, and purpose. New technologies and processes can only thrive when people understand why they matter and how they improve care. When we keep the patient at the center of every decision, we find clarity amid uncertainty. In imaging, contrast helps reveal what might otherwise remain unseen. Leading through change works in much the same way. By viewing every transition through the lens of the patient, we can distinguish what matters most and move forward with confidence, compassion, and shared purpose.

99mTc-Pyrophosphate Scintigraphy: History, Evolution, and Role in Cardiac Amyloidosis

Faisal Jamal, MD; Jeevika, MBBS; Sagar Kulkarni, MBBS; Snehanish Roy Chaudhary, MD

Abstract

Cardiac amyloidosis is an important cause of heart failure, particularly among the elderly population. It manifests as restrictive cardiomyopathy resulting from myocardial infiltration of misfolded amyloid fibrils (light chain or transthyretin), leading to heart failure with preserved ejection fraction. The two main forms of cardiac amyloidosis are amyloid light chain and transthyretin-related (ATTR). There has been a notable increase in the prevalence of cardiac amyloidosis due to advances in diagnostic methods and effective treatment for ATTR amyloidosis after the discovery of tafamidis. We aim to discuss the interesting history and evolution of the pyrophosphate scan, which plays an important role in the diagnosis of ATTR amyloidosis.

Keywords: cardiac imaging, nuclear medicine

Introduction

The 99mTechnetium-pyrophosphate (99mTc-PYP) scan is a nuclear medicine imaging technique that is widely used for the diagnosis of cardiac amyloidosis. Its primary use has evolved from detecting acute myocardial infarction (AMI) to diagnosing cardiac amyloidosis, particularly transthyretin-related (ATTR) cardiac amyloidosis. Cardiac amyloidosis is a restrictive cardiomyopathy resulting from myocardial infiltration of misfolded amyloid fibrils (light chain or transthyretin), leading to heart failure. The two main forms of cardiac amyloidosis are amyloid light chain (AL) and transthyretin-related (ATTR). ATTR amyloidosis can be hereditary or wild type, which progresses slowly with advancing age.¹ AL

amyloidosis is rare (8-12 per million people per year) and caused by the accumulation of misfolded light chain proteins (amyloid fibrils) in the heart and different organs in plasma cell tumors such as multiple myeloma and carries a poor prognosis.^{2,3} Wild-type ATTR (ATTRwt) is relatively more common, with its prevalence at 10-16% among elderly heart failure patients with or without aortic stenosis. Transthyretin (TTR) is a normal protein made by the liver; however, with advancing age, this can become unstable, misfold, and form amyloid deposits in various organs of the body, including the heart.⁴

Understanding the historical trajectory of the 99mTc-PYP scan reveals its scientific strengths, clinical utility, and the shifts in its role over the decades.

Early Cardiac Imaging and Myocardial Infarction Detection (1970s-1980s)

Originally introduced as a bone-imaging agent, 99mTc-PYP was among the earliest radiotracers used for cardiac imaging. In 1974, Parkey et al. found its utility in AMI, showing that PYP localizes to calcium deposits in infarcted myocardium, allowing for visualization of necrotic myocardial tissue.⁵ Later, Werner et al. studied the clinical applications of 99mTc-PYP and demonstrated its high sensitivity (~90%) in transmural myocardial infarction but less so in subendocardial infarcts (~38%).⁶ This was a novel discovery, as it allowed and set the stage for noninvasive cardiac imaging of infarcted myocardium, complementing electrocardiograms and serum enzymes creatine phosphokinase myocardial specific.

While it remained a major tool for AMI detection in the 1970s and 1980s, its use gradually declined in the 1990s due to the use of better diagnostic

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Figure 1. SPECT/CT image of the chest with strong myocardial uptake (shown by arrow) consistent with TTR amyloidosis.

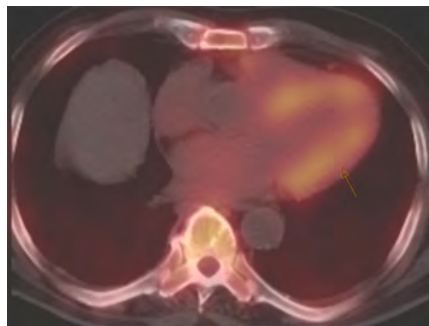


Figure 2. SPECT/CT image of the chest without any myocardial uptake, ruling out the possibility of TTR amyloidosis.



tools and treatments, including cardiac-specific biomarkers such as troponins, the development of echocardiography, percutaneous coronary intervention, and thrombolytic therapy.⁷⁻⁹

Early Recognition of Cardiac Amyloidosis (1980s)

In the early 1980s, 99mTc-PYP uptake was unexpectedly observed in many patients with cardiac amyloidosis. Wizenberg et al. reported diffuse, intense myocardial uptake in 10 consecutive patients with biopsy-proven amyloidosis, all exhibiting restrictive cardiomyopathy.¹⁰ Other studies during the 1980s suggested the usefulness of 99mTc-PYP in the diagnosis of cardiac amyloidosis; however, due to variable diagnostic accuracy in undifferentiated ATTR and AL subtypes, its clinical use was limited.¹¹ Clinical interest also remained limited due to a lack of disease-modifying therapies

and some concerns over nonspecific tracer accumulation in the heart and other tissues.

Resurgence for ATTR Cardiac Amyloidosis and Technical Refinements (2000s-Present)

Perugini et al. in 2005 demonstrated that 99mTc-DPD (diphosphono-1,2-propanodicarboxylic acid) scintigraphy could noninvasively differentiate ATTR cardiac amyloidosis from AL amyloidosis with high accuracy.¹² ATTR cardiac amyloidosis showed uptake for bone radiotracers, whereas AL cardiac amyloidosis showed minimal to no uptake (Figures 1, 2). They also developed the visual Perugini grading scale (0-3) for semiquantitative assessment as below.¹²

Perugini grading scale:

1. Grade 0: no cardiac uptake and normal rib uptake.
2. Grade 1: Cardiac uptake, which is less than rib uptake.
3. Grade 2: Cardiac uptake with intensity, similar to rib uptake.
4. Grade 3: Cardiac uptake greater than rib uptake with mild/absent rib uptake.

Three clinically available bone-avid radiotracers—99mTechnetium (Tc)-bisphosphonate derivatives (99mTc-pyrophosphate), 99mTc-3,3-diphosphono-1,2-propanodicarboxylic acid (99mTc-DPD), and 99mTc hydroxymethylene-diphosphonate (99mTc-HMDP)—are used for the detection of myocardial ATTR amyloid deposition, but not AL amyloid.¹³ 99mTc-PYP is primarily used in the United States, while 99mTc-DPD and 99mTc-HMDP are predominant in Europe. However, these tracers are viewed as interchangeable and can be used as alternatives to each other because of similar diagnostic performance for ATTR amyloidosis.¹⁴⁻¹⁶

Continued advancements in nuclear imaging, particularly in SPECT/CT, led to improved anatomical localization

and reduced blood-pool artifact, and eventually better diagnostic ability. In 2013, Bokhari et al. developed a standardized method, the heart-to-contralateral (H/CL) ratio, for differentiating AL versus ATTR amyloidosis. 45 patients underwent 99mTc-PYP planar and SPECT imaging, and cardiac uptake was assessed with both a semiquantitative visual score (0 with no uptake to three with diffuse uptake) and by a quantitative method by drawing a region of interest over the heart and contralateral lung (H/CL ratio). They demonstrated that an H/CL ratio >1.5 had 97% sensitivity and 100% specificity for ATTR.¹⁷ They concluded that Tc-99m PYP can be a simple, widely adopted method for diagnosing ATTR amyloidosis.

Maurer et al., in the Transthyretin Amyloidosis Cardiomyopathy Clinical Trial (ATTR-ACT), found that patients on the drug tafamidis, a TTR stabilizer, had reduced mortality and cardiovascular-related hospitalizations and improved functional capacity compared to those on placebo.¹⁸ Its approval by the FDA in 2019 for ATTR amyloidosis led to widespread adoption of 99mTc-PYP imaging in the ATTR diagnostic algorithm. As of 2025, the FDA has approved two more drugs for ATTR: acoramidis (2024), another TTR stabilizer, and vutrisiran (2025), a TTR silencer.¹⁸ Acoramidis prevents amyloid formation by stabilizing the TTR tetramer, while vutrisiran prevents amyloid formation through degradation of TTR messenger RNA.¹⁸

Current Guidelines and Protocols

Cardiac amyloidosis should be suspected in individuals with heart failure and thickened ventricles (>1.2 cm) with relative apical sparing and grade two or greater diastolic dysfunction on echocardiography.¹ However, due to the lack of specificity of echocardiography, cardiac magnetic resonance imaging (CMR) aids in identifying the diffuse, subendocardial, and transmural late-gadolinium enhancement (LGE)

pattern seen in patients with cardiac amyloidosis.

Subendocardial LGE is more commonly seen in AL, and transmural LGE in ATTR cardiac amyloidosis.^{19,20} Moreover, both native (non-contrast) and post-contrast T1 mapping for calculating expanded extracellular volume (ECV) show excellent diagnostic ability for cardiac amyloidosis. Baggiano et al. in their study found that a native T1 < 1036 ms yields a negative predictive value of 98%, and a native T1 > 1164 ms yields a positive predictive value (PPV) of 98% for cardiac amyloidosis, with an ECV cutoff of 0.37 as an excellent diagnostic tool within the range.²¹

Multi-society expert consensus 2021 suggests blood and urine exam for monoclonal proteins and 99mTc-PYP cardiac scintigraphy as key investigations for suspected cardiac amyloidosis, clinically or based on echocardiogram and CMR.¹ If 99mTc-PYP is negative with no monoclonal proteins in the blood and urine, then cardiac amyloidosis is very unlikely. Grade 2- or 3-positive 99mTc-PYP scintigraphy without evidence of monoclonal proteins in blood and urine is diagnostic of ATTR cardiac amyloidosis (specificity and PPV > 98%).²²

When monoclonal proteins are detected in both blood and urine, a histological diagnosis should be confirmed by endomyocardial biopsy. This is necessary because low-grade 99mTc-PYP uptake lacks specificity for ATTR cardiac amyloidosis, and approximately 20% of patients with AL amyloidosis may also show low to moderate 99mTc-PYP uptake.^{16,22} Therefore, ruling out AL amyloidosis—by confirming normal serum and urine light chain profiles—is essential for an accurate diagnosis of ATTR amyloidosis.²³ Serum protein electrophoresis alone is insensitive and unreliable for detecting AL amyloidosis. Instead, serum and urine immunofixation, along with serum-free light chain assays, are critical diagnostic tools.¹ For confirmed ATTR amyloidosis, TTR gene sequencing is required to differentiate between ATTRwt and variant (ATTRv) forms.¹

The standard imaging protocol involves an intravenous injection of approximately

15–20 mCi (555–740 MBq) of 99mTc-PYP. Imaging is performed at early (1 h) and delayed (2–3 h) phases using planar gamma cameras and SPECT/CT.^{1,23} Relying solely on planar imaging may lead to indeterminate findings; therefore, SPECT/CT acquisition at 2–3 h is essential, as it allows for improved anatomical localization of radiotracer uptake and better visualization of early cardiac amyloid deposition sites, including atrial and septal regions.¹⁶ Both planar and SPECT images should be evaluated using semi-quantitative visual scoring (Perugini grading). Notably, recent addenda to the multisociety expert consensus recommendations have removed the use of quantitative H/CL ratio criteria due to inconsistent results, emphasizing instead visual assessment and SPECT interpretation.¹⁶

Conclusion

Since its introduction in the 1970s as a tool for early myocardial, 99mTc-PYP scintigraphy has become a cornerstone diagnostic modality for ATTR). As cardiac amyloidosis is increasingly recognized as a cause of heart failure among elderly patients, 99mTc-PYP imaging plays a central role in the diagnosis of ATTR cardiac amyloidosis after the exclusion of AL amyloidosis in the absence of monoclonal proteins in the blood and urine. A distinct advantage of 99mTc-PYP imaging is its wide accessibility and very high specificity for the diagnosis of ATTR amyloidosis noninvasively without the need for endomyocardial biopsy.

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Couples Match in Diagnostic Radiology

Cailin O'Connell, MD, MEng

Applying to residency in a pair, often referred to simply as “couples matching,” is when 2 people link their residency applications together in the National Residency Matching Program (NRMP). For me, the idea of being able to not only pursue diagnostic radiology, but to do so with my partner by my side, was incredibly exciting. I sought out the help of the internet to see what was out there about diagnostic radiology applicants successfully matching with their partners or best friends, and was met with a lot of contradictory opinions and left with anxiety about the process.

After going through the 2023 to 2024 Electronic Residency Application Service (ERAS) cycle with my now husband (who applied and matched to combined internal medicine and dermatology), I have some of my own tales to tell! Here is everything I learned on my journey, and the advice of some program directors (PDs) I met along the way.

Note: If you're looking for general tips on applying for radiology residency, the *AMSER Guide to Applying to Radiology Residency* is a must read, for couples matchers and non-couples matchers alike.

Tip #1: Plan Ahead for Signaling

Program signals are a newer addition to the residency application process that allow applicants to indicate their interest in a program with a limited resource. For the 2026 application season, diagnostic radiology provides 15 signals. As program signals are now a permanent fixture in ERAS, applicants should be using them to their advantage. During the months leading up to application submission, both sides of the couple should do their

due diligence in figuring out what programs they are competitive for, what cities and regions have high concentrations of programs, and which programs may be a good personality or goal match. After applicants have a program wish list, they can come together and see where the intersections are; *as much as possible, your respective signals should overlap, either by city or program*. If both applicants love “program A,” they should both signal “program A.” If one applicant loves “community program in city B” and their partner loves “academic program in city B,” you each should signal those programs.

Applicants can also compare geographic program concentration across each of your specialties easily with Medmap.io (<https://medmap.io/specialty>), which allows you to map programs across the US and mark them with colored pins. Try to cluster signals around major cities to maximize signaled combinations, but always consider program competitiveness and individual preferences.

In the event of signal mismatch, in which one applicant has more signals than the other, the partner with more signals can either: cluster their signals around the partner who has fewer signals; or use their signals for additional programs that both partners would want to attend, understanding that the other partner may not be interviewed without a signal. This is very specialty dependent, and meeting with specialty mentors can help in selecting an individualized strategy for signaling.

Once both applicants figure out where the majority of program signals will be, cross-reference them with the ERAS geographic preferences list. The Association of Program Directors

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in Radiology showed data in 2023 demonstrating that alignment of geographic preferences and program signals works to the applicant's benefit. That said, only signal programs that you truly have a preference for and identify geographic preferences in places where you want to live for 4 to 5 years.

Tip #2: Don't Leave Preliminary Programs for the Last Minute

Couples matching into an advanced specialty is especially challenging since applicants also need to think about preliminary positions. The radiology applicant should select at least 2 to 3 preliminary programs for each of the signaled programs, especially if their partner is applying into a categorical specialty, where all residency training is completed in one program. Another strategy is to focus on preliminary programs near the applicant's current location, to prevent 2 moves. While it's not mandatory that you do that first year together, the intern year is hard and having a support system nearby is helpful.

After you start to hear back from advanced programs, email the preliminary programs in the area, letting them know that you are interviewing nearby and very interested in their program in the same city. Adding that you are couples matching also helps, and we will get into that in Tip #4.

Tip #3: Get on the Same Page

This one is short and sweet. When it comes time to push "submit" on your applications, sit down and run through the list together. I cannot tell you how important this is, as it is very easy to accidentally leave off a program code by mistake when you're trying to line everything up with your partner.

Tip #4: Get an Interview, Send an Email

This is probably the most important tip I could give: don't be shy about sending the couples match email! When you get an interview, reach out immediately to the PD and program coordinator (PC) of your program expressing your gratitude and excitement, and ask them to notify your partner's program of your interview status. I never asked for my partner to be interviewed, as each specialty will be looking at applicants for their specific qualities, but rather, I asked my program to notify the other of my upcoming interview, to put my partner on their radar for review. Be sure to include the contact info for the other specialty's PD and PC in this email to make communication easier.

In the case that my partner got an interview and I did not, I sent a variation of this email again expressing my interest in the program, stating that my partner was interviewing and asking to be considered for a position in the radiology residency. This process may feel like a lot at first, but we found that being direct

helped to ensure that our couples match status didn't fall through the cracks.

Tip #5: Bring Each Other Up

This one is slightly more controversial, but my partner and I found that programs were very receptive to hearing that we had an important person that we were going to prioritize in the match decision. If you and your partner have family in a specific city where you're interviewing, include that in your response when interviewers ask: "Why this program?" The person interviewing you wants a resident who wants to be both at that program and in that city.

Additionally, when programs see you are couples matching on your application, they may ask about your partner's specialty. I'd recommend having your answer ready and give a little background about why your partner is excited about their specialty. If your partner is applying into a particularly competitive specialty, you may sometimes encounter hesitation from the interviewer, but just remember that you are a team—you should be your partner's biggest cheerleader. Your confidence in your partner is key in these interactions.

Tip #6: Rank Separately First, Then Come Together

Keep a separate, rank-order list (ROL) that's hidden from your partner and have them do the same. Update it after every interview. To remember how you felt after interacting with each program, consider recording a short clip of yourself after each interview, or taking notes and creating a pros and cons list. Either way, you will have factors that are important to you when choosing a program, and you should weigh them as if you're matching alone, at first.

You can use software like Couples Match Tool (<https://couplesmatchtool.com>, created by a couple in medicine) to enter your lists in and combine them using factors such as average rank and distance. We elected to use all our possible combinations in order to maximize our chances of matching, since we felt some distance between us would be better than not having a job at the end of the process. We also opted to include match/no match combinations, in which one partner matches but the other does not, but that is something you need to decide as a pair.

We found the best method for us was to generate a list sorted by distance, then average rank. Combinations with zero distance were priority, and from there the average programs rating controlled the order. We also found it helpful to do some post-analysis in which we grouped combinations by distance of 25 to 50 miles, 50 to 100 miles, 100 to 200 miles, 200 to 400 miles, and so on, and then ranked combinations by average rank within those distance groupings. Our priority was to be physically in the same city; however, once we started to hit an hour and up of driving distance and flying distances, we took liberties with arranging the

list not just by mileage, but program preference. For instance, if we dropped down our list and had to be 6 hours apart by car, we wanted to both be at our favorite programs to make that distance a little more bearable.

Tip #7: Rank-Order Lists

Creating keyboard shortcuts for each program code helped us to enter all the combinations once we finalized our ROL. In iOS, we created text replacements (Settings > Keyboard > Text Replacements) so I could type in “program” and auto-populate the NRMP code without having to worry about typos. You will need to enter a program code for each of the up to 300 combinations and make preliminary lists for each advanced program. This trick really saved my sanity. You also have the option to import in an Excel file of your list, which may be even faster. Duplicate combinations are not allowed by the NRMP software, but it is possible to accidentally transpose combinations, so we spent lots of time performing multiple checks of our ROL combinations prior to submission.

Match Day Reflections

Couples match is a difficult process, and my partner and I had plenty of misgivings about the possibility that we could end up across the country from each other. In March of 2024, the wait

was over: my partner and I opened our match day letters and found out that we would be spending the next 5 years together in Philadelphia, Pennsylvania, in our specialties of choice. We continue to be so grateful to our mentors who advocated for us and supported us in our dream to train together in the same city, and we couldn't be happier with where we ended up!

Important Links Mentioned in the Article

National Residency Matching Program

<https://www.nrmp.org/residency-applicants/get-ready-for-the-match/couples-in-the-match/>

AUR Resources for Applying to Residency

<https://www.aur.org/applying-diagnostic-radiology-residency>

Residency Explorer™ Tool

<https://www.residencyexplorer.org/>

APDR Quarterly Roundtable: Post Mortem on ERAS Program Signaling (2023)

[https://youtu.be/swUY_-DGmWc?](https://youtu.be/swUY_-DGmWc?si=4c1wr9cHwKATdtzo&t=390)

[si=4c1wr9cHwKATdtzo&t=390](https://youtu.be/swUY_-DGmWc?si=4c1wr9cHwKATdtzo&t=390)

AAMC Geographical preferences

<https://students-residents.aamc.org/applying-residencies-eras/publication-chapters/biographical-information#geographic>

Residency Couples Match Rank List Tool

<https://couplesmatchtool.com/>

Moving Toward a More Sustainable Diagnostic and Interventional Radiology Department

Gennaro D'Anna, MD; Chiara Perazzo, MD; Joshua A. Hirsch, MD; James M. Milburn, MD, MMM

Abstract

Radiology significantly impacts the environment, contributing to the healthcare sector's approximately 5% of global greenhouse gas emissions. This is largely due to high electricity consumption from advanced imaging technology and increasing demand for services. A single interventional procedure, for example, can generate 77-243 kg of CO₂ equivalent (CO₂e) emissions and around 8 kg of waste. Environmental burdens include excess energy usage, substantial medical product waste from single-use materials, hazardous substances, and wastewater pollution from contrast agents. A significant problem is the improper mixing of hazardous and nonhazardous waste, which not only exacerbates pollution but also dramatically increases disposal costs, as hazardous waste is ten times more expensive to manage. Studies show that up to 85% of operating theater waste may be incorrectly disposed of as biohazardous. Sustainability in radiology focuses on: 1). Materials optimization: Prioritizing reusable devices, seeking eco-friendly alternatives, implementing recycling programs, and converting to multi-dose contrast vials with weight-based dosing. 2). Waste segregation: Establishing clear protocols to ensure accurate classification of waste, disposing of only visibly blood-saturated items as hazardous, thereby reducing costs and environmental impact. 3). Energy efficiency: Employing as-low-as-reasonably-achievable (ALARA) principles, improving climate control management, powering off unused equipment (which can reduce energy use by up to 70% in standby mode), and collaborating with manufacturers for energy-efficient systems, including those with micro-cooling technology for MRI scanners. 4). Responsible care planning: Reassessing the appropriateness of imaging studies to avoid unnecessary scans, which annually contributed an estimated 3,550-129,200 metric tons of avoidable CO₂e emissions from 2017 to 2021 in the US Medicare Part B population. While artificial intelligence offers potential, its significant data and energy requirements for training models present a "double-edged sword." Radiology departments hold crucial potential to lead sustainable healthcare transitions by optimizing protocols, adopting low-dose technologies, and redesigning waste management in collaboration with industry.

Keywords: sustainability, radiology, waste

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There is no question that advances in radiology have led to remarkable improvements in diagnosis and treatment across a wide range of conditions and diseases. Yet, while these successes and contributions to health care should be celebrated, the impact of medical imaging

on the environment should also be considered and addressed.

Pollution greatly impacts population health by contributing to the development of cardiovascular and respiratory diseases^{1,2} and a host of other conditions related to the impacts of climate change.

Health care has a significant impact on climate change: worldwide, the health care sector is responsible for roughly 5% of total greenhouse gas emissions, which include carbon dioxide, methane, and ozone, among others; the percentage can vary with nation.^{3,4} Diagnostic and interventional radiology are among the highest contributors to health care greenhouse emissions, owing to high electricity consumption by the technology, coupled with increasing demand for services.⁵ For example, the estimated mean CO₂ equivalent (CO₂e) emissions for a single interventional procedure can be between 77 and 243 kg².

Artificial intelligence (AI) is gaining attention for its potential to improve sustainability in radiology in multiple ways, including accelerating imaging and optimizing scanners to improve patient workflows. However, tremendous data and storage requirements for AI and the energy to train models present another challenge as a double-edged sword.⁶

The Hidden Waste

All surgical suites share a common challenge with respect to reducing waste. A typical interventional radiology department places a significant burden on the environment in terms of excess energy usage, waste generation, and water pollution. There is tremendous energy utilization by imaging equipment, medical product waste created by single-use materials and hazardous substances, and wastewater pollution, particularly from iodinated and gadolinium-based contrast agents voided by patients. Researchers estimate that one neurointerventional procedure alone generates approximately 8 kg of waste.⁷⁻⁹

Different Wastes, Different Discard Ways

The improper mixing of hazardous and nonhazardous waste not only exacerbates environmental pollution but also leads to significantly increased disposal costs. When nonhazardous materials are mistakenly discarded as biohazardous waste, the cost of disposal escalates owing to the stringent handling and treatment processes required for hazardous waste. This misclassification not only places an undue financial burden on health care facilities but also underscores the need for better waste segregation protocols and staff training. By improving these practices, radiology departments can reduce their environmental footprint, lower operational costs, and contribute to a more sustainable health care system.

Waste Reduction Strategies

In recent years, the concept of sustainability and its potential to mitigate the impact of pollution and climate change have become more widely recognized in mainstream culture and business practices in the Western world.^{10,11} Waste reduction strategies are a common focus of sustainability initiatives. Increased awareness among frontline health care professionals and departmental, institutional, industry, and government leaders, as well as taking concrete steps to address these issues, can help to substantially reduce medical waste.¹⁰⁻¹² Beyond hospitals, politicians must be educated to help elevate their awareness of the importance and potential impact of proper waste management.

Materials Optimization

All diagnostic and interventional radiology clinicians can have a direct impact on waste reduction by carefully evaluating the materials they use. Prioritizing reusable devices over

disposables and seeking eco-friendly alternatives, for example, can minimize waste without compromising patient safety. Along these lines, comprehensive recycling programs can significantly reduce waste.¹³ Regarding contrast, several vendors offer consulting services to help radiology teams convert from single-dose to multi-dose contrast vials and to help implement weight-based contrast dosing.¹⁴

Waste Segregation

Disposing of hazardous waste costs ten times more than nonhazardous waste,¹⁵ and yet studies have shown that up to 85% of waste in operating theaters is incorrectly disposed of as biohazardous waste, leading to increased disposal costs and environmental impacts.^{7,8} Hazardous waste, including blood-soaked materials, requires specific handling owing to its biohazard risk. Such waste should be disposed of in designated clinical waste bins (typically yellow bags or containers) immediately after use to prevent contamination. Importantly, only items visibly saturated with blood require such treatment; lightly stained materials can often be discarded as nonhazardous waste, depending on local guidelines. Implementing clear waste segregation protocols and educating staff can significantly improve safety and sustainability, ensuring that only truly infectious waste enters the hazardous waste stream.

Energy Efficiency

Climate control systems represent the largest source of carbon emissions from hospitals. Energy expenditure can be reduced by employing as-low-as-reasonably-achievable (ALARA) principles with respect to radiation exposure. In addition, maintaining a consistent temperature in the operating room and managing in-room climate settings can help to reduce electricity consumption.^{2,10}

Energy consumption can also be reduced by powering off unused workstations and monitors, turning off lights in rooms not being used, and implementing energy-efficient equipment. In a recent paper, researchers analyzed the energy consumption and carbon footprint of interventional imaging systems in radiology, cardiology, and urology. They found that systems consume significant energy even in standby mode and that turning them off when not in use could cut energy use by up to 70%.^{2,16,17} Medical device manufacturers also play a crucial role in enhancing sustainability. Several radiology departments are working with vendors to help create more energy-efficient systems.¹⁸ MRI and CT scanners are available with standby modes to reduce energy consumption; some allow customization of scan duration for energy efficiency. Moreover, many newer MRI scanners employ efficient micro-cooling technology that reduces the amount of liquid helium required to cool their magnets.

Responsible Care Planning

Sustainability, optimizing energy use, and managing waste can also be aided through a critical reassessment of imaging appropriateness. A recent study published in the *Journal of the American College of Radiology* revealed that between 4% and 26% of imaging studies performed in the US Medicare Part B population between 2017 and 2021 were potentially inappropriate.¹⁹ These unnecessary exams contributed an estimated 3,550-129,200 metric tons of avoidable CO₂-equivalent emissions annually, primarily from CT and MRI. Such data underscore a dual responsibility of radiologists, to ensure diagnostic accuracy while actively reducing environmental harm. Limiting low-value or unnecessary imaging can make a measurable contribution to climate change mitigation—aligning

clinical excellence with planetary health. Although unnecessary procedures are fewer in interventional radiology than in some other specialties, restricting procedures only to those that are truly essential not only reduces patient radiation exposure but also lowers energy consumption and costs.^{19,20}

Conclusion

Sustainability is no longer just an ethical choice; it's a necessary component of mitigating the environmental consequences of our actions. In its diagnostic and interventional dimensions, radiology holds a unique and strategic position in this landscape. With their heavy reliance on advanced technologies, energy-intensive equipment, and single-use materials, radiology departments are among the highest contributors to hospital-related emissions and waste production. Yet, this also means that they hold untapped potential to lead the transition toward more sustainable health care. From optimizing imaging protocols to adopting low-dose technologies and rethinking waste management practices in interventional suites, every radiology department can make a difference. Interventional radiology, in particular, must actively engage in redesigning workflows and re-evaluating materials (also in cooperation with industry) to reduce environmental harm without compromising clinical efficacy.

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Contrast-Enhanced US: Effective, Safe, Underutilized

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Microbubbles as an ultrasound-enhancing agent (UEA) improve the quality of acquired images for a range of clinical indications in both cardiology and radiology, offering real-time, well-tolerated visualization of vital structures. Despite proven benefits of contrast-enhanced US (CEUS)—including lack of nephrotoxicity or ionizing radiation—concerns about UEA safety have seemingly hindered its widespread adoption in the United States, after a 2007 FDA black box warning noted the potential for rare but serious cardiopulmonary reactions. Numerous studies went on to show that the most serious adverse events (SAEs) happened in patients with severe, underlying cardiac or pulmonary illnesses, the true risk of these agents was extremely low, and UEAs were well tolerated even in critically ill patients.¹⁻³ Despite recent anecdotal reports of CEUS's steady clinical growth—and documented steady market size growth⁴—reticence remains about its use.

Seeking to allay fears and highlight the safety profile of CEUS, Jordan B. Strom, MD, MSc, Director of the Echocardiography Laboratory in the Division of Cardiovascular Medicine at Beth Israel Deaconess Medical Center in Boston, and fellow researchers performed a large, nationwide, claims-based analysis of echocardiograms administered with and without UEAs, from 2018 to 2022. Results published last May in the *Journal of the American Heart Association*⁵ found that SAEs associated with UEAs are “uncommon,” occurring in 1 in 10,000 cases.

“My goal was to test the continued safety of these agents, ultimately finding that the risks [of CEUS]

continue to be vastly exceeded by the benefits,” Dr Strom says.

Similar studies have demonstrated the safety of CEUS in radiology, which has grown in use in recent years, according to Richard G. Barr, MD, PhD, Professor of Radiology at Northeastern Ohio Medical University, radiologist at Southwoods Health, and Editor-in-Chief of the *Journal of Ultrasound in Medicine*.

“Our safety data⁶⁻⁸ is very similar to what [Dr Strom] found,” reports Dr Barr, noting zero deaths in a review of 609,582 patient exams across 118 publications; only 22 SAEs at a rate of less than 1 in 25,000, with adverse events (AEs) occurring at similar rates to contrast-enhanced CT and MRI exams.

David T. Fetzer, MD, Associate Professor of Abdominal Imaging and Director of Ultrasound in the Department of Radiology at UT Southwestern Medical Center, a self-described “busy non-cardiac user of CEUS,” addresses the startling overstatement of rare AEs linked to their use.

“Ultrasound, and particularly microbubble contrast agents, have been held to a different bar than what we have seen with iodinated agents in CT and gadolinium agents in MRI. We all know that there are rare, but true, adverse events in CT and MRI, and there isn't the same overreaction, compared to the reaction we see when there are events in ultrasound,” Dr Fetzer says. “Why is there such a stigma against an otherwise incredibly safe contrast agent? I don't know how many papers we have to come out with as a community to show its relative safety compared to widely used medica-

tions and agents to continue to validate contrast-enhanced ultrasound's utility."

Dr Strom agrees that while medicine inherently involves a level of risk—for example, in the cath lab—the expectation of any treatment is for the benefit to exceed the risk.

"In terms of imaging [in the echo lab], we have to think about [UEAs] in the same way. We have a lot of benefits, and we have a very, very low risk. It makes sense for us to use these agents, and they're not being used," he explains. "We know 10% to 20% of people potentially have an indication for [ultrasound] contrast. We only use contrast in the U.S. in about 6.8% of cardiac ultrasounds."

Cardiac Usage and Data

Dr Strom's recent study, based on data from more than 11.4 million patients, found that SAEs associated with UEAs were "uncommon"—1 in 10,000 cases—and that this low risk was consistent with results of previous studies and was similar across the 4 years and commercially available agents (Lumason from Bracco Diagnostics; Definity from Lantheus Medical Imaging; and Optison from GE Healthcare).

Further, the study evaluated rates of death, anaphylaxis, myocardial infarction, ventricular tachycardia, or cardiac arrest within 2 days of transthoracic echocardiography/stress echocardiography among adults both receiving and not receiving UEAs, and the odds of death were actually lower in patients who received them when accounting for differences in those who receive and don't receive UEAs.

"These findings overall signify the continued safety of UEAs in contemporary clinical practice," according to Dr Strom, who uses UEAs in about 40% of echo lab cases, up from 2.6% from 2000 to 2018.¹⁰ CEUS enhances visualization of left ventricular pacification in the setting of poor endocardial border resolution, assessment of wall motion abnormalities, and identification of masses, aneurysms, apical abnormalities of the heart, and cardiomyopathies, among other cardiac and vascular conditions,¹¹ he says.

"We've really grown the program to allow for sonographers and other technical staff to be able to give UEAs independently within their scope of practice," Dr Strom says of his organization's culture of safety, noting that CEUS may be underutilized nationwide due to sonographer's lack of training with intravenous medication administration, which creates workflow hurdles.

When administering UEAs, it is critical that staff be properly trained in recognition and management of allergic reactions, including the use of an allergy kit, he adds.

"Anaphylaxis is a big issue for a very small number of people, but we need to identify [them] ahead of time," continues Dr Strom, who

is currently working with an allergy group from the Vanderbilt University Medical Center in Nashville to create an echo lab screening tool for polyethylene glycol (PEG) allergy.

In acute intensive care patients, suboptimal image quality of standard echocardiography can lead to downstream or duplicative tests, Dr Strom notes. When making a critical decision, real-time CEUS enhances diagnostic confidence efficiently.

"I strongly feel that we should use all the tools at our disposal to get the best possible diagnostic imaging upfront, so we're making the right decisions at the right time and avoiding repeat testing for our patients," Dr Strom says. "My hope is that the safety data will be reassuring."

Radiology Applications

While used at significantly lower volumes than in cardiology, CEUS is an effective technique for improving the visualization, characterization, and diagnostic accuracy of lesions and vascular structures, and most commonly used in kidney and liver imaging and exams in pediatric and pregnant patients. The tool can be used to assess lesions at the point of care—for example, in the emergency room—and facilitate their characterization to expedite next steps, says Dr Barr, who says renal masses are better diagnosed using thinner-slice CEUS than CT and MR.

"We're getting to the point now where we can almost make a histological diagnosis by evaluating the enhancement pattern...because we have this high frame rate and really good enhancement," explains Dr Barr.

In patients with chronic liver disease being screened for the development of hepatocellular carcinoma (HCC), giving contrast upon lesion detection can facilitate a diagnosis, he adds. "Several studies have shown that 85% of the time ... they don't need to go on for further CT or MR," which saves time and worry for the patient.

While radiology sonographers are trained in managing AEs relating to contrast use, from a safety standpoint, Dr Barr reiterates that SAEs are rare.

"I'm estimating between about 7,000 and 8,000 cases, we've only had one reaction [for which] we actually had to monitor the patient and give medication, and no deaths. We see more reactions with CT and MR than we see with contrast ultrasound," Dr Barr says, adding that ahead of agent administration, it is important to inquire about a known PEG allergy.

Dr Fetzer, who uses CEUS for renal and liver mass characterization and US-guided intervention, appreciates the benefits of same-day CEUS for incidental or surveillance findings.

"[If] we see a mass [on a standard grayscale image], we then do contrast-enhanced ultrasound and are able to diagnose HCC that same day, which accelerates workup," Dr Fetzer says, noting an improved patient experience given long wait times for MRIs.

“We can, with a clear conscious, recommend contrast-enhanced ultrasound because we know for a fact that it has no nephrotoxicity. We can often get the same or similar diagnostic information without the worry that comes along with CT and MRI agents,” Dr Fetzer adds, noting the tool is useful for pregnant women since the agents do not cross the placenta into fetal circulation.

Dr Fetzer, who is co-chair of the LI-RADS working group for CEUS, contributed to research and creation of the algorithm for diagnosing HCC and for evaluating HCC after non-radiation-based liver-directed treatment, demonstrating the value of CEUS and enabling higher volumes of real-world data. CEUS can now be used for HCC diagnosis and for exception points in the management of patients waiting for liver transplantation.

Continuing to reiterate the relative safety of CEUS should reduce hesitancy of use throughout the imaging community, particularly among trained sonographers, concludes Dr Fetzer.

“There’s the misconception that a radiologist always has to be involved [for CEUS]. Yes, you still need two pairs of hands, but that second pair of hands does not need to be a radiologist. You build a team of people who are comfortable administering ultrasound contrast. Highlighting contrast ultrasound safety may help with that adoption and lower the barrier for sonographers to learn it and do it well.”

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Leptomeningeal Spread of Metastatic Wilms Tumor

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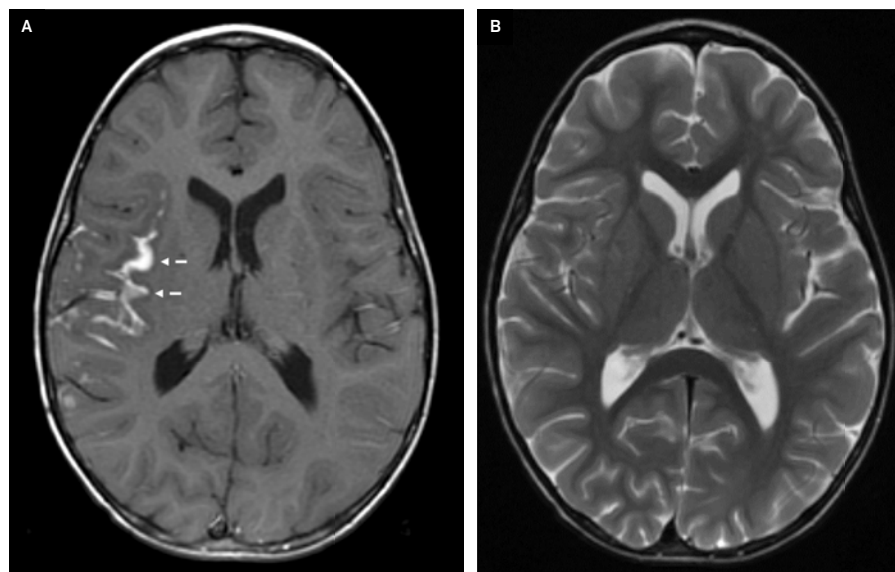
Case Summary

A child with previously confirmed stage III Wilms tumor (WT) who underwent left nephrectomy and whole-abdomen radiation and who had received cycles of chemotherapy presented with multiple lung metastatic lesions 6 months after initial chemotherapy. He underwent resection of the lung lesions, and pathology confirmed WT relapse. Five months later, he presented to the emergency department with seizures and headaches. Cerebrospinal fluid (CSF) analysis obtained in the emergency department showed no abnormal findings.

Imaging Findings

Cerebral magnetic resonance imaging (MRI) (Figure 1) demonstrated signal abnormality in the Sylvian fissure along the insular cortex. No significant vasogenic edema was noted. Cranial computed tomography (CT) (Figure 2) obtained 19 days later showed an interval increase in the extension of the hyperattenuating lesion in a gyriform distribution, at this time also involving the right frontal lobe, allowing for the differences in modalities between

Figure 1. A post-contrast axial gradient-echo T1-weighted image (A) demonstrates gyriform enhancement in the deep Sylvian fissure, most pronounced along the insular cortex (dashed arrows). The corresponding axial turbo spin echo T2-weighted image (B) demonstrates no significant surrounding parenchymal vasogenic edema. The lesion is not easily visible on this sequence.



studies. A follow-up MRI obtained 7 days after the CT demonstrated a mass-like lesion with gyriform distribution, markedly increased size, and significant surrounding vasogenic edema, consistent with worsening leptomeningeal disease (Figure 3).

Diagnosis

Intracranial metastasis of WT.

Discussion

WT is the most common renal malignancy in children.¹ In the United States, approximately 500 new cases are diagnosed each year, most commonly in children <15 years old. WT typically presents as a solitary lesion; however, 7% of cases are multifocal and 5-9% are bilateral.¹ The tumor is caused by abnormal kidney embryogenesis due to

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Figure 2. Post-contrast axial brain CT images demonstrate new, mass-like hyperattenuation in the right frontal lobe (A, solid arrows) and more pronounced hyperattenuating lesions in the right Sylvian fissure, in a gyriform distribution along the insular cortex and frontotemporal operculum (B, arrows), compared with a brain MRI 19 days earlier.

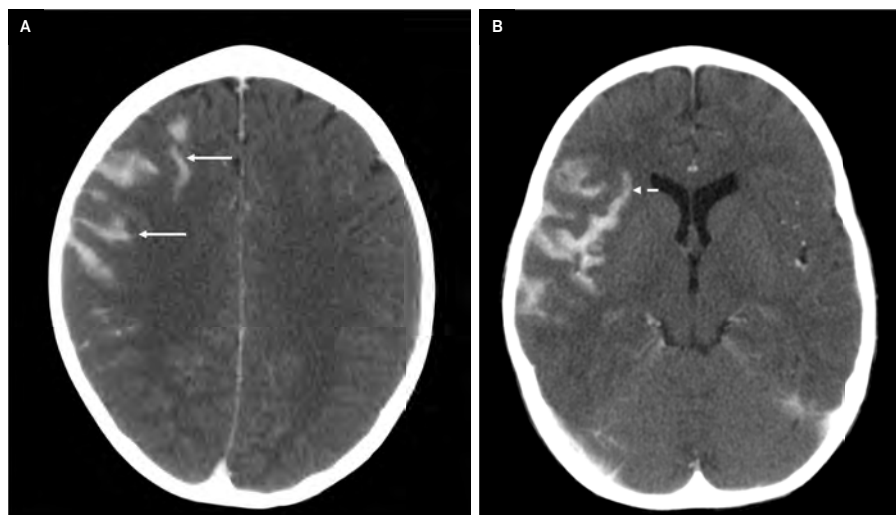
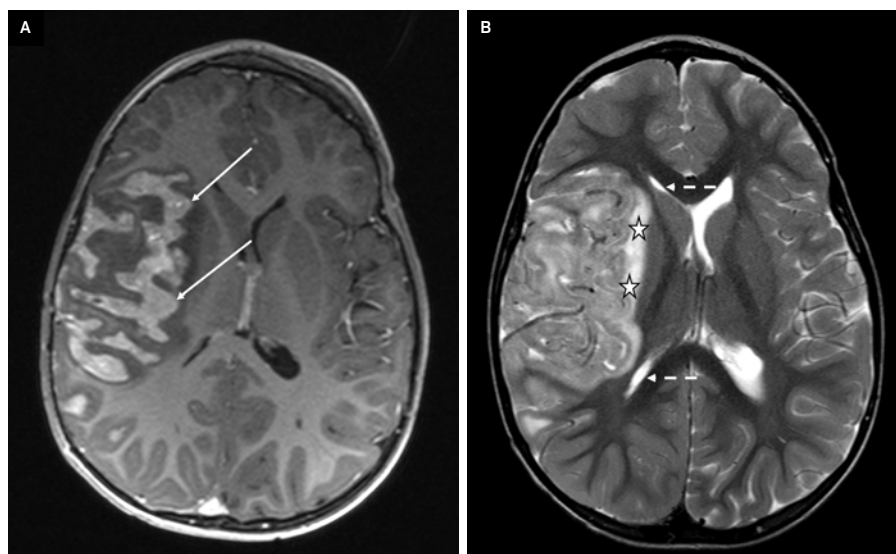


Figure 3. Axial post-contrast gradient echo T1-weighted image (A) and axial turbo spin-echo T2-weighted image (B). A brain MRI performed one week after CT demonstrates rapid progressive disease with an enhancing mass-like lesion with a gyriform distribution occupying the sulci, consistent with leptomeningeal disease (A, solid arrows). Note the interval worsening of the right cerebral hemisphere edema seen with T2 signal of the underlying brain parenchyma (B, stars), partial effacement of the right lateral ventricle (B, dashed arrows), and leftward midline shift.



mutations in genes such as WT1, CTNNB1, and WTX, which lead to the failure of intermediate mesoderm to properly transform into metanephric mesenchyme, a crucial step in the development of functional kidney cell types. However, these mutations only account for a small proportion of cases.¹ Some WT cases occur

as part of multiple malformation syndromes, such as WAGR, Beckwith-Wiedemann, and Denys-Drash syndrome.¹ Prior to the advent of effective chemotherapy, intracranial metastases were found in up to 13% of cases at autopsy. However, with modern therapeutic protocols, the incidence of brain metastases has

decreased significantly, ranging between 0.5% and 1%.² Leptomeningeal metastases from solid tumors can occur through various mechanisms, with hematogenous spread being the most common.⁶

The reported case provides insight into the pathogenesis of metastatic WT to the brain. Early lesions may present as leptomeningeal nodular enhancing lesions along the cortical surface, which can rapidly evolve into large masses over time. Leptomeningeal metastases are rare in children and typically occur as a late complication of cancer progression or recurrence after current oncologic treatments that allow longer survival.^{6,7} In this case, the patient presented with nonspecific neurological symptoms and CSF analysis did not demonstrate malignant cells. Consistent with the literature, this patient experienced relapse of intracranial disease several months to years following first-line treatment.²⁻⁵

When reviewing the prior published cases of intracranial relapse of WT,⁷⁻⁹ we found that only three prior patients in the literature had demonstrated intracranial metastasis in the form of leptomeningeal disease, confirmed by imaging. Porto et al described a patient with relapse 15 months after initial diagnosis. An MRI of the patient's brain demonstrated a nodular enhancing lesion along the cortical surface in the left frontal lobe, which might represent leptomeningeal disease.⁷ Takamiya et al showed head CTs from a 4-year-old patient who presented with generalized convulsion following nephrectomy for WT.⁹ Initial CT demonstrated hyperattenuation along the sulci within the bilateral frontal lobes and left Sylvian fissure, which was interpreted as hemorrhage. Ten months later, numerous high-attenuation masses were noted bilaterally, which were later confirmed by biopsy as metastases of WT. In retrospect, we hypothesize that the hyperattenuating areas along the sulci in their case were likely an early manifestation of leptomeningeal disease, remarkably similar to our case. Madsen et al described a 4-year-old patient in

whom MRI demonstrated a heterogeneous, multinodular, enhancing area in the left parietal and posterior frontal lobes, also consistent with leptomeningeal spread.⁸ The remainder of the cases that we reviewed from the literature presented with intracranial masses rather than predominantly leptomeningeal involvement. While one may question whether these masses represent the result of enlargement and confluence of leptomeningeal disease, it is not possible to confirm this without early imaging. Furthermore, it is possible that the larger cohorts of intracranial relapse in WT patients may include individuals with leptomeningeal disease, rather than intra-axial masses.^{2,3} However, detailed imaging analysis was beyond the scope of these prior studies.

Overall, intracranial relapse of WT remains a diagnostic dilemma. Due to the absence of standardized screening methods across different pathologies, these cases are likely to be underestimated.^{6,7} However, early recognition is of utmost importance, as 5-year survival rates after intracranial recurrence may be as low as 28%.² In pediatric patients with leptomeningeal disease secondary to non-hematological, non-central nervous system malignancies, CSF analysis is not always helpful. As seen in our case, false-negative

lumbar punctures are possible in pediatric patients with leptomeningeal disease. Porto et al demonstrated that only 11 out of 18 patients (61%) with brain MRI findings consistent with leptomeningeal metastases had cytologically positive lumbar puncture.⁷ Additionally, the clinical presentation of these patients is nonspecific.^{2,3}

Conclusion

Intracranial metastasis is a rare but known complication of WT. Neuroimaging, particularly MRI, is crucial for evaluating cancer patients with neurological symptoms, as CSF cytology and clinical presentation lack specificity. With imaging, we observed leptomeningeal disease, an infrequent occurrence in WT documented in only 3 other cases in the literature. Our findings provide comprehensive imaging characteristics of leptomeningeal disease and contribute to the understanding of the pathogenesis of this rare presentation of intracranial relapse in WT patients.

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The Value of Generic Contrast Utilization in Imaging

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The Value of Generic Contrast Utilization in Imaging

Acknowledgement

This article highlights the knowledge and experience of the following professionals from University of California, San Diego health system with transitioning their radiology department to generic iodinated and gadolinium-based contrast agents: Cynthia Santillan, MD, Clinical Professor of Radiology, Vice Chair of Clinical Operations, Department of Radiology; Irina Kalyan, Radiology Manager, Quality, Safety & Performance Improvement; Jeannie Cruz, MRI Manager, Lead Technologist; Laura Israel, CT Manager, Lead Technologist; Joseph Savoie, Senior Director of Radiology.

Executive Summary

This white paper explores the clinical, operational, and financial rationale for adopting US Food and Drug Administration (FDA)-approved generic contrast agents in magnetic resonance imaging (MRI) and computed tomography (CT) imaging. It demonstrates that generic contrast media provide a reliable means to manage rising imaging costs and supply challenges while maintaining diagnostic quality and patient safety. Held to the same safety and efficacy standards as their proprietary counterparts under the FDA's Abbreviated New Drug Application (ANDA) pathway, generic agents present a cost-conscious alternative that aligns with value-based care objectives.

The primary considerations for adopting generic contrast agents discussed include:

- **Therapeutic equivalence:** FDA-approved generics are required to meet identical quality, safety, and performance standards as their proprietary counterparts.
- **Economic impact:** Generic agents reduce per-unit cost and enable significant long-term savings across imaging departments.
- **Operational continuity:** Diversification of contrast suppliers mitigates risk during shortages and supports sustainable, efficient workflows.
- **Clinical validation:** Pilot evaluation and ongoing monitoring of quality and safety can help confirm diagnostic equivalence and maintain clinician confidence.
- **Stakeholder collaboration:** Success requires early engagement across radiology, pharmacy, procurement, information technology (IT), and finance teams.
- **Phased implementation:** A gradual rollout, accompanied by staff education and data-driven periodic reviews ensures a seamless transition and patient safety oversight.

By sharing insights gained from the successful transition to Fresenius Kabi's generic gadolinium-based and iodinated contrast agents at the University of California San Diego (UCSD), this paper further demonstrates how other healthcare organizations can employ similar strategies to enhance supply chain stability while maintaining quality patient care.

Introduction

The burden of an aging population and more people living with chronic diseases has led to a rise in the number of diagnostic imaging examinations performed in the US, a significant portion of which utilize contrast agents to enable accurate diagnoses.^{1,2} Nevertheless, imaging exams are associated with a high-cost burden, and proprietary

contrast agents often account for a sizable portion of imaging expenses.

In the broader healthcare landscape, healthcare organizations and insurers have long been leveraging generic pharmaceuticals to contain costs and manage operational budgets without compromising patient care.^{3,4} With the enactment of the Drug Price Competition and Patent Term Restoration Act of 1984, also known as the Hatch-Waxman Act,

the US has seen a steady rise in the uptake of generic pharmaceuticals.⁵ This legislation created a framework for manufacturers to market generic medicines more efficiently by basing approval on therapeutic equivalence to their proprietary counterparts. The impact of this law is clear: according to the Association for Accessible Medicines, the use of FDA-approved generic and biosimilar pharmaceuticals accounted for 90%

of all prescriptions filled in 2024, but only represented 12% of the total prescription costs, yielding \$467 billion in savings for patients and the US healthcare system.⁶

The same cost-savings pressures are now affecting radiology departments, and having the option to switch to generic contrast agents can help alleviate the financial burden of imaging examinations. With generic agents subject to the same strict regulatory standards as proprietary contrast media, there is a unique opportunity for radiology departments and healthcare organizations to save costs without compromising diagnostic quality or patient safety. Moreover, stocking generic options promotes supplier diversification, eliminates vulnerabilities to contrast media shortages, and ensures supply chain stability.⁷

This paper examines the rationale for using generic contrast agents, highlights their economic, clinical, and operational benefits, and provides an overview of key implementation considerations to support the successful integration of these agents into practice.

Generic Contrast Influences and Drivers

The acceptance of generic contrast media by healthcare organizations is largely driven by financial, operational, and clinical factors that aim to provide value-based care. Rising healthcare costs, reimbursement pressures, and budgetary cuts are among the most immediate motivators. Generic pharmaceuticals offer a practical solution to help address these motivators and stabilize product supply.

The global iodinated contrast media supply shortage in 2022 underscored the need to diversify contrast media sourcing to mitigate risks to patient care and ensure

consistent product availability.⁷ Organizations responded by re-evaluating the need for contrast in many exams, minimizing individual doses to reduce waste, exploring the feasibility of other imaging modalities, and, in some cases, delaying non-critical procedures.⁷⁻⁹

Following the shortage, the University of California, San Diego (UCSD) health system switched some of their agents to generic iodinated and gadolinium-based contrast agents supplied by Fresenius Kabi.^{10,11} “The iodinated contrast media shortage significantly impacted us, and with the pharmacy’s recommendations, we had an interest in diversifying supply across modalities,” says Joseph Savoie, senior director of radiology at UCSD.

Having alternative source options can help prevent the need to ration contrast media—a compelling consideration given that generic products meet the same standards for quality, strength, and efficacy as proprietary agents, as ensured through the FDA’s ANDA process ensures.¹²

Furthermore, healthcare organizations that have adopted generic contrast agents often report a generally smooth transition, as confirmed by the experience at UCSD. Cynthia Santillan, MD, who is a clinical professor of radiology and the vice chair of clinical operations in the department of radiology at UCSD, notes, “It was certainly a value to diversify the brands of contrast agents that we use in our institution because we did not want to restrict the utilization of contrast agents for patient care. Fresenius Kabi’s generic contrast agents are therapeutically equivalent to the branded agents as determined by the FDA. From the QA perspective, I was quite pleased with how the adoption went.”

Another major driver for the adoption of generic contrast is the standardization and sustainability

it brings to radiology workflows. Streamlining formularies to include generic options can simplify inventory management and reduce product waste, ultimately supporting environmental sustainability and operational workflow goals, particularly when a generic alternative replaces its proprietary counterpart. This alleviates the need for a comprehensive product evaluation, which is standard practice when considering changes to contrast agents that are not a one-for-one swap. With generic utilization, a one-for-one change promotes consistency in imaging protocols, workflow efficiency, and bypasses the need for in-depth staff training.

Generic contrast options can give organizations greater flexibility to balance cost, quality of care, and product supply. Rather than being locked into a single supplier or proprietary formulation, organizations can design a formulary that includes one or more agents to align with their clinical and financial objectives. This flexibility can enable organizations to make data-driven choices that enhance operational efficiency while maintaining quality patient care.

The Implementation of Generic Contrast Agents

Transitioning to a generic contrast agent requires careful planning, education, and stakeholder engagement to ensure smooth and successful adoption. A successful feasibility assessment, which includes multidisciplinary representation from administrative leadership, radiology, nursing, pharmacy leadership, procurement and supply chain, quality and safety, IT, and finance, is crucial to meeting the expected outcomes. Involving these stakeholders at the outset enables clear goal setting around cost savings and operational objectives, product training,

Key Takeaways

Best practices for the successful implementation of generic contrast media:

- Establish timelines and financial and operational goals, including those for potential cost savings, product training, tracking and review of safety, and implementation process.
- Determine and engage internal stakeholders early in the process, with representation from administrative leadership, radiologists, technologists, nurses, pharmacy, procurement, quality and safety, IT, and finance.
- Address stakeholder questions and provide supporting clinical data.
- Prepare a formulary kit to introduce the product into clinical practice, including NDC numbers, packaging presentations, pricing, and approved indications.
- Work with the IT team to build entries into the organization's systems with product information and proper billing and reimbursement coding.
- Collaborate with the generic supplier to stock products prior to phasing out proprietary contrast, and update reporting templates and the electronic health record system to list the generic name.
- Educate and train the imaging staff (ie, radiologists, technologists, nurses) on product handling and the importance of monitoring.
- Monitor conversion progress by performing a comparative or pilot evaluation before the complete transition from proprietary to generic contrast.
- Document outcomes post-implementation to ensure continued image quality, patient safety, and workflow efficiency.
- Reinforce the overall goal(s) for generic conversion through validation and effective communication among all stakeholders.
- Review cost savings associated with generic contrast implementation.

quality standards, and verification of clinical and safety equivalence. The product information and clinical data collected throughout the feasibility process not only inform stakeholders but can also be used to facilitate formulary decision-making by pharmacy and therapeutics committees, and support IT efforts to update systems with proper product entries and billing and reimbursement coding.

Jeannie Cruz, MRI manager, technical manager, and lead technologist at UCSD, notes that key steps to generic contrast rollout include educating the imaging staff, securing product from suppliers, and updating reporting templates and electronic health records before phasing out the currently stocked agent. “We did not start the switch until we had supplies on hand. And we made sure to use all the old contrast first. We rolled out communication and training to staff,

and when it was time to start using the generic contrast, the team made sure to monitor patients and report any adverse events immediately. We had overlap to ensure consistency of care, especially in the event of reactions or any other issue.” Using such a phased approach ensures proper documentation and continuity of patient care with minimal disruption to imaging operations.

Conduct a Pilot Evaluation

Although generic contrast agents must demonstrate therapeutic equivalency to their proprietary counterparts, it is important to consider conducting a pilot evaluation to validate contrast performance in the real-world setting. The FDA mandates that generic formulations provide the same active ingredient and strength.¹² However, a pilot evaluation or comparative review can help instill clinician confidence

through hands-on experience and address operational concerns before system-wide rollout.

Engage Early

Transparent and proactive communication during the transition process can help ease end-user hesitancy and skepticism. The longstanding familiarity with the currently used proprietary contrast agent may lead staff to question the quality or diagnostic performance of the generic contrast. Organizations can manage the transition effectively by engaging the entire team of radiologists, technologists, and pharmacy staff early in the process, explaining the stringent standards for generic products set forth by the FDA. Hands-on training via the pilot evaluation can ensure operational continuity and foster acceptance of the generic contrast by radiology staff.

Enact a Feedback Loop

Successful implementation also relies on an evaluation loop that supports continuous monitoring. Once a generic contrast agent is introduced, feedback from radiologists and technologists, along with data on image quality, patient safety, and workflow impact, should be reviewed by a multidisciplinary team to address any challenges promptly. This review ensures patient safety and fosters trust within the radiology department.

Moreover, sharing positive findings such as demonstrating equivalent image quality and the safety of the proprietary contrast agent further validates the decision to adopt a generic product. The safety monitoring performed at UCSD during the change to generic contrast serves as an example. Irina Kalyan, radiology quality manager for safety, quality, and performance improvement notes, “Standardization is key, but keeping patient safety and quality at the forefront is the most important aspect of a product rollout. We have a quality dashboard that allows us to track and trend events. Since switching to generic contrast, we have not observed any differences in patient care.”

Align Goals

Alignment between clinical requirements and financial goals can help determine the value of generic contrast. In addition to the clinical metrics discussed, financial and operational advantages should be quantified and benchmarked against the performance of the proprietary contrast. These include cost per unit, the amount wasted, supply predictability, and budget impact. Balancing financial analyses with clinical data can validate

return on investment, determine cost avoidance, and help justify the expansion of system-wide generic contrast use.

Evaluate, Re-Evaluate, Communicate

Finally, periodic data-driven re-evaluation can help healthcare organizations adapt to new product availability and updated regulatory guidance, while maintaining efficient and high-quality imaging standards. By combining structured evaluation, multidisciplinary collaboration, and financial oversight, organizations can sustain the use of generic contrast media with both clinical confidence and economic efficiency.

Proactively implementing a process in collaboration with radiologists to monitor patient safety trends is critical to the long-term success of the transition. Capturing and sharing safety-related metrics post-implementation can guide informed decision-making, build staff confidence, and justify expanding the use of additional generic products. Ultimately, one successful transition can serve as the blueprint and guide future transitions.

Conclusions

Generic contrast agents can help healthcare organizations address costs and streamline operational processes. With FDA oversight ensuring efficacy and patient safety through therapeutic equivalence standards, these agents are well-positioned to become more commonly used in imaging practices across the US. A carefully managed implementation process, guided by stakeholder engagement, hands-on experience, and ongoing clinical monitoring, can expand the use of

generic contrast agents and unlock significant value for healthcare organizations and patients alike.

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Primary Small Cell Carcinoma of the Tonsil

Joshua E. Cunningham, MD; Tomy Kalapparambath, MD

Case Summary

A middle-aged patient presented to the otolaryngologist with a progressive sore throat and cough. The patient's medical history included ischemic cardiomyopathy with automatic implantable cardioverter defibrillator placement, coronary artery disease with myocardial infarction and coronary artery bypass graft, cerebrovascular accident, atrial fibrillation, mitral valve regurgitation, diabetes mellitus, and dyslipidemia. They denied any history of smoking or alcohol use.

On exam, the patient was found to have a right tonsillar mass, which was subsequently biopsied.

Pathology demonstrated the proliferation of crowded malignant cells. Neoplastic cells were found to be positive for OSCAR pancytokeratin, CD56, synaptophysin, and chromogranin. P16 was found to be positive. P40, CK5/6, and P63 were negative.

Imaging Findings

Contrast-enhanced CT of the neck (Figure 1) demonstrated bilateral neck lymphadenopathy and a right palatine tonsil mass. Initial ¹⁸F fluorodeoxyglucose PET/CT scan (Figure 2) demonstrated significant uptake in right palatine tonsil mass (Standardized Uptake Value (SUV) max 22) and bilateral neck lymph

nodes (SUV max 11). The scan revealed no other FDG-avid masses specifically in the lungs. Following 4 cycles of cisplatin/etoposide chemotherapy and radiation therapy (60 Gy, Figure 2) and 5 months after the patient's initial presentation, PET/CT demonstrated complete metabolic response with resolution of abnormal metabolism in right palatine tonsil mass and bilateral neck lymphadenopathy.

Diagnosis

Primary small cell carcinoma (SCC) of the tonsil

Discussion

SCCs are poorly differentiated tumors most commonly seen in the lungs, with extrapulmonary SCCs occurring in only 5% of all cases.¹ Tonsillar tumors are most often diagnosed as squamous cell carcinomas, which are associated with risk factors such as smoking, alcohol consumption, and human papilloma virus (HPV) infection.² Primary tonsillar SCC is extremely rare, with approximately 30 cases reported since it was first described in 1972.²⁻⁵ Symptoms of tonsillar SCC include neck mass, tonsil pain, odynophagia, cervical lymphadenopathy, sore throat, and metastasis.²⁻⁵ It

has been suggested that HPV may play a role in the pathogenesis of tonsillar SCC.³ There have also been reports of tonsillar SCC mixed with SqCC,^{3,6} and it has also been suggested that SCC may represent a form of disease progression of SqCC.³

SCC is primarily diagnosed pathologically with H&E staining, although diagnosis is often aided by immunohistochemical analysis. These entities commonly stain positive for CD56, chromogranin, and synaptophysin.¹ CT often demonstrates a tonsillar mass with cervical lymphadenopathy.^{2,4,5} SCC of the tonsil should prompt investigation for metastasis from other sites, particularly from the lung.

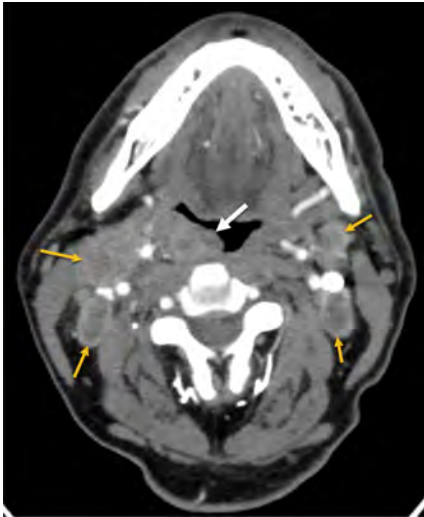
Paraneoplastic syndromes have a well-known association with SCC of the lung.⁵ While previous reviews have not reported paraneoplastic syndromes with tonsillar SCC,⁵ Mineta et al reported ectopic antidiuretic hormone (ADH) production, while Omakobia et al reported a likely case of paraneoplastic syndrome associated with cerebellar signs and diplopia.⁷

Given the rarity of the disease, there is no standard treatment protocol for tonsillar SCC. However, treatment typically combines chemotherapy (platinum-based regimens with etoposide), radiation therapy, and resection.^{2,8} These treatments are guided mostly by previously established treatment standards in SCC of the lung or larynx.² While the initial response may appear promising, primary disease resolution is often followed by the discovery of distant metastases.^{2,6} Common sites of metastasis include the

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Figure 1. CT scan of the neck with intravenous contrast demonstrates a right palatine tonsil mass (white arrow) and bilateral neck lymphadenopathy (yellow arrows).

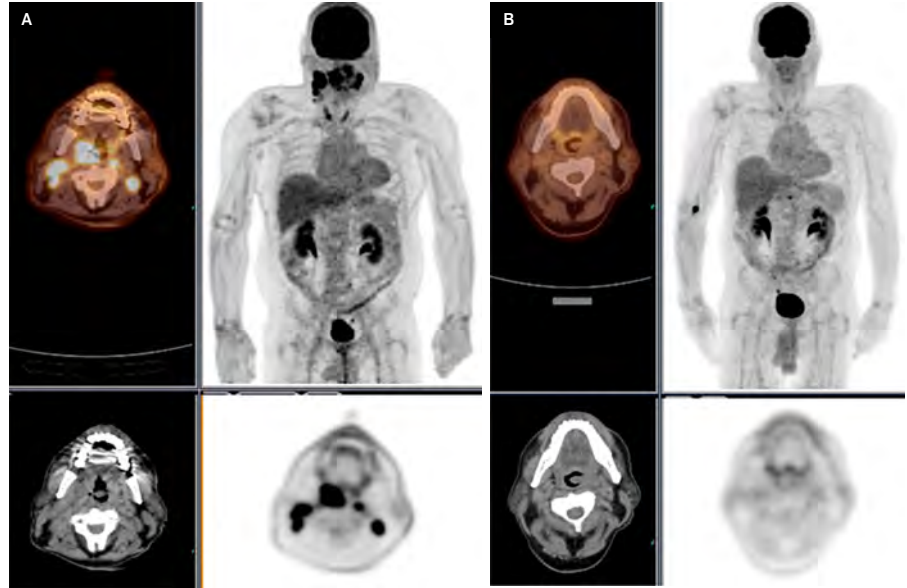


liver, lungs, bones, brain, and skin.^{2,4,9,10} Primary tonsillar SCC carries a dismal prognosis, with one recent review reporting recurrence or distant metastasis in 66.7% of cases and a median survival of 18 months.²

Conclusion

Primary SCC of the tonsil is exceedingly rare and has a significant mortality rate despite chemotherapy, radiation therapy, and tumor resection. Patients may present with a sore throat, odynophagia, cough, neck mass, cervical lymphadenopathy, and metastasis. Imaging commonly demonstrates a tonsillar mass with local cervical lymph node spread. Discovery of tonsillar SCC should prompt investigation to exclude other sites of primary SCC, such as the lungs. Although initial treatment may appear successful, clinicians should proceed with careful and recurrent evaluation of patients owing to the significant risk for metastasis.

Figure 2. (A) An F-18 fluorodeoxyglucose (¹⁸FDG) PET/CT scan with significant uptake in the right palatine tonsil and bilateral neck lymph nodes. (B) ¹⁸FDG PET/CT scan demonstrates complete metabolic response and resolution of abnormal metabolism in the right palatine tonsil and bilateral neck lymph nodes.



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Calcific Subcoracoid Bursitis

Rishi Kalra, DO; Swati Malik, DO; Armand E. Abulencia, MD; Etan Dayan, MD

Case Summary

An elderly patient presented to their orthopedic surgeon complaining of right shoulder pain. The patient had been experiencing discomfort localized to the anterior and superior shoulder for the past 2 months, with no preceding history of trauma. The patient's medical history included obstructive sleep apnea, laryngopharyngeal reflux disease, chronic rhinitis, hypertension, and hyperlipidemia. Upon physical examination, tenderness was noted over the anterior shoulder and the acromioclavicular joint, along with positive impingement signs and a positive cross-over test. In response, the patient received intra-articular glenohumeral and subacromial-subdeltoid bursal injections containing a steroid and an anesthetic. The patient was advised to engage in gentle range-of-motion exercises as tolerated and to take nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen for pain management as needed. Following 2 weeks without significant improvement in their symptoms, a prednisone taper was prescribed. Although the patient reported some relief, their pain persisted.

Imaging Findings

Right shoulder radiographs revealed a 2.8 × 3.4 × 1.7 cm (medial-lateral ×

craniocaudal × anteroposterior) calcified macro-lobulated density anterior to the humeral head in a subcoracoid position on the scapular Y view (Figure 1). Notably, the calcification appeared denser in the inferior dependent portion. Non-contrast MRI depicted a uniformly mild T2 hyperintense and proton density isointense lesion, relative to skeletal muscle, with layering of hypointense material in the posteroinferior dependent portion, corresponding to the denser calcification observed on radiographs (Figure 2). The lesion resided in a subcoracoid position, anterior to the subscapularis muscle, and extended between the short and long head biceps tendons, within the subcoracoid bursa. These findings were consistent with the location of the multilobulated calcified mass identified on the prior X-ray. Subsequently, an MRI with and without contrast revealed peripheral enhancement around the synovial lining of the distended subcoracoid but no internal enhancement (Figure 3).

Diagnosis

Calcific subcoracoid bursitis.

Discussion

Hydroxyapatite crystal deposition disease (HADD) is a crystal-induced

syndrome characterized by the accumulation of hydroxyapatite crystals within joint spaces, tendons, or bursae. The pathogenesis of calcific tendinopathy, a hallmark of HADD, is attributed to decreased oxygen tension within tendons, prompting a phenotypic shift of tenocytes to chondrocytes and subsequent calcification.¹ While HADD predominantly affects the shoulder, particularly the rotator cuff tendons, instances involving the subcoracoid bursa are rare. The subcoracoid bursa, delineated superiorly by the coracoid process and tendons of the short head of the biceps and coracobrachialis, with inferior borders formed by the subscapularis tendon, infrequently exhibits involvement in HADD.²

Conventional radiography typically reveals the characteristic appearance of HADD as a globular, homogeneous hyperdensity with smooth or indistinct margins. However, ultrasound offers a more dynamic assessment, showcasing calcific tendinopathy in various stages of calcification. These stages encompass precalcific, calcific, and postcalcific phases.³ Within the calcific stage, differentiation is made between a resting phase, marked by solid calcifications resulting in complete acoustic shadowing on ultrasound, and a resorptive phase, where softer calcifications lead to partial or absent shadowing.³ MRI further elucidates the pathology, depicting calcific tendinosis or bursitis as a T2 hypointense, homogeneous ovoid signal, often accompanied by variable hyperintense peripheral signals. These peripheral hyperintensities may denote concurrent edema or bursal fluid accumulation.⁴

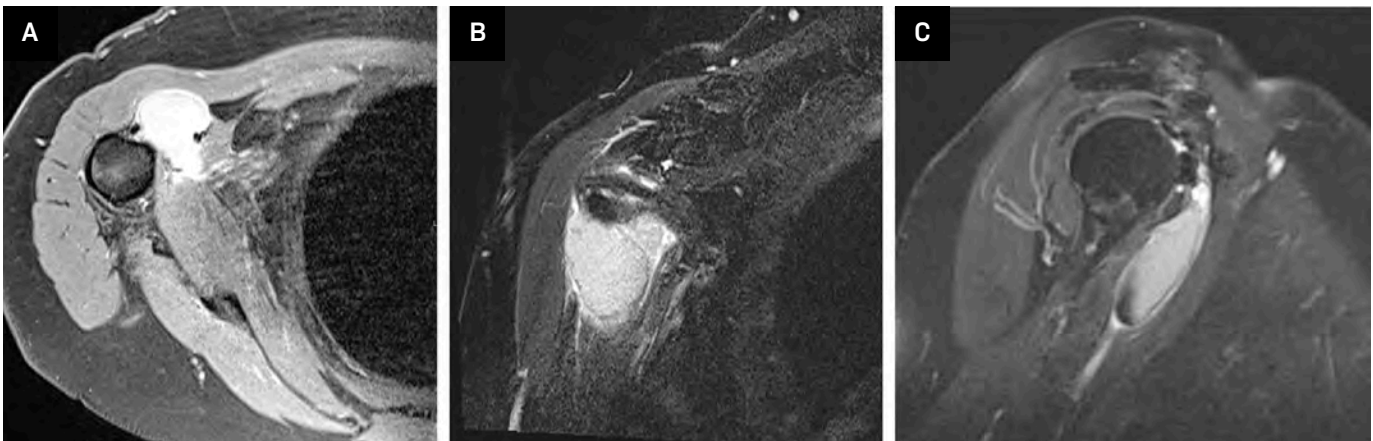
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Figure 1. Radiographs of the right shoulder: Internal rotation (A), external rotation (B), and scapular Y-view (C) demonstrated multilobulated calcifications adjacent to the glenohumeral joint.



Figure 2. MRI shoulder without contrast: Axial view (A) of a proton density fast-spin echo sequence and a coronal view T2 fat-suppressed image (B) showed a $1.5 \times 3.4 \times 4.1$ cm lesion which was hyperintense compared to skeletal muscle, but hypointense compared to fluid, located in a subcoracoid position. Sagittal view (C) showed a mild T2 hypointense signal along the inferior aspect of this lesion.



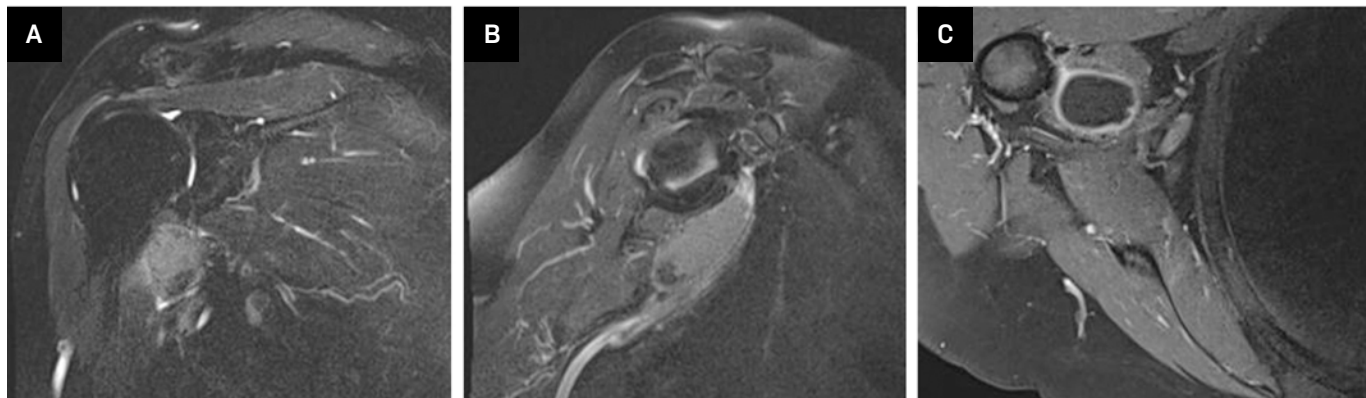
During the resorptive phase of HADD, the migration of softer crystals to adjacent tissues via delaminating zones poses significant clinical challenges.³ Patients afflicted with this condition, frequently women with a median age ranging from 31 to 40 years,⁴ commonly present with symptoms such as joint swelling, diminished range of motion, and instability, often accompanied by episodes of acute shoulder pain. The resorptive phase exacerbates symptoms, particularly

during movement, leading to pronounced discomfort. In such cases, interventions aimed at pain management become imperative. Under ultrasound guidance, the orthopedic aspirated our patient's bursa, resulting in the extraction of 10 mL of tan chalky fluid from the affected area. The aspirated fluid was subsequently sent for crystal analysis. Ultrasound imaging confirmed successful decompression of the bursa. Ultrasound-guided corticosteroid injections or needling/lavage of the

affected bursa are frequently employed to alleviate pain and restore functionality,³ mirroring the approach undertaken in our patient's case.

HADD can manifest acutely, precipitating erosive changes in surrounding osseous structures and precipitating destructive shoulder arthropathy, exemplified by conditions like Milwaukee shoulder syndrome, attributed to hydroxyapatite crystal deposition. Furthermore, intraosseous calcifications

Figure 3. MRI with and without contrast: Coronal view (A) and sagittal (B) T2 fat-suppressed image without contrast again showed a hyperintense lesion within the subcoracoid bursa. A T1 axial fat-suppressed post-contrast image (C) showed peripheral enhancement around the synovial lining without internal enhancement.



may ensue, potentially manifesting as lytic lesions within the shoulder region.

Distinguishing HADD from other systemic diseases marked by intra-articular calcifications, such as calcium pyrophosphate deposition disease (CPPD) and gout, is imperative. While CPPD calcifications typically exhibit a more linear and diffuse pattern, gout can present with MRI findings akin to those observed in HADD.⁴ Notably, patients afflicted by gout often present with elevated urate levels, yet both gout and hydroxyapatite crystals exhibit negative birefringence under polarized light.⁴

It is imperative to discern HADD from more aggressive pathologies, as migration of hydroxyapatite crystals may lead to pronounced osseous changes characterized by cortical erosion, periosteal reaction, intramedullary edema, and soft tissue calcifications.¹ Key differentiating features favoring a diagnosis of HADD over a more aggressive entity include

the absence of joint effusion or soft tissue mass.¹ Additionally, during the acute phase, HADD may exhibit MRI findings resembling those of infectious entities, typified by an extraosseous T1 hypointense rim and T2 hyperintense signal.¹

Conclusion

While calcific bursitis frequently involves the supraspinatus tendon, the predominant site for calcific tendinopathy, our case report highlights a rare occurrence of calcific subcoracoid bursitis. Understanding the diverse imaging characteristics of this benign condition is paramount in preventing unwarranted interventions and facilitating timely and suitable symptom alleviation for patients. By enhancing awareness of such atypical presentations, clinicians can optimize diagnostic accuracy and therapeutic interventions, ultimately

improving patient outcomes. Continued research into the nuanced manifestations of calcific bursitis is essential for refining diagnostic protocols and advancing management strategies in clinical practice.

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Pseudotumoral Sarcoidosis of the Spleen

Sarth Shah, BS; Angela Fast, MD; Alexandra Roudenko, MD

Abstract

Sarcoidosis is a nonneoplastic condition characterized by noncaseating granulomas, primarily in the lungs. This condition is usually asymptomatic; however, extrapulmonary manifestations may exist, including noncaseating granulomas in other organs such as the spleen. On imaging, these lesions may resemble cancer, such as lymphoma, necessitating a biopsy for further histological workup. In patients with a history of malignancy, this workup is absolutely indicated to rule out more ominous conditions compared to the relatively benign condition of sarcoidosis. Once lymphoma and other neoplastic conditions are ruled out, a splenectomy may be performed if the patient is experiencing splenomegaly or pancytopenia to resolve symptomatology. In our patient with a cancerous history and confirmed sarcoidosis of the lungs who was experiencing splenomegaly and pancytopenia, radiograph imaging and further histological analysis were absolutely necessary to rule out neoplastic conditions, and a splenectomy was performed to resolve her symptoms.

Keywords: sarcoidosis, pseudotumor, splenic lesions

CASE SUMMARY

An elderly patient presented for a routine checkup, with recent lab work demonstrating progressive anemia. The patient's medical history included breast cancer treated with chemotherapy/radiation and lumpectomy; Hodgkin lymphoma and non-Hodkin lymphoma treated with chemotherapy; sarcoidosis; obstructive sleep apnea; and asthma. Other notable history included multiple packed red blood cell transfusions required for the previous surgeries.

Clinical blood work demonstrated low hemoglobin, hematocrit, and red blood cell levels. The physical exam demonstrated splenomegaly on palpation.

IMAGING FINDINGS

Given the patient's cancer history and anemia, CT imaging was performed, demonstrating a mildly hyperdense 13.1 cm lesion in the portal venous phase (Figure 1), with no other significant findings. Multiphasic, multiplanar MRI demonstrated a 3.3 cm × 2.7 cm mildly T2 hyperintense, enhancing lesion in the posterior aspect of the spleen (Figure 2).

Pathology demonstrated noncaseating granulomas without evidence of malignancy, ruling out breast cancer or lymphoma metastasis. Acid-fast bacilli and Grocott methenamine silver stains were negative for microorganisms. No foreign material was seen under polarizable light. The findings were deemed consistent with splenic involvement of sarcoidosis.

DIAGNOSIS

Pseudotumoral sarcoidosis of the spleen.

Differential diagnoses included lymphoma, metastasis, and sarcoidosis.

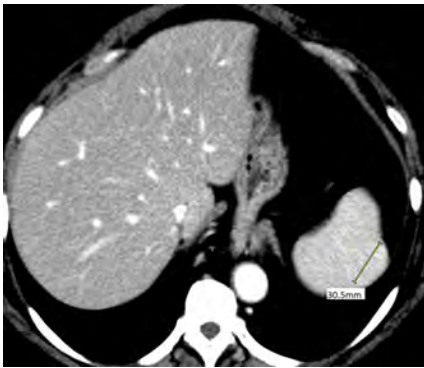
DISCUSSION

Sarcoidosis was first reported in 1877 by Jonathan Hutchinson, who described unusual skin nodules of unknown pathophysiology.¹ The exact etiology of sarcoidosis remains unknown, but it is theorized to involve genetic components as well as possible exposure to substances and infectious agents.² However, sarcoidosis is known to be a nonneoplastic condition characterized by the development of noncaseating granulomas in various organs and systems, most commonly the lungs and lymph nodes. Other areas are less commonly involved, with manifestations in the spleen and other organ systems reported in approximately 10-50% of patients.³

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Figure 1. Axial CT abdomen demonstrates a mildly hyperdense solitary 3.1 cm lesion in portal venous phase.



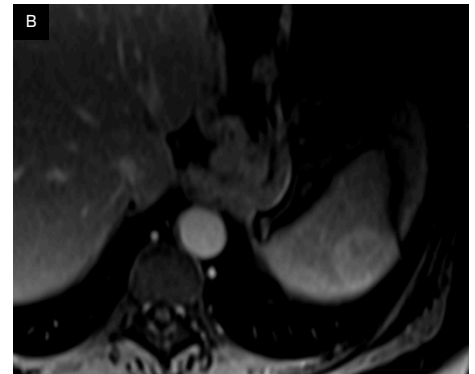
Presentation is often asymptomatic,⁴ and the condition is often discovered incidentally on imaging. However, patients may experience constitutional symptoms such as cough, dyspnea, weight loss, and fever, with up to 30% experiencing extrapulmonary symptoms. Patient morbidity is often due to pulmonary complications; therefore, thoracic imaging findings are used to stage severity.

The most common scoring system for sarcoidosis is the Scadding staging system, which uses chest radiography to stage disease progression.⁵ However, extrapulmonary manifestations found on imaging may present a diagnostic challenge. The typical presentation of extrapulmonary sarcoidosis in the abdomen includes multiple small and often hypoenhancing nodules in the liver and spleen.⁶

Solitary, solid-appearing, enhancing masses are uncommon⁷ and present a diagnostic conundrum, given that more ominous and potentially malignant etiologies, such as lymphoma, are to be considered, especially in patients with a history of malignancy.

In the absence of a concerning history of such conditions as immunocompromise or malignancy, a less aggressive approach can be considered when abdominal manifestations of sarcoid present with typical imaging findings of multiple hypoenhancing nodules. These cases often follow a benign clinical course and, absent systemic symptoms or significant

Figure 2. (A) T2 axial MRI demonstrates a mildly hyperintense 3.3 cm × 2.7 cm solitary lesion in the periphery of the spleen. (B) Post-contrast MRI scan in the portal venous phase demonstrates mildly heterogeneous enhancement.



pancytopenia, conservative management with steroids and patient monitoring is appropriate; splenomegaly tends to regress within one year.⁸

However, the presence of atypical features on imaging, such as a large, solitary, solid mass, raises concern for and typically necessitates histopathological confirmation to rule out malignancy. This is particularly important, as the radiologic appearance of sarcoid lesions can closely mimic that of splenic lymphoma or other metastatic processes, especially in patients with an oncologic history.⁹

Additionally, some splenic sarcoidosis patients experience pancytopenia, which may also mirror lymphoma. Moreover, if symptoms such as abdominal pain, splenomegaly, and pancytopenia are present, a splenectomy may be considered.¹⁰ In our patient, a history of malignancy and pancytopenia was present, requiring an aggressive histological approach to rule out malignancy. A splenectomy was performed, resulting in complete resolution of symptoms.

Although extrapulmonary lesions are common in sarcoidosis, ominous findings may require further investigation. Imaging is necessary to identify possible masses in sarcoidosis patients with splenomegaly and prior malignancies; histological sampling is further indicated to diagnose the cause of the masses, and splenectomy may be considered to resolve any associated symptoms. This stepwise

process is essential for diagnosis, guiding treatment options, and reduction of morbidity and mortality.

CONCLUSION

Sarcoidosis is a nonneoplastic condition with the development of noncaseating granulomas, most commonly in the lungs and less commonly in extrapulmonary locations such as the spleen. Unusual imaging manifestations of sarcoidosis, including pseudotumoral presentation with a solitary mass, can present significant diagnostic challenges. Recognition of this presentation is essential, as the condition impacts treatment options and management decisions.

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"My dear, here we must run as fast as we can, just to stay in place. And if you wish to go anywhere you must run twice as fast as that."

—Lewis Carroll, *Alice in Wonderland*

Follow Up?

C. Douglas Phillips, MD, FACR



Dr Phillips is a professor of Radiology, director of Head and Neck Imaging, at Weill Cornell Medical College, NewYork-Presbyterian Hospital, New York, New York. He is a member of the *Applied Radiology* Editorial Advisory Board.

One of the many things about radiology that I have found impactful—*impactful? Is that a word? Hmmm, guess so. It's in the dictionary*—is the concept of a temporal element of pathology. Things change over time, or may change over time, or don't change at all over time. We know that how things change (or don't change) over time can help clue us in to their significance. And, we know, a lot of things are either not going to change or will change slowly. You see a thing, you know it is likely an entity that doesn't change much, likely not an operable lesion, and you dictate that it is what it is, and that follow-up isn't necessary unless something else changes. Like clinical findings. We do it all the time. And ... you know where I'm going. It gets followed up like a *hawk*. Monthly MR studies. Biweekly US examinations. Repeat chest film ad infinitum. I think I could save the system a fair amount of money if I was allowed to control when the follow-up studies for some things were performed. A follow-up for a bone island in 3 months? Yep; I've seen it. And, lo and behold, it didn't change. And it didn't on the next 3-month follow-up. No more follow-up studies on that one (perhaps the patient found a new doctor).

There is another element of this follow-up thing that can occasionally make me pound my head on

a table. You're worried about something. You ask for a follow-up. You are persuasive. And they even put in their note "follow up for change; we will see them back when this is repeated." They did what you recommended, and you see the repeat. It grew. It changed. And ... they do nothing. Order another follow-up. New note in the system: "Follow up for more change; we will see them back when this is repeated." Jeez.

The last minor point in this is that some things that are still a nothing *may* change. They are still likely a nothing; they just are a nothing that changed. The occasional smirk I get when I see a colleague who tells me about the nothing that I picked up and recommended nothing on (and they followed up, because, see paragraph 1) and changed a little on the follow-up is a little disconcerting, but I have seen enough now that I don't let it bother me. I even look at the study for them. "Yes, it changed a little. And is still nothing."

An important concept an early radiology mentor of mine drove home to me is the following: "We don't drive the trucks, we just load them." Time to load some more trucks.

Keep doing that good work. Mahalo.