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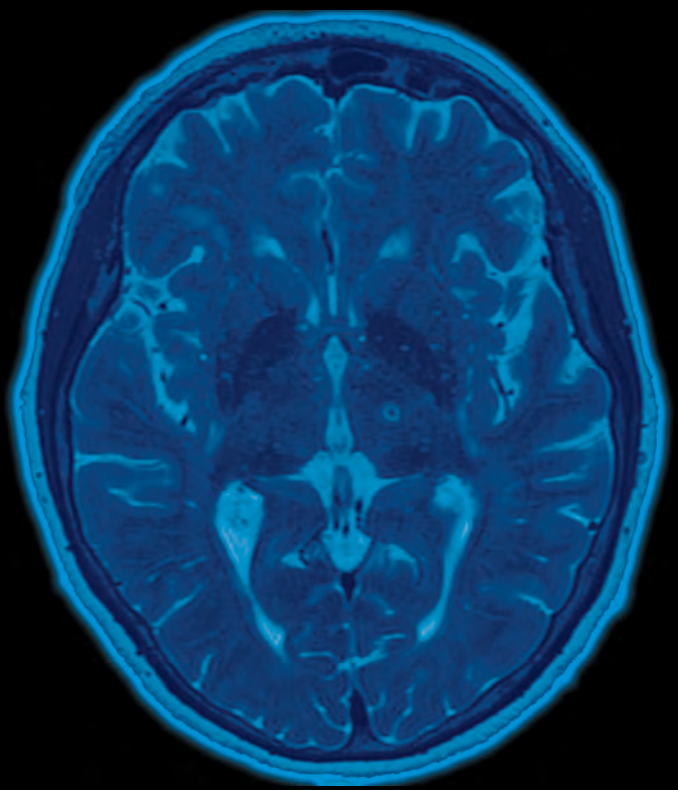

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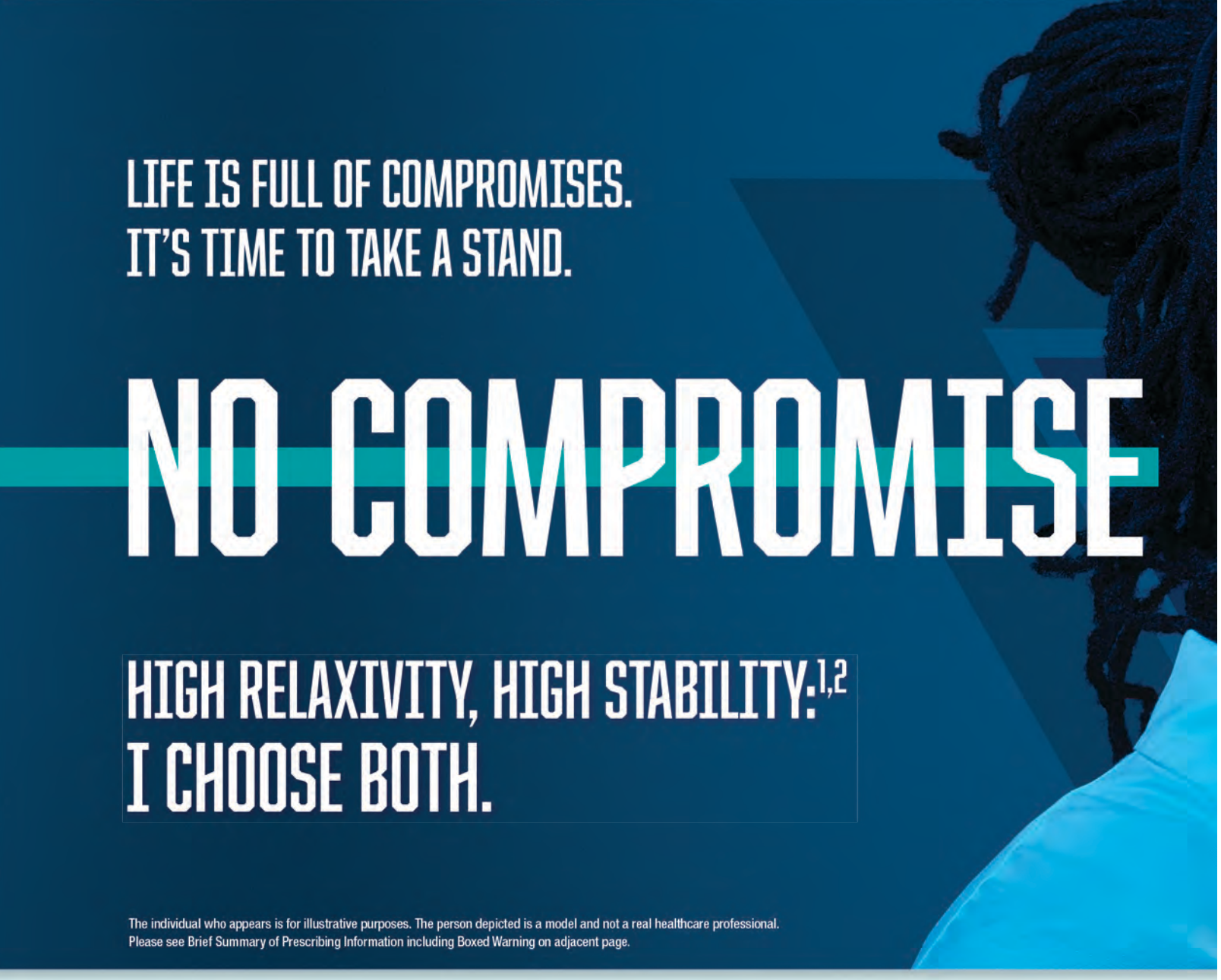

LIFE IS FULL OF COMPROMISES. IT'S TIME TO TAKE A STAND.

NO COMPROMISE

HIGH RELAXIVITY, HIGH STABILITY:[1,2] I CHOOSE BOTH.

The individual who appears is for illustrative purposes. The person depicted is a model and not a real healthcare professional.
Please see Brief Summary of Prescribing Information including Boxed Warning on adjacent page.

VUEWAY™ (gadopiclenol) solution for injection

Indications
VUEWAY injection is indicated in adults and children aged 2 years and older for use with magnetic resonance imaging (MRI) to detect and visualize lesions with abnormal vascularity in:

- the central nervous system (brain, spine and surrounding tissues),
- the body (head and neck, thorax, abdomen, pelvis, and musculoskeletal system).

IMPORTANT SAFETY INFORMATION

WARNING: NEPHROGENIC SYSTEMIC FIBROSIS (NSF)

Gadolinium-based contrast agents (GBCAs) increase the risk for NSF among patients with impaired elimination of the drugs. Avoid use of GBCAs in these patients unless the diagnostic information is essential and not available with non-contrasted MRI or other modalities. NSF may result in fatal or debilitating fibrosis affecting the skin, muscle and internal organs.

- **The risk for NSF appears highest among patients with:**
  - **Chronic, severe kidney disease (GFR <30 mL/min/1.73 m^2), or**
  - **Acute kidney injury.**
- **Screen patients for acute kidney injury and other conditions that may reduce renal function. For patients at risk for chronically reduced renal function (e.g. age >60 years, hypertension, diabetes), estimate the glomerular filtration rate (GFR) through laboratory testing.**
- **For patients at highest risk for NSF, do not exceed the recommended VUEWAY dose and allow a sufficient period of time for elimination of the drug from the body prior to any re-administration.**

Contraindications
VUEWAY injection is contraindicated in patients with history of hypersensitivity reactions to VUEWAY.

Warnings
Risk of **nephrogenic systemic fibrosis** is increased in patients using GBCA agents that have impaired elimination of the drugs, with the highest risk in patients chronic, severe kidney disease as well as patients with acute kidney injury. Avoid use of GBCAs among these patients unless the diagnostic information is essential and not available with non-contrast MRI or other modalities.

Hypersensitivity reactions, including serious hypersensitivity reactions, could occur during use or shortly following VUEWAY administration. Assess all patients for any history of a reaction to contrast media, bronchial asthma and/or allergic disorders, administer VUEWAY only in situations where trained personnel and therapies are promptly available for the treatment of hypersensitivity reactions, and observe patients for signs and symptoms of hypersensitivity reactions after administration.

INTRODUCING

Vueway™
(gadopiclenol) injection
485.1 mg/mL

HALF THE GADOLINIUM DOSE COMPARED TO OTHER MACROCYCLIC GBCAS IN APPROVED INDICATIONS.[1,3-6] FROM BRACCO, YOUR TRUSTED PARTNER IN MRI.

BRACCO
LIFE FROM INSIDE

Gadolinium retention can be for months or years in several organs after administration. The highest concentrations (nanomoles per gram of tissue) have been identified in the bone, followed by other organs (brain, skin, kidney, liver and spleen). Minimize repetitive GBCA imaging studies, particularly closely spaced studies, when possible.

Acute kidney injury requiring dialysis has occurred with the use of GBCAs in patients with chronically reduced renal function. The risk of acute kidney injury may increase with increasing dose of the contrast agent.

Ensure catheter and venous patency before injecting as **extravasation** may occur, and cause tissue irritation.

VUEWAY may **impair the visualization of lesions** seen on non-contrast MRI. Therefore, caution should be exercised when Vueway MRI scans are interpreted without a companion non-contrast MRI scan.

The most common adverse reactions (incidence ≥ 0.5%) are injection site pain (0.7%), and headache (0.7%).

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

Please see BRIEF SUMMARY of Prescribing Information for VUEWAY, including BOXED WARNING on Nephrogenic Systemic Fibrosis.

Manufactured for Bracco Diagnostics Inc. by Liebel-Flarsheim Company LLC - Raleigh, NC, USA 27616.

VUEWAY is a trademark of Bracco Imaging S.p.A.

References: 1. Vueway™ (gadopiclenol) Injection Full Prescribing Information. Monroe Twp., NJ: Bracco Diagnostics Inc.; September 2022. **2.** Robic C, Port M, Rousseaux O, et al. Physicochemical and Pharmacokinetic Profiles of Gadopiclenol: A New Macrocyclic Gadolinium Chelate With High T1 Relaxivity. *Invest Radiol.* 2019 Aug;54: 475–484. **3.** GADAVIST® (gadobutrol) Injection. Full Prescribing Information. Bayer HealthCare Pharmaceuticals Inc. Whippany, NJ; April 2022. **4.** DOTAREM® (gadoterate meglumine) Injection. Full Prescribing Information. Guerbet LLC. Princeton, NJ; April 2022. **5.** CLARISCAN™ (gadoterate meglumine) injection for intravenous use. Full Prescribing Information. GE Healthcare. Marlborough, MA; February 2020. **6.** ProHance® (Gadoteridol) Injection. Full Prescribing Information and Patient Medication Guide. Monroe Twp., NJ: Bracco Diagnostics Inc.; December 2020.

VISIT VUEWAY.COM FOR MORE INFORMATION

Bracco Diagnostics Inc.
259 Prospect Plains Road, Building H
Monroe Township, NJ 08831 USA
Phone: 609-514-2200
Toll Free: 1-877-272-2269 (U.S. only)
Fax: 609-514-2446

Bracco Diagnostics Inc.

Vueway™

(gadopiclenol) injection, for intravenous use

BRIEF SUMMARY: Please see package insert of full prescribing information.

WARNING: NEPHROGENIC SYSTEMIC FIBROSIS (NSF)

Gadolinium-based contrast agents (GBCAs) increase the risk for NSF among patients with impaired elimination of the drugs. Avoid use of GBCAs in these patients unless the diagnostic information is essential and not available with non-contrasted MRI or other modalities. NSF may result in fatal or debilitating fibrosis affecting the skin, muscle and internal organs.

- **The risk for NSF appears highest among patients with:**
  - **Chronic, severe kidney disease (GFR <30 mL/min/1.73 m²), or**
  - **Acute kidney injury.**
- **Screen patients for acute kidney injury and other conditions that may reduce renal function. For patients at risk for chronically reduced renal function (e.g. age >60 years, hypertension, diabetes), estimate the glomerular filtration rate (GFR) through laboratory testing.**
- **For patients at highest risk for NSF, do not exceed the recommended Vueway dose and allow a sufficient period of time for elimination of the drug from the body prior to any re-administration *[see Warnings and Precautions (5.1) in the full Prescribing Information]*.**

INDICATIONS AND USAGE

Vueway™ (gadopiclenol) is a gadolinium-based contrast agent indicated in adult and pediatric patients aged 2 years and older for use with magnetic resonance imaging (MRI) to detect and visualize lesions with abnormal vascularity in:

- the central nervous system (brain, spine, and associated tissues),
- the body (head and neck, thorax, abdomen, pelvis, and musculoskeletal system).

CONTRAINDICATIONS

Vueway is contraindicated in patients with history of hypersensitivity reactions to gadopiclenol.

WARNINGS AND PRECAUTIONS

Nephrogenic Systemic Fibrosis Gadolinium-based contrast agents (GBCAs) increase the risk for nephrogenic systemic fibrosis (NSF) among patients with impaired elimination of the drugs. Avoid use of GBCAs among these patients unless the diagnostic information is essential and not available with non-contrast MRI or other modalities. The GBCA-associated NSF risk appears highest for patients with chronic, severe kidney disease (GFR <30 mL/min/1.73 m²) as well as patients with acute kidney injury. The risk appears lower for patients with chronic, moderate kidney disease (GFR 30-59 mL/min/1.73 m²) and little, if any, for patients with chronic, mild kidney disease (GFR 60-89 mL/min/1.73 m²). NSF may result in fatal or debilitating fibrosis affecting the skin, muscle, and internal organs. Report any diagnosis of NSF following Vueway administration to Bracco Diagnostics Inc. (1-800-257-5181) or FDA (1-800-FDA-1088 or www.fda.gov/medwatch).

Screen patients for acute kidney injury and other conditions that may reduce renal function. Features of acute kidney injury consist of rapid (over hours to days) and usually reversible decrease in kidney function, commonly in the setting of surgery, severe infection, injury or drug-induced kidney toxicity. Serum creatinine levels and estimated GFR may not reliably assess renal function in the setting of acute kidney injury. For patients at risk for chronically reduced renal function (e.g., age >60 years, diabetes mellitus or chronic hypertension), estimate the GFR through laboratory testing.

Among the factors that may increase the risk for NSF are repeated or higher than recommended doses of a GBCA and the degree of renal impairment at the time of exposure. Record the specific GBCA and the dose administered to a patient. For patients at highest risk for NSF, do not exceed the recommended Vueway dose and allow a sufficient period of time for elimination of the drug prior to re-administration. For patients receiving hemodialysis, physicians may consider the prompt initiation of hemodialysis following the administration of a GBCA in order to enhance the contrast agent's elimination *[see Use in Specific Populations (8.6) and Clinical Pharmacology (12.3) in the full Prescribing Information]*. The usefulness of hemodialysis in the prevention of NSF is unknown.

Hypersensitivity Reactions With GBCAs, serious hypersensitivity reactions have occurred. In most cases, initial symptoms occurred within minutes of GBCA administration and resolved with prompt emergency treatment.

- Before Vueway administration, assess all patients for any history of a reaction to contrast media, bronchial asthma and/or allergic disorders. These patients may have an increased risk for a hypersensitivity reaction to Vueway.
- Vueway is contraindicated in patients with history of hypersensitivity reactions to Vueway *[see Contraindications (4) in the full Prescribing Information]*.
- Administer Vueway only in situations where trained personnel and therapies are promptly available for the treatment of hypersensitivity reactions, including personnel trained in resuscitation.
- During and following Vueway administration, observe patients for signs and symptoms of hypersensitivity reactions.

Gadolinium Retention Gadolinium is retained for months or years in several organs. The highest concentrations (nanomoles per gram of tissue) have been identified in the bone, followed by other organs (e.g. brain, skin, kidney, liver, and spleen). The duration of retention also varies by tissue and is longest in bone. Linear GBCAs cause more retention than macrocyclic GBCAs. At equivalent doses, gadolinium retention varies among the linear agents with gadodiamide causing greater retention than other linear agents such as gadoxetate disodium, and gadobenate dimeglumine. Retention is lowest and similar among the macrocyclic GBCAs such as gadoterate meglumine, gadobutrol, gadoteridol, and gadopiclenol.

Consequences of gadolinium retention in the brain have not been established. Pathologic and clinical consequences of GBCA administration and retention in skin and other organs have been established in patients with impaired renal function *[see Warnings and Precautions (5.1) in the full Prescribing Information]*. There are rare reports of pathologic skin changes in patients with normal renal function. Adverse events involving multiple organ systems have been reported in patients with normal renal function without an established causal link to gadolinium.

While clinical consequences of gadolinium retention have not been established in patients with normal renal function, certain patients might be at higher risk. These include patients requiring multiple lifetime doses, pregnant and pediatric patients, and patients with inflammatory conditions. Consider the retention characteristics of the agent when choosing a GBCA for these patients. Minimize repetitive GBCA imaging studies, particularly closely spaced studies, when possible.

Acute Kidney Injury In patients with chronically reduced renal function, acute kidney injury requiring dialysis has occurred with the use of GBCAs. The risk of acute kidney injury may increase with increasing dose of the contrast agent. Do not exceed the recommended dose.

Extravasation and Injection Site Reactions Injection site reactions such as injection site pain have been reported in the clinical studies with Vueway *[see Adverse Reactions (6.1) in the full Prescribing Information]*. Extravasation during Vueway administration may result in tissue irritation *[see Nonclinical Toxicology (13.2) in the full Prescribing Information]*. Ensure catheter and venous patency before the injection of Vueway.

Interference with Visualization of Lesions Visible with Non-Contrast MRI As with any GBCA, Vueway may impair the visualization of lesions seen on non-contrast MRI. Therefore, caution should be exercised when Vueway MRI scans are interpreted without a companion non-contrast MRI scan.

ADVERSE REACTIONS

The following serious adverse reactions are discussed elsewhere in labeling:

- Nephrogenic Systemic Fibrosis *[see Warnings and Precautions (5.1) in the full Prescribing Information]*
- Hypersensitivity Reactions *[see Contraindications (4) and Warnings and Precautions (5.2) in the full Prescribing Information]*

Clinical Trials Experience Because clinical trials are conducted under widely varying conditions, adverse reaction rates observed in the clinical trials of a drug cannot be directly compared to rates in the clinical trials of another drug and may not reflect the rates observed in clinical practice.

The safety of Vueway was evaluated in 1,047 patients who received Vueway at doses ranging from 0.025 mmol/kg (one half the recommended dose) to 0.3 mmol/kg (six times the recommended dose). A total of 708 patients received the recommended dose of 0.05 mmol/kg. Among patients who received the recommended dose, the average age was 51 years (range 2 years to 88 years) and 56% were female. The ethnic distribution was 79% White, 10% Asian, 7% American Indian or Alaska native, 2% Black, and 2% patients of other or unspecified ethnic groups.

Overall, approximately 4.7% of subjects receiving the labeled dose reported one or more adverse reactions.

Table 1 lists adverse reactions that occurred in >0.2% of patients who received 0.05 mmol/kg Vueway.

TABLE 1. ADVERSE REACTIONS REPORTED IN >0.2% OF PATIENTS RECEIVING VUEWAY IN CLINICAL TRIALS

Adverse Reaction	Vueway 0.05 mmol/kg (n=708) (%)
Injection site pain	0.7
Headache	0.7
Nausea	0.4
Injection site warmth	0.4
Injection site coldness	0.3
Dizziness	0.3
Local swelling	0.3

Adverse reactions that occurred with a frequency ≤ 0.2% in patients who received 0.05 mmol/kg Vueway included: maculopapular rash, vomiting, worsened renal impairment, feeling hot, pyrexia, oral paresthesia, dysgeusia, diarrhea, pruritus, allergic dermatitis, erythema, injection site paresthesia, Cystatin C increase, and blood creatinine increase.

Adverse Reactions in Pediatric Patients

One study with a single dose of Vueway (0.05 mmol/kg) was conducted in 80 pediatric patients aged 2 years to 17 years, including 60 patients who underwent a central nervous system (CNS) MRI and 20 patients who underwent a body MRI. One adverse reaction (maculopapular rash of moderate severity) in one patient (1.3%) was reported in the CNS cohort.

USE IN SPECIFIC POPULATIONS

Pregnancy Risk Summary There are no available data on Vueway use in pregnant women to evaluate for a drug-associated risk of major birth defects, miscarriage or other adverse maternal or fetal outcomes. GBCAs cross the human placenta and result in fetal exposure and gadolinium retention. The available human data on GBCA exposure during pregnancy and adverse fetal outcomes are limited and inconclusive *(see Data)*. In animal reproduction studies, there were no adverse developmental effects observed in rats or rabbits with intravenous administration of Vueway during organogenesis *(see Data)*. Because of the potential risks of gadolinium to the fetus, use Vueway only if imaging is essential during pregnancy and cannot be delayed. The estimated background risk of major birth defects and miscarriage for the indicated population(s) are unknown. All pregnancies have a background risk of birth defect, loss, or other adverse outcomes. In the U.S. general population, the estimated background risk of major birth defects and miscarriage in clinically recognized pregnancies is 2% to 4% and 15% to 20% respectively. Data *Human Data* Contrast enhancement is visualized in the placenta and fetal tissues after maternal GBCA administration. Cohort studies and case reports on exposure to GBCAs during pregnancy have not reported a clear association between GBCAs and adverse effects in the exposed neonates. However, a retrospective cohort study comparing pregnant women who had a GBCA MRI to pregnant women who did not have an MRI reported a higher occurrence of stillbirths and neonatal deaths in the group receiving GBCA MRI. Limitations of this study include a lack of comparison with non-contrast MRI and lack of information about the maternal indication for MRI. Overall, these data preclude a reliable evaluation of the potential risk of adverse fetal outcomes with the use of GBCAs in pregnancy.

Animal Data Gadolinium Retention: GBCAs administered to pregnant non-human primates (0.1 mmol/kg on gestational days 85 and 135) result in measurable gadolinium concentration in the offspring in bone, brain, skin, liver, kidney, and spleen for at least 7 months. GBCAs administered to pregnant mice (2 mmol/kg daily on gestational days 16 through 19) result in measurable gadolinium concentrations in the pups in bone, brain, kidney, liver, blood, muscle, and spleen at one-month postnatal age.

Reproductive Toxicology: Animal reproduction studies conducted with gadopiclenol showed some signs of maternal toxicity in rats at 10 mmol/kg and rabbits at 5 mmol/kg (corresponding to 52 times and 57 times the recommended human dose, respectively). This maternal toxicity was characterized in both species by swelling, decreased activity, and lower gestation weight gain and food consumption.

No effect on embryo-fetal development was observed in rats at 10 mmol/kg (corresponding to 52 times the recommended human dose). In rabbits, a lower mean fetal body weight was observed at 5 mmol/kg (corresponding to 57 times the recommended human dose) and this was attributed as a consequence of the lower gestation weight gain.

Lactation Risk Summary There are no data on the presence of gadopiclenol in human milk, the effects on the breastfed infant, or the effects on milk production. However, published lactation data on other GBCAs indicate that 0.01% to 0.04% of the maternal gadolinium dose is excreted in breast milk. Additionally, there is limited GBCA gastrointestinal absorption in the breast-fed infant. Gadopiclenol is present in rat milk. When a drug is present in animal milk, it is likely that the drug will be present in human milk *(see Data)*. The developmental and health benefits of breastfeeding should be considered along with the mother's clinical need for Vueway and any potential adverse effects on the breastfed infant from Vueway or from the underlying maternal condition. Data In lactating rats receiving single intravenous injection of [^{153}Gd]-gadopiclenol, 0.3% and 0.2% of the total administered radioactivity was transferred to the pups via maternal milk at 6 hours and 24 hours after administration, respectively. Furthermore, in nursing rat pups, oral absorption of gadopiclenol was 3.6%.

Pediatric Use The safety and effectiveness of Vueway for use with MRI to detect and visualize lesions with abnormal vascularity in the CNS (brain, spine, and associated tissues), and the body (head and neck, thorax, abdomen, pelvis, and musculoskeletal system) have been established in pediatric patients aged 2 years and older.

Use of Vueway in this age group is supported by evidence from adequate and well-controlled studies in adults with additional pharmacokinetic and safety data from an open-label, uncontrolled, multicenter, single dose study of Vueway (0.05 mmol/kg) in 80 pediatric patients aged 2 to 17 years. The 80 patients consisted of 60 patients who underwent a CNS MRI and 20 patients who underwent a body MRI *[see Adverse Reactions (6.1) and Clinical Pharmacology (12.3) in the full Prescribing Information]*.

The safety and effectiveness of Vueway have not been established in pediatric patients younger than 2 years of age.

Geriatric Use Of the total number of Vueway-treated patients in clinical studies, 270 (26%) patients were 65 years of age and over, while 62 (6%) patients were 75 years of age and over. No overall differences in safety or efficacy were observed between these subjects and younger subjects.

This drug is known to be substantially excreted by the kidney, and the risk of adverse reactions to this drug may be greater in patients with impaired renal function. Because elderly patients are more likely to have decreased renal function, it may be useful to monitor renal function.

Renal Impairment In patients with renal impairment, the exposure of gadopiclenol is increased compared to patients with normal renal function. This may increase the risk of adverse reactions such as nephrogenic systemic fibrosis (NSF). Avoid use of GBCAs among these patients unless the diagnostic information is essential and not available with non-contrast MRI or other modalities. No dose adjustment of Vueway is recommended for patients with renal impairment. Vueway can be removed from the body by hemodialysis *[see Warnings and Precautions (5.1, 5.3, 5.4) and Clinical Pharmacology (12.3) in the full Prescribing Information]*.

OVERDOSAGE

Among subjects who received a single 0.3 mmol/kg intravenous dose of gadopiclenol (6 times the recommended dose of Vueway), headache and nausea were the most frequently reported adverse reactions. Gadopiclenol can be removed from the body by hemodialysis *[see Clinical Pharmacology (12.3) in the full Prescribing Information]*.

PATIENT COUNSELING INFORMATION Advise the patient to read the FDA-approved patient labeling (Medication Guide).

Nephrogenic Systemic Fibrosis Inform the patient that Vueway may increase the risk for NSF among patients with impaired elimination of the drugs and that NSF may result in fatal or debilitating fibrosis affecting the skin, muscle and internal organs.

Instruct the patients to contact their physician if they develop signs or symptoms of NSF following Vueway administration, such as burning, itching, swelling, scaling, hardening and tightening of the skin; red or dark patches on the skin; stiffness in joints with trouble moving, bending or straightening the arms, hands, legs or feet; pain in the hip bones or ribs; or muscle weakness *[see Warnings and Precautions (5.1) in the full Prescribing Information]*.

Gadolinium Retention Advise patients that gadolinium is retained for months or years in brain, bone, skin, and other organs following Vueway administration even in patients with normal renal function. The clinical consequences of retention are unknown. Retention depends on multiple factors and is greater following administration of linear GBCAs than following administration of macrocyclic GBCAs *[see Warnings and Precautions (5.3) in the full Prescribing Information]*.

Injection Site Reactions Inform the patient that Vueway may cause reactions along the venous injection site, such as mild and transient burning or pain or feeling of warmth or coldness at the injection site *[see Warnings and Precautions (5.5) in the full Prescribing Information]*.

Pregnancy Advise pregnant women of the potential risk of fetal exposure to Vueway *[see Use in Specific Populations (8.1) in the full Prescribing Information]*.

Rx only

US Patent No. 10,973,934

Manufactured for Bracco Diagnostics Inc. by Liebel-Flarsheim Company LLC - Raleigh, NC, USA 27616.

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Anderson Publishing, Ltd
180 Glenside Avenue,
Scotch Plains, NJ 07076
Tel: 908-301-1995
Fax: 908-301-1997
info@appliedradiology.com

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Radiologists are the Imaging Experts

Erin Simon Schwartz, MD, FACR

Dr Schwartz is the Editor-in-Chief of *Applied Radiology*. She is the Chief of the Division of Neuroradiology and holds the Robert A. Zimmerman Chair in Pediatric Neuroradiology in the Department of Radiology at The Children's Hospital of Philadelphia. She is also a Professor of Radiology, Perelman School of Medicine, University of Pennsylvania. She can be reached at erin@appliedradiology.com.

Sometimes, physicians react negatively when we reach out to discuss a study request. They, and our electronic medical record systems, consider these "orders." But, in reality, they are requesting a consultation regarding how to answer their diagnostic question accurately. For some folks, however, it's just "I want this because I want it. Don't question me." Surely many fellow radiologists can relate.

I know of a radiologist who is fond of responding to approaches like this with, "It's not 'you want fries with that?'" This is their not-so-subtle reminder that our department is not some fast-food drive-thru and that we are not here to supersize their "order."

They may not always be willing to acknowledge it, but healthcare professionals seeking an imaging study for their patient—especially a cross-sectional or invasive diagnostic exam—are consulting with fellow medical specialists in their own right, with a level of expertise in medical imaging that surpasses that of their own.

And these study *requests*—a more accurate characterization—require us as radiologists to analyze the question(s) the study is expected to answer, which in turn requires us to have enough information to make that determination. This, in turn, requires the requestor to obtain a detailed history, perform a thorough physical examination, generate a hypothesis, consider which imaging exam(s) will support or refute their hypothesis, and document it all in the medical record.

At least, that's how it should be. It used to be that way back when physicians actually had time to see their patients, think about what might be wrong with them, and make a diagnosis based on the patient's history, clinical exam, labs, and radiology results.

Of course, there were fewer imaging modalities to choose from in those days, but radiologists had much less access to medical records. There were also no pre-authorization hoops to jump through, and study volumes were far more manageable, as Doug Phillips so eloquently describes in this issue's "Wet Read" column.

It is understandable that healthcare professionals feeling rushed, burned out, and overwhelmed these days might jump to the first study they think might help their patient, or whatever they think insurance will "approve," but that does not make it right.

In 1735, Benjamin Franklin famously wrote, "An ounce of prevention is worth a pound of cure." Franklin was referencing housefires and the importance of keeping one's home from burning down in the first place. The same logic applies to our specialty. We radiologists are the ones who best know how to keep patients from having to undergo the wrong and/or additional imaging they could avoid if we were only consulted in the first place.

So, the next time someone argues with me when I'm reaching out to discuss a study request, I'll take a deep breath and remind myself—and them—that we are all in this together for the service of our patients. I'll also remind them that the best patient care comes from collaboration and mutual respect, and (try to) convince them to request the optimal study.

Is it more time consuming than simply handing over just what the doctor ordered? Absolutely. But it's far better for our patients and the entire healthcare system.

A Radiologist's Guide to Radiation Dose Index Monitoring

Description

Radiation dose index monitoring systems are widely commercially available and have been adopted in response to regulatory and accreditation requirements. They may or may not be implemented with radiologist direction or involvement. RDIM has capabilities and use cases that can directly benefit radiologists who understand how to take advantage of them, but these may not be the priorities of administration, IT, or other stakeholders.

This activity is designed to educate radiologists about radiation dose index monitoring systems, including their technology and system architecture, data collection and processing capabilities, end user analytics and applications, use cases in clinical quality management, and a review and overview of radiation dosimetry quantities used in medical imaging.

Learning Objectives

Upon completing this activity, the reader should be able to:

- Identify quality management opportunities that leverage radiation dose index monitoring capabilities
- Describe the appropriate use of radiation dose index monitoring data in patient management in radiology.
- Evaluate the features and capabilities of commercial, open-source, custom, or in-house developed radiation dose index monitoring systems

Target Audience

- Radiologists
- Related Imaging Professionals

Authors

David W. Jordan, PhD, FACR, FAAPM; Andrew T. Dietz, BS, CIIP, CNMT, RT(N)

Affiliations: Case Western Reserve University School of Medicine; Department of Radiology, Louis Stokes Cleveland VAMC; Department of Radiology, University Hospitals Cleveland Medical Center, Cleveland, OH (Dr Jordan); VA Radiation Dose Network (VARDN), Louis Stokes Cleveland VAMC, Cleveland, OH 44106 (Mr Dietz)

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None

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CME DETAILS ON PAGE 7

A Radiologist's Guide to Radiation Dose Index Monitoring

David W. Jordan, PhD; Andrew T. Dietz, BS, CIIP, CNMT, RT(N)

Radiation dose index monitoring (RDIM) software can automatically collect and store digital data related to patient radiation exposure and other examination parameters in diagnostic imaging. Numerous commercial solutions provide various tools to analyze and interpret the data. This review provides radiologists with a brief overview of these technologies and relevant informatics considerations. It also provides several use cases in quality management.

There are several important points that radiologists should be mindful of with respect to implementing RDIM technology. First, RDIM enables automated collection of large amounts of data for analysis from a single modality device or from throughout an entire facility or enterprise. Such data sets can be valuable for quality management purposes, as they provide robust information about the behavior and performance of imaging equipment for a given patient population.

Second, RDIM collects data that are *related* to patient radiation dose but do not constitute *actual* patient dose. Dose index values are usually correlated to the radiation output of a device and may or may not include other factors needed to determine dose (eg, patient body habitus). These data should be interpreted with caution and with assistance from a qualified medical physicist.[1]

Third, while it is a quality management tool, RDIM with few exceptions should not be used for clinical decision making; eg, for recording cumulative patient dose histories or guiding decisions about future radiological procedures.[2] Every radiological procedure is accompanied by an independent benefit-risk consideration for each patient in their current circumstances, and past exposure does not affect the risk when considering another procedure.[3–5] In many cases, RDIM data do not contain accurate calculations of patient absorbed dose, organ dose, or effective dose.[6]

Furthermore, no universally accepted standard method exists for measuring image quality in RDIM systems. A number of techniques have been developed to automatically quantify image quality,[7,8] while many RDIM systems focus solely on radiation dose index data. Since image quality strongly affects the benefit of a radiological procedure, RDIM data and analytics are usually unable to present a comprehensive or balanced view of risk and benefit. Clinical decision making should follow evidence-based consensus guidelines and appropriateness criteria.[9]

Fourth, RDIM systems are complex informatics platforms that require substantial expert effort to implement, validate, and maintain.[10] Radiologists should engage sufficient medical physics and informatics support for clinical use of these systems to ensure data quality and system reliability.

Radiation Dose Quantities and Dose Indices

Absorbed dose (expressed in mGy) describes the amount of energy deposited in matter (such as tissue) by an episode of radiation exposure, while *effective dose* (expressed in mSv) adjusts the absorbed dose by the relative radiosensitivity of the exposed tissue to provide a quantitative value that correlates more closely to risk. This is valid for populations and unlikely to be meaningful for individual patients.

Organ dose is the dose absorbed by a specific organ. *Peak skin dose* (PSD) is the highest absorbed dose delivered to any location on a patient's skin during a radiologic procedure.

There are a number of *dose index* values for specific imaging modalities that quantify the amount of source radiation that delivers absorbed, organ, skin, and effective doses to patients.[11] Examples include

Affiliations: Department of Radiology, University Hospitals Cleveland Medical Center; Department of Radiology, Case Western Reserve University; Department of Radiology, Louis Stokes Cleveland VA Medical Center; Cleveland, OH (Dr Jordan); VA Radiation Dose Network, Louis Stokes Cleveland VA Medical Center, Cleveland, Ohio (Dr Dietz).
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Table 1. REM Registry Quartile Data for 2022 showing Achievable Doses and Diagnostic Reference Levels for CT exams of three body regions.

BODY PART	AD (CTDIVOL)	FY22 Q1 AD	FY22 Q2 AD	FY22 Q3 AD	FY22 Q4 AD	FY 22 AVG AD
Abd/Pelvis	17 mGy	11.8 mGy	12 mGy	12.3 mGy	12.5 mGy	12.1 mGy
Chest	14 mGy	5.5 mGy	5.3 mGy	7.1 mGy	5.5 mGy	9.5 mGy
Head	57 mGy	47.1 mGy	47.3 mGy	47.9 mGy	47.8 mGy	47.5 mGy
BODY PART	**DRL (CTDIVOL)**	**FY22 Q1 DRL**	**FY22 Q2 DRL**	**FY22 Q3 DRL**	**FY22 Q4 DRL**	**FY 22 AVG DRL**
Abd/Pelvis	25 mGy	15.94 mGy	15.98 mGy	17.3 mGy	17.3 mGy	16.6 mGy
Chest	21 mGy	9.2 mGy	9 mGy	9.69 mGy	10.1 mGy	9.5 mGy
Head	75 mGy	56.28 mGy	56.28 mGy	56.26 mGy	55.75 mGy	56.1 mGy

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volume CT dose index (CTDIvol) and dose-length product (DLP) in CT or reference point air kerma (Ka,r) and kerma-area product (PKA) in interventional fluoroscopy.

Technical Description

Radiological imaging equipment stores information about radiation exposure, as well as other relevant patient, exam, protocol, and technique factors, in log files formatted as digital imaging and communications in medicine (DICOM) Radiation Dose Structured Report (RDSR) objects.

Typically, an RDSR is generated at the end of an exam or procedure and stored locally in the modality database. It may or may not be visible in the patient or image directory. RDSR objects may automatically be transmitted to a designated network node, or the user may be required to send them manually. Other data formats have been used in the past, but the utility and widespread availability of RDSR data from imaging modalities have relegated other approaches, such as modality performed-procedure step message collection or optical character recognition of exam information page images, to legacy status, and commercial RDIM solutions are likely to discontinue support of them in the near future.

RDIM implementation consists of the following: a DICOM node to collect incoming RDSR objects; processing to parse the contents of the RDSR and extract data elements of interest; a database to store the extracted data elements; and one or more applications to either present the database information to a user as charts, tables, or graphs, or export the data in files for further analysis. An on-premises implementation may use a single physical or virtual server connected to the same local area network (LAN) as the imaging modality equipment and running all of these functions.

For enterprise applications, a typical hybrid implementation includes one or more DICOM nodes on the imaging facility LAN or virtual LAN (VLAN) with processing, database, and user applications hosted on a remote server or cloud computing platform.[12] The collecting DICOM node or nodes on the facility LAN forward the collected RDSR objects to the cloud platform over a virtual private network connection for further processing and long-term storage.

In a hybrid topology, the LAN-based collecting node may perform some processing and extract data from the RDSR objects, or it may simply forward the objects to the remote server. Some implementations may modify RDSR objects to anonymize or de-identify data at the LAN node before transmission to the remote server to comply with institutional policies or local laws or regulations concerning the privacy and confidentiality of personally identifiable patient information, especially since such information is not needed for most RDIM use cases.

The data stored in the RDIM database contain two types of values. *Primary* values are stored in the RDSR object by the originating imaging modality and then directly extracted and stored in the RDIM database. *Derived* values are calculated, usually by the RDIM processing or ancillary applications, and stored in the RDIM database. Derived values usually use information from the RDSR and may require additional information, such as patient body habitus from images or digital phantoms. Examples of derived values in CT include size-specific dose estimates,[13] organ doses, and effective doses.

There are numerous possibilities for end-user applications, which are normally accessed through a web browser. Common capabilities include: chronological trends in dose index values for a specific modality and exam; histograms of dose index values for specific exams; alert dashboards showing exams for which dose index values exceed predetermined thresholds; tables of detailed data values; and displays of the full database record for an individual patient record or procedure. Most analytics interfaces allow the user to search, filter, and sort the data in real time, as well as to save specific

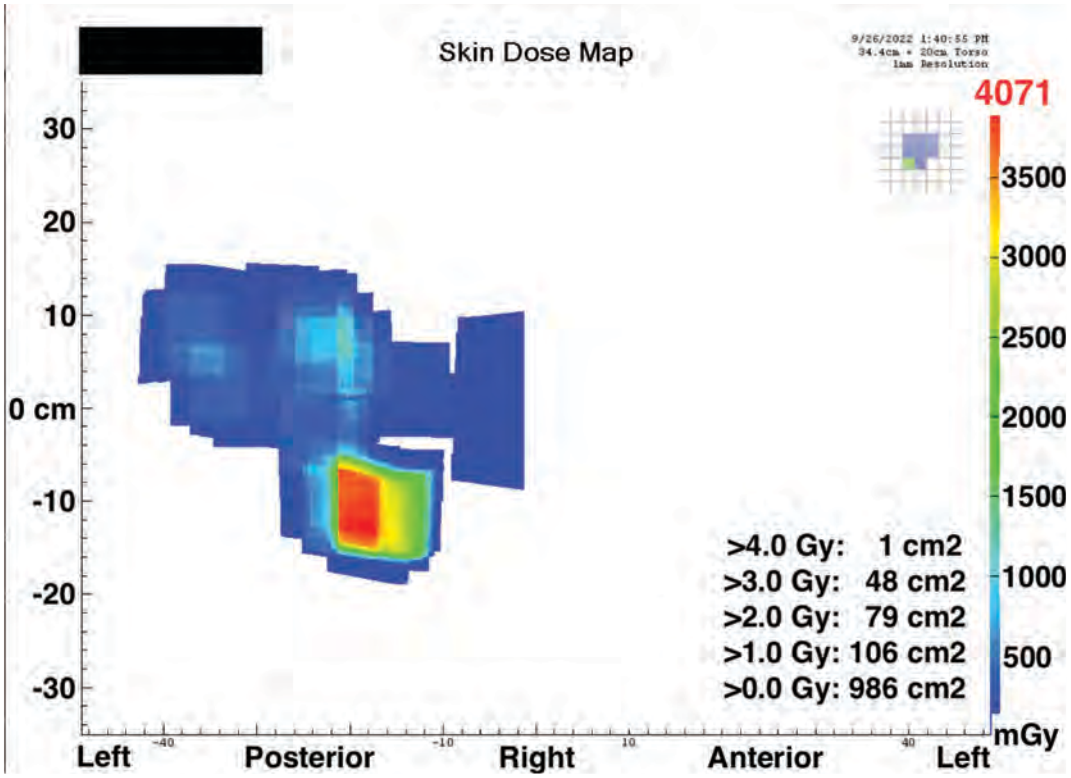


Figure 1. Mapping of peak skin dose from a fluoroscopic procedure from a commercial RDIM system.

search and filter criteria for repeated review. User applications may provide access to primary data, derived values, or both.

RDIM Use Cases

Radiation Exposure Benchmarking

RDIM can be useful for comparing a facility's radiation exposure parameters to external benchmarks and monitoring trends. Sources of benchmark values for specific exams and patient populations include scientific and medical literature,[14] accreditation program standards,[15,16] and professional consensus practice guidelines.[17]

Facility data are used to calculate the Diagnostic Reference Level (DRL) and Achievable Dose (AD) for various exams.[18,19] RDIM provides a useful data source for these calculations, and some RDIM tools include automated routines or macros to select exams and time periods of interest and to calculate DRL and AD from the database. The facility DRL and AD values can be compared to the external benchmarks to determine whether any practice changes are indicated to align patient radiation exposure with the chosen benchmarks.

Figure 2. Visualization of peak skin dose from a commercial RDIM system.

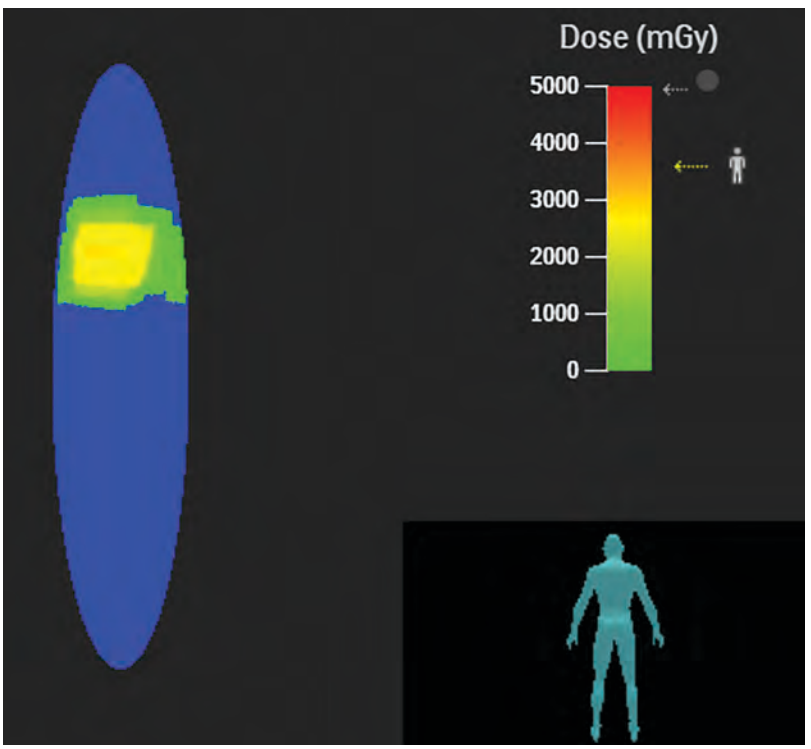
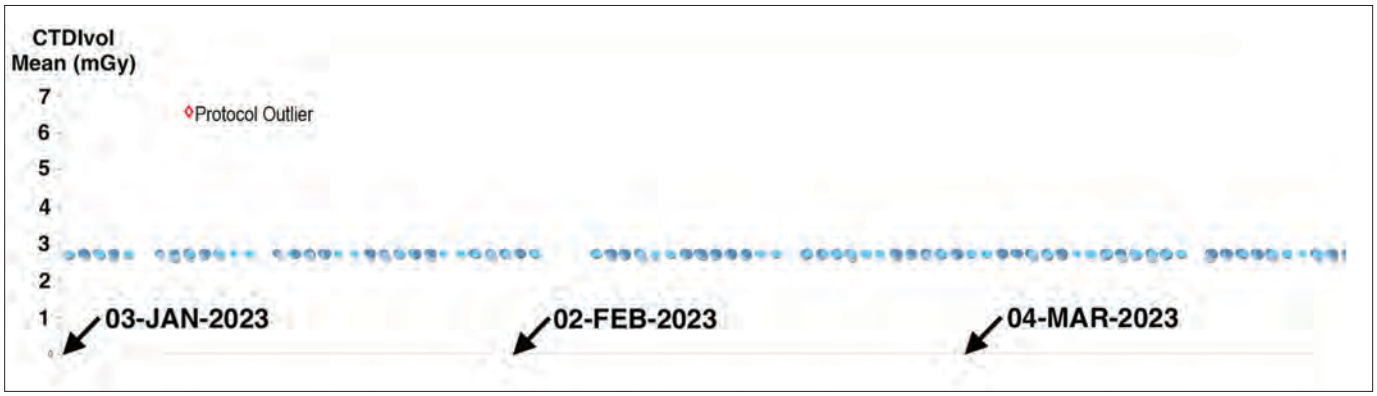


Figure 3. A review of low-dose lung cancer screening CT exams revealing inappropriate dose index values, which were traced to inappropriate use of routine diagnostic thorax CT acquisition protocols for lung cancer screening exams.



Radiation Dose Registries

RDIM has enabled the creation of large registries of radiation dose index data aggregated across multiple facilities to aid in benchmarking and making comparisons. The American College of Radiology's Dose Index Registry (DIR) has continuously collected data on millions of exams from thousands of participating sites since its inception in 2011.[20] Users receive regular feedback comparing their results with national and regional facilities of similar sizes and practice profiles. Within the US Veterans Health Administration (VA), the VA Radiation Dose Network was formed to connect RDIMs across VA facilities, culminating in the creation of the VA's Radiation Exposure Monitoring (REM) Registry. The VA REM Registry provides dose index comparisons within a facility, across a Veterans Integrated Service Network, or across the entire REM Registry (Table 1), enabling facility users to identify outlier exams and protocols that do not conform to typical operating and performance levels across the organization.

To maximize participation, registries typically accommodate data connections from participants using a variety of RDIM software platforms. The simplest implementation is for participating sites to forward raw RDSR objects to another RDIM system operated as the registry. This has the advantage of compatibility, as no special protocols are needed for the systems to communicate. The disadvantage is that any derived data produced by the site RDIM may not be stored in the registry. To capture derived data elements from site RDIM systems, registries must be configured to communicate with the site RDIM via protocols that may be proprietary to either or both of the connected systems.

Fluoroscopy Peak Skin Dose

The PSD from a fluoroscopic procedure can be estimated using data collected by RDIM.[21] These estimates can be refined using the data captured by RDIM describing X-ray tube and patient-table positioning, and some RDIM systems can construct sophisticated geometric mapping of estimated skin dose distributions.[22] These calculated estimates and maps can be valuable in determining which patients are at risk for radiation-induced skin injury and recommending appropriate follow-up.

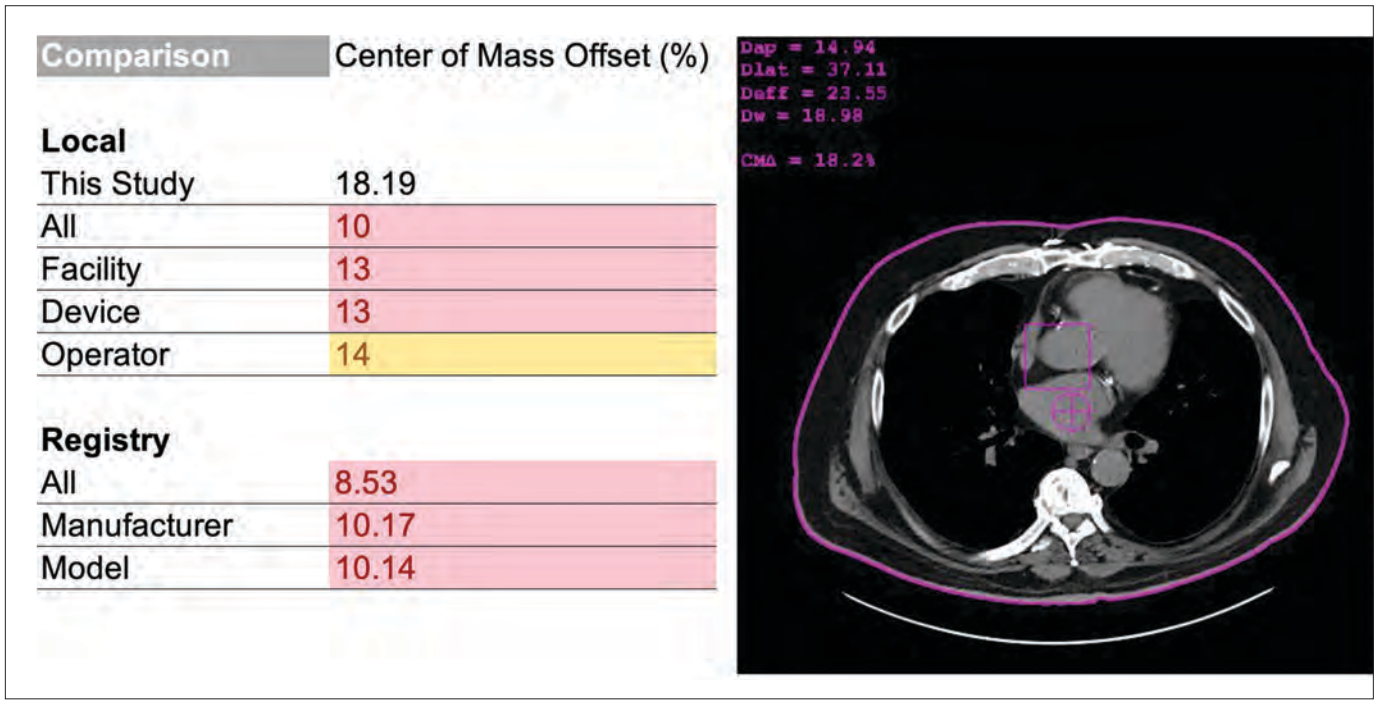
Patients whose exposure exceeds a Substantial Radiation Dose Level (SRDL) threshold (as defined by the facility) should receive additional post-procedure instructions and specific follow-up examinations depending on the magnitude of the suspected dose.[23,24] As it is important to provide this information to patients before discharge, identification of SRDLs and calculation of PSD estimates must be completed fairly quickly after completion of the procedure, especially for outpatient procedures. An RDIM system could send an immediate alert to the medical physicist once the data for the SRDL procedure is received and processed, and the PSD estimate could be calculated automatically for rapid review and validation. Examples are shown in Figures 1 and 2.

RDIM can also assist interventional radiologists in assessing a patient's recent skin doses and potential for increased sensitivity to radiation-induced injury during the next procedure. This is a setting where cumulative skin dose histories for individual patients are useful. When planning a procedure, the interventional radiologist could review the patient's history in the RDIM system for any recent exposures, particularly fluoroscopy of the same area. Current guidance suggests that all exposures within a 60-day period be summed when estimating risk of skin injury; thus, a patient's threshold for skin injury should be considered reduced by the skin dose received within the 60 days prior to the current procedure.[24]

CT Protocol Management

In addition to dose data, RDIM captures a number of other details about imaging procedures in the RDSR data object. These include details that can be used to examine adherence to the facility's established imaging

Figure 4. Center of mass offset for a CT exam compared with registry values. This study has an offset of 18.2% which exceeds the average value of 8.5% for the entire registry and the average value of 10.2% for exams acquired on the same manufacturer and model of scanner.



protocols and the use of correct and appropriate scanning protocols for a given exam. This capability can be used for ongoing monitoring of all procedures, as well as troubleshooting of specific situations.

For example, the timeline plot in Figure 3 shows a substantial variation in dose index for one low-dose CT lung cancer screening scan of the thorax. This discrepancy was noted when reviewing RDIM data for screening exams, as indicated by the exam description. Upon investigating, the facility's medical physics personnel found that the CT technologists occasionally selected the routine diagnostic thorax CT protocol rather than the specific protocol created for lung cancer screening. The medical physics team was able to identify the problem and complete the investigation in a matter of minutes, without leaving their desks.

Other Applications

RDIM can be a valuable tool for a radiation safety officer overseeing clinical research when determining the facility's typical patient effective doses for specific exams. While RDIM-calculated effective dose estimates are neither accurate[6] nor meaningful[25] for individual patient radiation risk estimates, the aggregated estimates for a patient population can inform the risk assessment for research trials in a similar population. This information can be used to guide investigators and institutional review boards concerned with radiation risk to subjects, and is often needed for informed consent documents as well. In any event, for many procedures, typical dose values are difficult to find in the literature and may not be applicable to the facility's technology.

Automated data collection, once established for RDIM, may provide infrastructure for other business intelligence or analytics applications that are not directly related to radiation exposure but can benefit from automated large-scale collection of structured data. Examples include equipment uptime, room turnover time, and other asset and staff utilization information that can be directly extracted from RDSR data or inferred from information found there.

Quality Indicators

Radiologists should consider RDIM that includes assessments of image or exam quality. In CT, a common, and correctable, quality issue is improper vertical centering of patients.[26–30] In the example in Figure 4, the RDIM system uses patient images to calculate the offset between the rotational center of the CT scanner and the center of mass of the patient; the result is labeled the "center of mass offset" and cited as a percentage. This calculation requires the CT images and RDSR to be sent to RDIM, but the results are stored in the database for review, trending, and even comparison with other sites. This example demonstrates an opportunity for quality improvement.

In digital radiography, RDIM can be used to monitor the Deviation Index, assuming the equipment is configured with appropriate Target

Exposure Index values for each exam and view, and that the system is configured to include Deviation Index in the RDSR files.[31]

RDIM: Used with Care, Powerful Tools

These use cases represent only a sampling of the many applications to which medical imaging personnel can put the power of radiation dose index monitoring software tools to use. Leveraging the ability of RDIM to collect and store vast amounts of digital data from sources as small as a single imaging device to as large as an entire enterprise, medical physics personnel can quickly and efficiently analyze the performance of their institution's imaging technology in a variety of circumstances and patient populations. However, RDIM systems are complex platforms, and radiologists should take care to engage expert medical physics and informatics support to ensure the quality of their data, the reliability of their system, and the accuracy of their results.

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Focused Ultrasound for Ablation in Neurosurgery — Present Use and Future Directions

Nina Yoh, MD, MS; Genesis De Los Santos, BA; Masih Tazhibi, BA; Zachary Englander, MD, MS; Angela Lignelli-Dipple, MD; Cheng-Chia Wu, MD, PhD; Gordon Baltuch, MD, PhD

Focused ultrasound (FUS) as a therapeutic modality for the treatment of neurological conditions has seen a rapid expansion over the past decade due to its ability to produce controlled and precise effects non-invasively. FUS has multiple mechanisms of action, but at higher frequencies, thermal ablation is predominant and is capable of precise and controlled lesioning of brain tissue. In particular, transcranial magnetic resonance-guided focused ultrasound surgery (MRgFUS), a non-invasive ablative modality has become a well-established tool in functional neurosurgery for movement disorders such as essential tremor (ET) and Parkinson Disease (PD). Since its FDA approval in 2016, MRgFUS has gained popularity amongst researchers, clinicians, and patients. Ongoing studies to evaluate additional indications are underway. Ongoing clinical trials include treatment of psychiatric illness, chronic pain, and epilepsy. Radiologists should be familiar with the expected neuroimaging findings following treatment and the entities for which this is utilized and being explored.

Affiliations: Department of Neurological Surgery (Drs Yoh, Englander, Baltuch) and Department of Radiology (Dr Lignelli-Dipple) Columbia University Irving Medical Center; Department of Radiation Oncology (Dr Wu; Ms De Los Santos, Mr Tazhibi), Columbia University Irving Medical Center, and Herbert Irving Comprehensive Cancer Center, New York, New York
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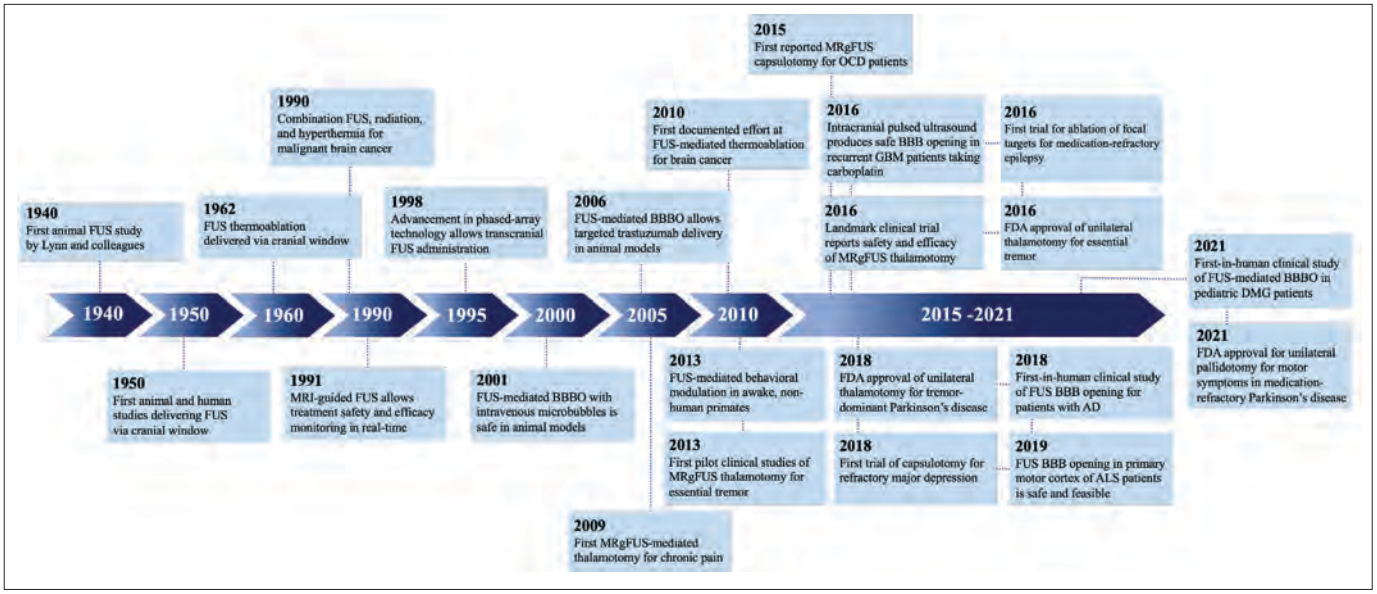
A Brief History of Focused Ultrasound

Although ultrasound was discovered in the late 1800s, the invention of FUS is attributed to Johannes Gruetzmacher, who placed curved quartz on a piezoelectric generator to concentrate waves in 1935. Initial trials in humans targeted deep structures for movement disorders, but lesions were imprecise prior to the advent of modern imaging. Furthermore, large portions of skull were removed to mitigate wave distortion and surface heating. In 1998, the use of MRI and a helmet equipped with two arrays and 64 elements was shown to transmit pulsed sonication through a piece of a human skull to induce tissue destruction in an animal model, which catapulted FUS into widespread use.

Since then, myriad developments such as real-time MRI guidance, have improved the safety and efficacy of FUS ablation (Figure 1). As of this writing, three neurological indications have been FDA-approved for MRI-guided FUS (MRgFUS): thalamotomy for ET, thalamotomy for tremor-dominant PD, and pallidotomy for the motor symptoms of PD. Multiple additional indications are currently being investigated (Table 1).

Radiographic findings shortly after FUS ablation have been well characterized as three concentric zones representing target coagulation necrosis (Zone I), cytotoxic edema (Zone II), and perilesional vasogenic edema (Zone III).[3] On T2 images, Zone I is seen as a central hypointense region. Zone II is strongly hyperintense region with a hypointense rim, while Zone III is a diffuse hyperintense region beyond Zone II (Figure 2). These regions appear 24 hours to 1 week after treatment and disappear over 1-3 months, leaving a single, minimally T2 hypointense lesion. This T2 pattern was also observed by researchers evaluating MRgFUS-induced lesions on T2, T1, diffusion weighted imaging, and susceptibility weighted imaging (SWI) at 3, 30, and 180-day timepoints after treatment.[4] Over a longer time horizon, once T2 signal resolves, a shrinking or disappearance of the lesion can continue to be visualized through day 180 on T1 scans. MRgFUS-induced

Figure 1. Timeline of focused ultrasound development and use from 1940 to 2021. AD = Alzheimer disease; ALS = amyotrophic lateral sclerosis; BBB = blood-brain barrier; BBBO = blood-brain barrier opening; DMG = diffuse midline glioma; FDA = US Food and Drug Administration; GBM = glioblastoma; MRgFUS = magnetic resonance-guided focused ultrasound; OCD = obsessive-compulsive disorder.



lesions have the most longevity on SWI, which is sensitive to even subtle hemosiderin remnants caused by the initial treatment.

Mechanism of Action for Ablation

The ablative action of focused ultrasound is dependent on frequency, which leads to either thermal or mechanical tissue destruction. At higher frequencies (~650 kHz), thermal ablation is predominant. The United States Food and Drug Administration (FDA) -approved hemispherical transducer (ExAblate 4000; Insightec, Inc) can achieve peak temperatures of 51°C to 60°C under continuous visual MR-guidance and MR-thermometry with an accuracy of <2mm.

High incident angles (>20°) prohibit targets closer to the skull from successful treatment; thermal ablation can only be applied to more central brain regions. Thick and poorly homogeneous skulls limit the penetration of ultrasound. Preoperative CT is obtained to assess patient-specific metrics such as skull thickness and skull homogeneity as quantified by skull density ratio (SDR). An SDR below 0.4 is considered inconducive to optimal thermal lesioning and FDA-labeling includes only patients with an SDR of 0.4 or higher.

At a single-center study, 50% of patients evaluated had a skull score under 0.4, suggesting that a significant number of patients may be ineligible for MRgFUS owing to skull characteristics.

Lower frequencies (around 220 kHz) produce therapeutic mechanical energy by interacting to rapidly expand and contract entrapped gas in a process called cavitation. Cavitation to the point of tissue destruction is focal and leaves the surrounding tissue intact. Lower frequencies are less susceptible to acoustic absorption and higher incident angles, expanding the potential reach of MRgFUS to the entire intracranial space. This remains an area of active research.

Current FDA-approved Indications

MRgFUS ablation has become a well-established tool in functional neurosurgery for movement disorders such as ET and PD. Given the small size of tissue targets and their central location within the skull, as well as an aged patient population with higher operative risk, movement disorders approximate ideal indications for noninvasive thermal ablation.

Essential Tremor

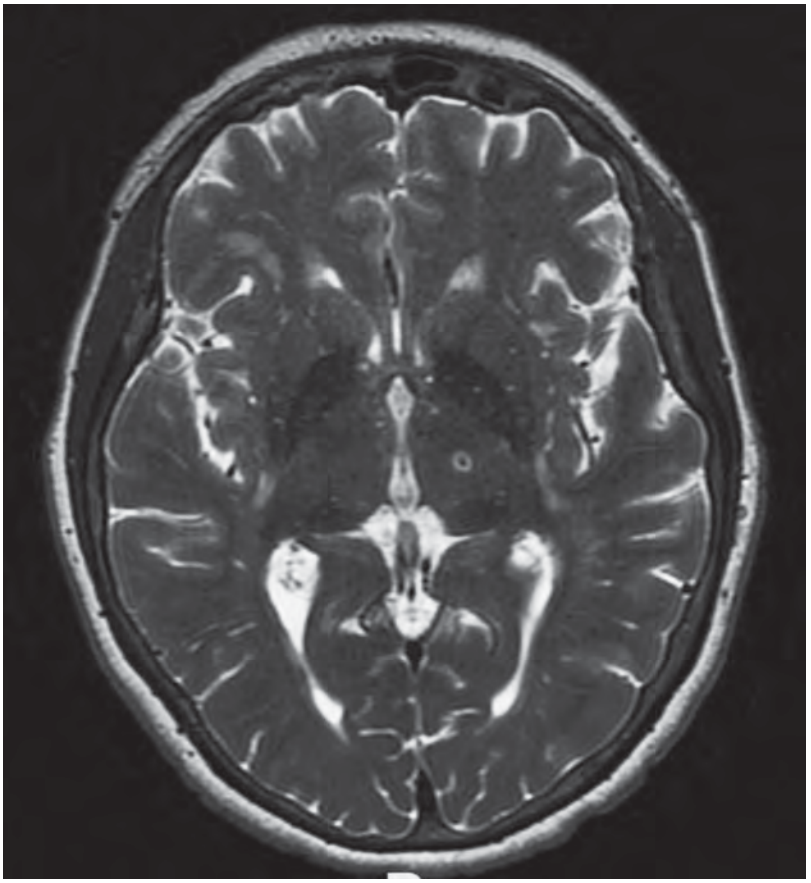
In July 2016, thalamotomy for refractory ET became the first FDA-approved intracranial use of MRgFUS. Essential tremor is the most common cause of action tremor in adults and remains progressive with no disease-modifying agents. Current first-line treatment for the condition consists of medical therapy; however, approximately 30% of patients see no therapeutic benefit.

Second-line treatment includes combination drug therapy. Patients failing adequate trials of medical therapy may be offered surgical options, which include treating the ventral intermediate nucleus of the thalamus with deep brain stimulation (DBS) or thalamotomy. Treatment is largely unilateral owing to concerns for increased complica-

Table 1. Current Clinical Trials of Focused Ultrasound for Intracranial Ablation

TRIAL NAME	LOCATION
Essential Tremor (ET)	
Bilateral Treatment of Medication Refractory ET	The Ohio State Medical Center, Ohio, United States
A Second Magnetic Resonance Guided Focused Ultrasound Thalamotomy for ET	Sunnybrook Health Sciences Centre, Ontario, Canada
Bilateral ET Treatment With FUS	Toronto Western Hospital, University Health Network, Ontario, Canada
Transcranial Ultrasound Therapy of ET	Pitié-Salpêtrière Hospital, Paris, France
ExAblate Transcranial MRgFUS for the Management of Treatment-Refractory Movement Disorders	"Sunnybrook Health Sciences Centre, Ontario, Canada Toronto Western Hospital, Ontario, Canada"
Parkinson's Disease (PD)	
ExAblate Pallidotomy for Medically-Refractory Dyskinesia Symptoms or Motor Fluctuations of Advanced PD	Multicenter: United States, Canada, Israel, Italy, Korea, Spain, Taiwan, UK
ExAblate Transcranial MRgFUS of the Subthalamic Nucleus for Treatment of PD	University of Virginia, Virginia, United States
MRgFUS Pallidothalamic Tractotomy for Therapy-Resistant PD	Chinese PLA General Hospital, Beijing, China
A Clinical Trial for the Safety and Effect of MRGuided FUS Subthalamotomy for Medication Refractory PD	Osaka University Hospital, Osaka, Japan
Obsessive-compulsive Disorder (OCD)	
The Use of Transcranial Ultrasound Treatment of OCD	Neurological Associates of West LA, California, United States
Trial of MR-guided Focused Ultrasound (MRgFUS) Bilateral Capsulotomy for the Treatment of Refractory OCD	"Foothill Medical Centre, Alberta, Canada Sunnybrook Health Sciences Centre, Ontario, Canada"
Depression / Anxiety	
The Use of Transcranial Focused Ultrasound for the Treatment of Depression and Anxiety	Neurological Associates of West LA, California, United States
The Impact of Focused Ultrasound Thalamotomy of the Anterior Nucleus for Focal-Onset Epilepsy on Anxiety	The Ohio State University, Ohio, United States
Trial of MR-guided Focused Ultrasound for Treatment of Refractory Major Depression	Sunnybrook Health Sciences Centre, Ontario, Canada
Pain	
Feasibility Study of ExAblate Thalamotomy for Treatment of Chronic Trigeminal Neuropathic Pain	University of Virginia, Virginia, United States
MR Guided Focused Ultrasound (FUS) for the Treatment of Trigeminal Neuralgia	University of Maryland Medical Center, Maryland, United States
Feasibility Study of ExAblate Thalamotomy for Treatment of Chronic Trigeminal Neuropathic Pain	"Univ. of Maryland School of Medicine, Maryland, United States Univ. of Maryland Medical Systems, Maryland, United States"
Multimodal MRI for MRgFUS Central Lateral Thalamotomy in Neuropathic Pain	Chinese PLA General Hospital, Beijing, China
Focused Ultrasound (FUS) Mesencephalotomy for Head & Neck Cancer Pain	University of Virginia UVA Health, University Hospital, Virginia, United States
Epilepsy	
A Pilot Study: Focused Ultrasound Thalamotomy for the Prevention of Secondary Generalization in Focal Onset Epilepsy	The Ohio State University, Columbus, Ohio, United States
MR-Guided Focused Ultrasound in the Treatment of Focal Epilepsy	"Stanford University Medical Center, California, United States University of Kansas Medical Center, Kansas, United States Mayo Clinic, Minnesota, United States University of Virginia, Virginia, United States"

Figure 2. Axial T2 image after MRgFUS treatment demonstrating central Zone I and peripheral Zone II/III findings in the left thalamus.



tions with bilateral thalamotomy, but recent evidence suggests a bilateral staged plan can be safe and effective. Essential tremor remains the subject of numerous active clinical trials to expand and optimize its treatment.

Parkinson Disease

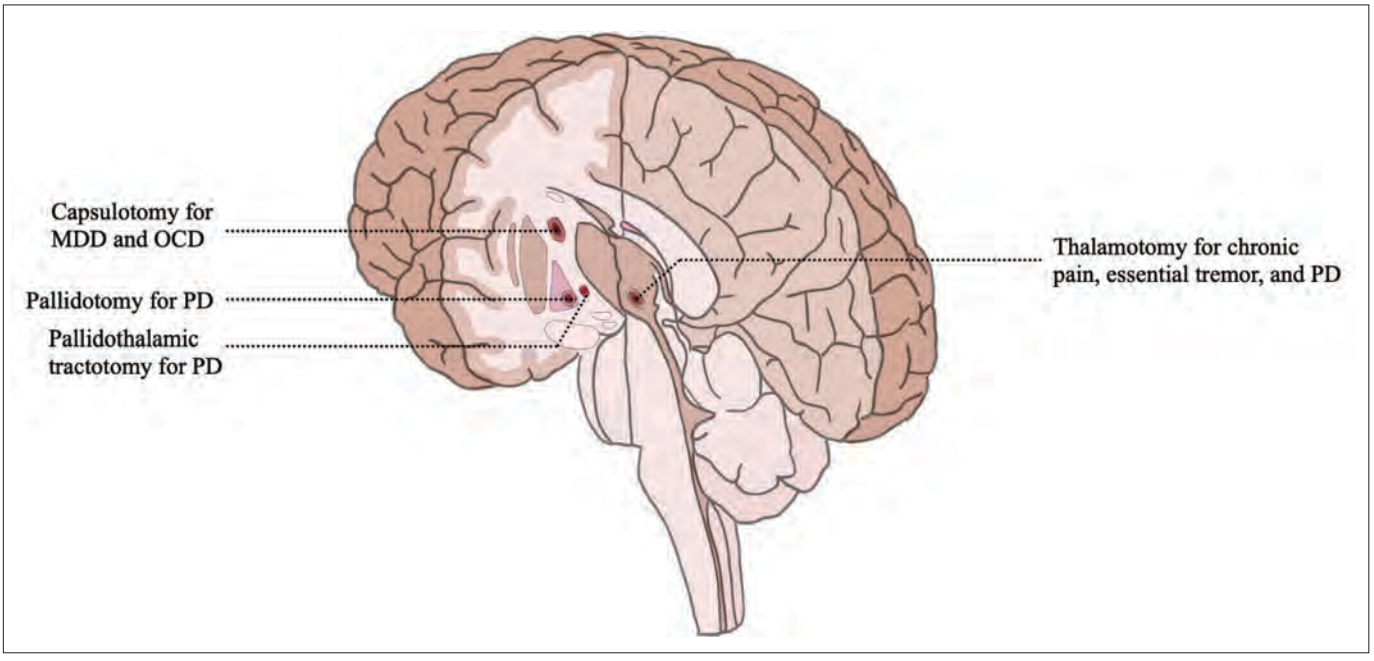
Parkinson disease is the second most common neurodegenerative disease, with a steadily increasing global prevalence. More than 6 million individuals are affected, a 2.5-fold increase over the past generation.

This number is projected to double again by 2040, even to as high as 17 million, given increasing longevity, declining smoking rates, and increasing industrialization.

In 1960, 50 patients with PD were among the first treated with FUS, a 14-hour procedure that required craniotomy, with only temporary improvement at best.

As the drug L-dopa was developed, medical management became primary. In 2018, thalamotomy for tremor-dominant PD received FDA approval, becoming the only addi-

Figure 3. Intracranial targets for magnetic resonance-guided focused ultrasound ablation include thalamotomy, pallidotomy and pallidothalamic tractotomy for Parkinson's disease (PD); anterior capsulotomy for major depressive disorder (MDD), and thalamotomy for chronic pain and essential tremor.



tional intracranial indication for FUS.

For patients with treatment-resistant PD, DBS has largely replaced conventional lesioning. The internal globus pallidus is commonly targeted in DBS, but its lateral location can be challenging for thermoablation. Nevertheless, MRgFUS pallidotomy has been shown to decrease tremor and improve motor function; FDA approval for pallidotomy has been granted.

A promising area of study is lesioning of the pallidothalamic tract for chronic therapy-resistant PD. A recent small study showed significant reductions in tremor and rigidity. Currently, multiple clinical trials are underway worldwide to study thermoablation targets for PD.

Frontier Indications

Psychiatric Diseases

MRgFUS capsulotomy is being studied as a potential treatment for obsessive–compulsive disorder (OCD), depression, and anxiety. Obsessive compulsive disorder is related to an imbalance of excitatory and inhibitory pathways in the corticostriatal–thalamocortical circuit. MRgFUS treatment has focused on the anterior limb of the internal capsule. Two trials studied MRgFUS anterior capsulotomy for medically refractory OCD with moderate reduction in symptomatology in some patients.

Major depressive disorder (MDD) is highly prevalent and treatment-refractory in one-hird of patients and is often comorbid with anxiety and other psychiatric illness. It is a heterogeneous disorder, implicating numerous structural and functional brain circuits, with historical surgical targets including the internal capsule, anterior cingulate, subcaudate tracts, and limbic system.

Clinical trials are underway to further evaluate the efficacy of MRgFUS for MDD and anxiety.

Chronic Pain

Pain lasting more than three months may be as high as 10% in the US population. Focused ultrasound was approved by the FDA in 2012 for the treatment of pain from osseous metastases, and clinical trials to investigate intracranial applications of MRgFUS for pain are ongoing.

Anterior cingulate, brainstem, spinal cord, and pituitary gland targets have all been considered, but the thalamus remains a principal target given its role in the relay of ascending nociceptive input from neurons of the spinal thalamic tract to key cortical areas. Bilateral central lateral thalamic nuclei thermoablation in a small study produced pain relief in >50% of subjects at 1 year.

Treatment of the neuropathic pain associated with trigeminal neuralgia with MRgFUS bilateral medial thalamotomy is being studied.

Chronic pain is a heterogeneous disease with multifactorial effectors, and while MRgFUS will not be a cure-all it will likely join the broad armamentarium of medical, percutaneous, and surgical treatments.

Epilepsy

Two clinical trials of MRgFUS in epilepsy are ongoing: one to investigate ablation of the anterior nucleus of the thalamus to prevent secondary generalization in focal onset epilepsy; the other in patients with comorbid moderate-to-severe anxiety. MRgFUS for epilepsy remains a nascent field for study.

Conclusion

Since its FDA approval in 2016, FUS has gained popularity among researchers, clinicians, and patients. Its utility is particularly relevant in neurological diseases where small, deep lesions provide a large effect in a multitude of pathological conditions (Figure 3). MRgFUS thalamotomy for ET and thalamotomy or pallidotomy for PD are becoming increasingly common. Initial studies of safety and efficacy for additional indications ranging from depression to neuropathic pain are encouraging and may soon garner regulatory approval.

Given the aging US population as well as the growing prevalence of diseases considered for treatment, MRgFUS should solidify its role as a noninvasive ablative therapeutic option for an increasing number of patients. Diagnostic and interventional radiologists should be familiar with the appearances of lesions on neuroimaging studies and the role this therapeutic modality can play in patient care.

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Want to Thrive in Healthcare? A Life Coach May Be for You

Kate Mangona, MD; Robyn Tiger, MD, DipABLM

Think of the best professional athlete or sports team you know. Now think of the best boss you have ever had. What do you think these examples share in common? Innate skills? Natural affinities? A sense of determination?

Certainly all three, but we would argue for a fourth: their mindset, a system of beliefs that resulted in habits and behaviors that ultimately led to their success, whether on the football field or in the medical field.

What people allow to occupy their headspace—what they think about—often leads them either to achieve great things or to cower in fear, not getting to create the relational synergies with colleagues that can help them reap the success and greatness that could be theirs.

As professional life coaches, we also know from experience that oftentimes all it takes to overcome this fear is the same thing that helps high achievers to excel in sports and other realms: a great coach.

Indeed, it might surprise you that many academic radiology chairs and chiefs work with high-performance executive life coaches to help develop their professional and leadership skills.

You can think of a life coach as a personal trainer for your mind. After all, it is your thoughts about a situation, not the situation itself, that cause your feelings and emotions and the action(s) you take or don't take as a result.

A good coach is non-judgmental and does not jump into a 'misery pool' with the client. Instead, they will create an emotionally safe environment in which to dissect difficult or uncomfortable topics. In this way, a coach can help the client to identify and improve upon their weaknesses, as well as to create a plan to clarify and achieve their goals. This can include developing new skills, improving efficiency, and expanding their knowledge base.

Here are five ways that a life coach can help you take your own professional performance to a higher level and bring back the joy of practicing medicine.

Help Prevent Burnout

We often meet with clients who say the increasing volume and complexity of patient cases and studies in radiology are forcing them to practice unsafe medicine. When we ask them how they are dealing with these situations, we often get responses such as:

"Oh, I just work here. I can't do anything about it."

"I have no power. No one values my opinion."

"I have to do what I am told, or I'll be considered unprofessional."

"Everyone else is faster and smarter than I am. I don't belong here."

It's true that our places of employment, the administration, the people we work with, PACS, and any number of other external factors can be sources of great stress to those of us who work in healthcare. However, a wealth of research has shown that we reap the most benefit when we focus on the things we can change in ourselves; for example, all-or-nothing thinking, perfectionism, people pleasing, and defeatist attitudes.

Ruminating over things we cannot control can make us unhappy, hurt our morale, and even lead to burnout. Indeed, the US Surgeon General declared burnout among healthcare workers to be a national crisis in his 2022 Advisory.[1]

The good news is that multiple studies have shown that life coaching significantly decreases emotional exhaustion, reduces "imposter syndrome," and increases self-compassion scores.[2] They have also found that a life coach can help provide healthcare workers, including radiologists, with strategies to manage stress and avoid burnout.

These include a recent study published in *JAMA*, "Effect of a Novel Online Group-Coaching Program to Reduce Burnout in Female Resident Physicians: A Randomized Clinical Trial,"[3] and one published in the *Annals of Surgery*, "Impact of a Virtual Professional Development Coaching

Affiliations: The authors of this paper are professional certified life coaches. Kate Mangona, MD, is the founder and owner of Medicine, Marriage, and Money, LLC and an Assistant Professor of Radiology at UT Southwestern Medical Center. Robyn Tiger, MD DiapABLM is the founder and owner of StressFreeMD. Prior publication/presentation: Parts of this paper were included in a presentation at the Society of Pediatric Radiology postgraduate course, May 2023.

Program on the Professional Fulfillment and Well-Being of Women Surgery Residents: A Randomized Controlled Trial."[4]

Help Foster Resilience

The word "resilience" has been known to make many physicians cringe, especially since the COVID-19 pandemic. However, it has been found that coaching does enhance the quality of resilience,[2] which is critical for coping with the stresses and challenges faced in the reading room.

Working with a coach, one can develop skills and strategies to avoid and bounce back from setbacks, juggle the never-ending litany of phone calls and reading lists, and maintain a positive outlook, regardless of circumstances. There's even a monetary value to coaching, as studies have shown that it can cost up to $1 million to replace a physician who resigns.[5,6]

Help Improve Communication Skills

Coaching can also help in more concrete, practical ways. Take communication, for example. Radiologists must communicate effectively with referring physicians, technologists, administrators and even patients, at times, to ensure appropriate care. High communication intelligence helps a radiologist to provide better care in a more meaningful and impactful way, while low communication intelligence can render even the most brilliant radiologist highly ineffective. A life coach can teach radiologists communication techniques that build rapport, increase engagement, and provide clear and concise instructions. This, in turn, can lead to more effective and appropriate patient care.

Help Foster Collaboration Skills

Radiologists also work closely with other healthcare professionals to ensure high-quality patient outcomes. Coaching can help radiologists cultivate not just the skills, but also, more importantly, the attitudes needed to collaborate effectively with other members of the healthcare team, including referring physicians, advanced practice providers, and other specialists.

Help Renew the Joy of Practicing Medicine

Great leaders—great professionals in general, for that matter—radiate authenticity, encourage unity, are approachable and inclusive, and embrace vulnerability and risk. These characteristics can inspire others to follow in their footsteps and take more action, responsibility, and accountability for their own success and that of the organization.

Life coaching can give radiologists the tools and support they need to grow these attitudes of mind, enhance their skills, prevent burnout, and foster greater communication and collaboration with colleagues and patients.

In short, coaching can help you bring back the joy of practicing medicine.

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How AI is Revolutionizing Opportunistic Detection in CT

Sarah Quenet

Opportunistic findings are those that are unexpected or incidental and discovered on medical imaging studies performed for other reasons. Artificial intelligence (AI) can help detect these small, and sometimes subtle, findings, leading to earlier treatment of potentially serious conditions.

Opportunistic detection of pulmonary embolism (PE) is one example among many. The frequency of incidental detection of PE among oncology patients is approximately 3.4%.[1] Up to 45% of PEs are missed by radiologists when "off-search" for the exam's primary purpose.[2] Undetected PE is associated with poorer outcomes; thus, prompt management is essential.

Oncology studies may be reviewed anywhere from hours to days after they have been acquired. This is particularly true of late, with the growing backlog of examinations associated with rising case volumes and staffing limitations.

Capable AI can work in the background, leveraging computer vision as an always-on assistant, unfettered by indication-related expectations, and ensuring that opportunistic findings are promptly identified, called to the radiologists' attention, and reported.

Incidental detection of disease on common examinations like CTs can also have a significant impact on health. For example, using AI to scrutinize CT scans acquired for other reasons can help identify unsuspected vertebral compression fractures (VCFs). These fractures can be difficult to detect, especially in patients who are not experiencing severe pain. AI-based screening of CT scans can lead to earlier treatment, preventing complete vertebral collapse, and improving patient quality of life.[3,4]

AI algorithms can also be used with CT to quantify visceral fat when evaluating for metabolic syndrome; to assess muscle bulk and density for sarcopenia diagnosis; to quantify liver fat in assessing hepatic steatosis; and to quantify aortic and coronary calcium for cardiovascular risk.[5,7]

These algorithms provide reproducible and reliable measurements to assess the hidden condition and help personalize patient management. Early studies also show their potential to predict treatment response and future adverse events.[8,9]

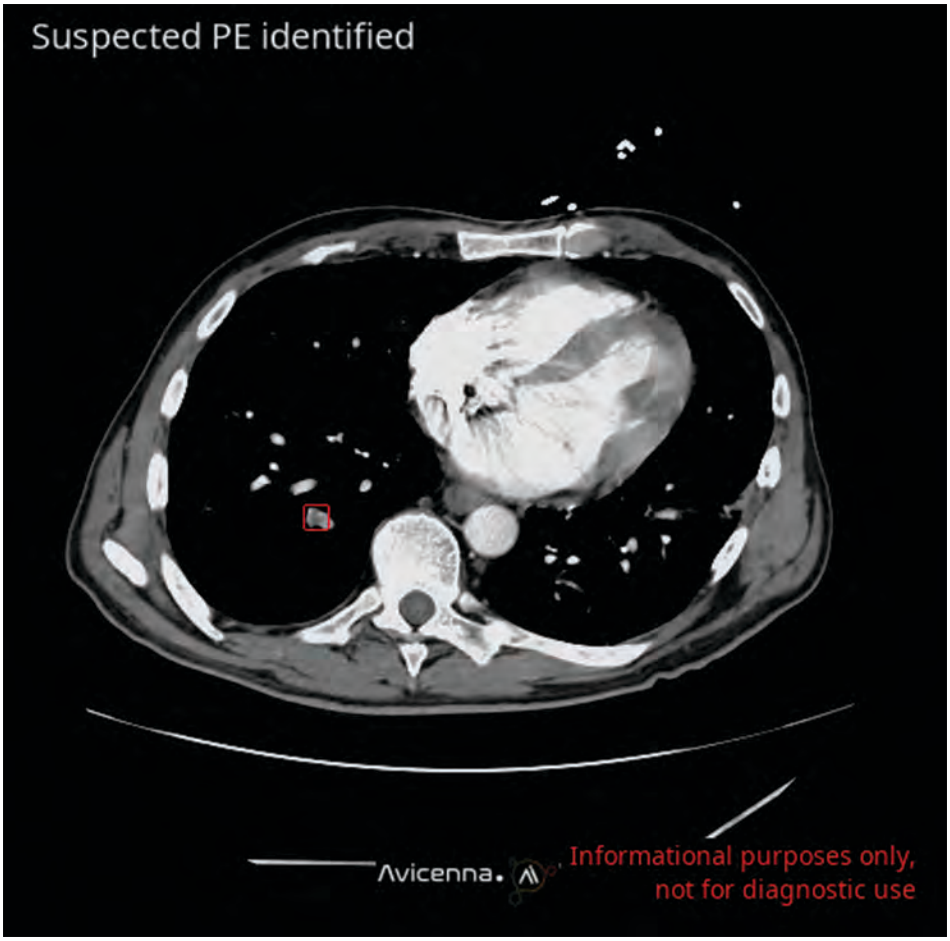
The American College of Radiology's Incidental Findings Committee, supports opportunistic identification and quantification of coronary calcium on routine CT scans of the chest as well as CT performed at low dose for lung cancer screening.[10]

Although these applications of AI have the potential to improve patient outcomes and increase efficiency, they also have drawbacks. It is true that some findings can be beneficial, but others may be clinically insignificant and yet lead to additional imaging, testing, and higher costs, as well as psychological distress, for patients. Convenient methods of informing the patient about the opportunistic finding and ensuring adequate follow-up are necessary for the appropriate use of such capabilities.

At present, only a limited number of AI-fueled applications are available for screening, particularly for diseases with low incidence. But more are expected in the coming years, and they may be able to weigh patient risk factors and contribute to disease prediction and prevention.

Sarah Quenet is a product manager at Avicenna.ai

Figure. Patient with a history of cancer and recent COVID-19 infection. Pulmonary embolism was not noted in the initial report. With the help of an automatic AI tool (CINA-iPE, Avicenna.AI, LA CIOTAT, FR), a small, right lower lobe pulmonary embolus was identified.



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Landing Your First Job: Contract Negotiations and Other Considerations

Yasha Parikh Gupta, MD

At the American College of Radiology (ACR) meeting in early May, the current shortage of radiologists was a hot topic of conversation among myself and many of my colleagues. This stands in stark contrast to a decade ago, when twice as many job seekers were available for every vacancy.[1]

As a newly minted radiologist you may in fact find it relatively easy to land a position in today's market. But in your eagerness to put your hard-earned skills to work, do not overlook the importance of knowing your negotiables and your non-negotiables—and not just as they apply to contracts.

For example, there are a few decisions you should make from the get-go, such as choosing between in-person work, hybrid work, and teleradiology. The conventional advice is for new attendings to avoid fully remote positions, as they need an "attendier attending" to show cases to and to help build their radiology repertoire—an opportunity that would be missed while working alone.

The post-pandemic era, however, has made hybrid work options a new reality, and radiologists can now work some shifts from home and some in the hospital. This can be a great option for new radiologists, especially those who have caregiving responsibilities, and who still need the help of veteran colleagues during the infancy of their career.

Another question to consider: Do you want to work in an academic or private practice setting? If you enjoy teaching and research, academics would certainly be an appropriate choice, but if you would rather focus more on clinical work, private practice is the way to go. Academics generally offers lower salaries but a better day-to-day lifestyle, while private practice typically affords higher salaries and more vacation time.

It's worth noting that the lines between the two have substantially blurred in recent years; many academic programs now have clinical tracks and some private practices are affiliated with residency programs, providing opportunities to teach.

Interview the Employer

Once you've landed an interview with a promising prospective employer, it's worth going beyond the basic interview to also speak with those who have left the practice as well as with junior attendings who may have joined the group recently. If your potential colleagues look miserable, there is a high chance that you will be miserable, too. If turnover is high, this should also set off alarm bells.

If you are looking to start a family, but there is no defined family leave policy, this could mean that the group is not used to, or particularly accommodating of, their radiologists taking extended periods of leave. Getting a well-rounded understanding of your prospective employer helps ensure that there will be no unfortunate surprises once you begin your job.

Contract Negotiations

Once you've landed a job offer, or two or three, it's time to enter into contract negotiations. While the granular details of a contract can and should be reviewed by a lawyer, here, again, it's important to know your negotiables from

Dr Gupta is a breast and oncologic imaging fellow/PGY-6 at Memorial Sloan Kettering Cancer Center in New York, New York. She is also a member of the editorial board of *Applied Radiology*.

your non-negotiables—and not just over salary, healthcare insurance, and vacation time.

You may hear the words, "all our contracts are standardized," but I have come to learn that many contract terms can still be modified. Indeed, the difference between landing a good job and a great one often comes down to the little things. For example, don't be afraid to ask for a home workstation, an education fund, a relocation stipend, and/or a signing bonus.

If you fail to negotiate, you are leaving money on the table, money that could be used for your retirement, your children's education fund, or even that vacation to Hawaii!

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Mixed Reviews for New Mammography Recommendations

Kerri Reeves

Kerri Reeves is a contributing editor based in Ambler, PA.

In May, the United States Preventive Services Task Force (USPSTF) released a recommendation for all women to get screened for breast cancer every two years starting at age 40. The recommendation represents a significant change from the USPSTF's prior recommendation for women to begin routine mammograms by age 50. While the radiology community is relieved that women in their 40s will experience increased detection and reduced mortality from the disease, the "how often" piece has frustrated many experts.

"The best way to summarize my reaction to the guidelines is mixed. I was so pleased to see they're finally recommending that women start having screening mammography at age 40, but disappointed that they didn't go farther in a number of areas, particularly to recommend annual mammography rather than biennial," says Nina Vincoff, MD, chief of breast imaging at Northwell Health in Lake Success, NY.

The task force did not take a separate stance on screening guidelines for women with dense breasts, other at-risk groups including Black women, or those age 75 and older, which is problematic, says Kemi Babagbemi, MD, FACR, vice chair for diversity, equity, and inclusion and associate professor of clinical radiology at Weill Cornell Medicine, New York City.

"The USPSTF is still not recognizing that 'one size does not fit all' when it comes to screening for breast cancer," Dr Babagbemi says. "What they say sets the tone, impacting policy and advocacy. They missed the chance to really set us on the right track."

While breast imagers and imaging societies are speaking out about the need for earlier risk assessments, clearer guidance for specific populations, and the benefits of yearly screening, the USPSTF, an independent panel of non-federal experts on prevention and evidence-based medicine, emphasizes that the recommendations for average-risk women are based on a balance of benefits and harms and available evidence.

"We still need more scientific evidence to help us understand whether and how additional screening could help the 40 percent of women in the US with dense breasts," says Carol Mangione, MD, MSPH, immediate past chair of the USPSTF. "We also need more information to better understand how to address health disparities...and about the benefits and harms of screening in women over the age of 75. We do not endorse a 'one-size-fits-all' approach, but rather have identified evidence gaps and called for additional research."

Dr Mangione is also chief of the division of general internal medicine and health services research, and the Barbara A. Levey, MD, and Gerald S. Levey, MD, endowed chair in medicine at the David Geffen School of Medicine at the University of California, Los Angeles.

Nina Vincoff, MD, chief of breast imaging at Northwell Health in Lake Success, NY.

Kemi Babagbemi, MD, FACR, vice chair for diversity, equity, and inclusion and associate professor of clinical radiology at Weill Cornell Medicine, New York City.

Carol Mangione, MD, MSPH, chief of the division of general internal medicine and health services research, and Barbara A. Levey, MD, and Gerald S. Levey, MD, endowed chair in medicine at the David Geffen School of Medicine at the University of California, Los Angeles and immediate past chair of the USPSTF

Stamatia Destounis, MD, FACR, managing partner of Elizabeth Wende Breast Care LLC in Rochester, NY and chair of the ACR Breast Commission.

"For now, the most important thing for women to know is to begin screening at age 40," she says, noting that the change from age 50 could result in 19% more lives saved, and will have significant benefit for Black women, who are 40% more likely to die from breast cancer.[1]

As the USPSTF evaluates public comments received through June 5, Dr Mangione summarizes the statement's impact as "good for women."

"It's going to lead to a lot more women getting screened, diagnosed, and treated. The predicted mortality reduction from this change is significant," she says.

How Often to Screen? That Is the Question

Previous USPSTF guidelines recommended that women in their 40s make an individual decision about when to start screening based on their health history and preference, and for all women to start by age 50. Stamatia Destounis, MD, FACR, managing partner of Elizabeth Wende Breast Care LLC in Rochester, NY, says the change was long overdue.

"We have been lobbying with women, with providers, with everyone who would listen how important it is to have early detection for women in their 40s. We are encouraged that we moved the needle," says Dr Destounis, who is also chair of the American College of Radiology (ACR) Breast Commission.

While there's generally a consensus for screening to begin at age 40, the interval strategy is up for debate. The USPSTF weighs the potential harms of screening, including false-positive results—and their potential for psychological impact—along with the need for additional imaging and biopsy, overdiagnosis, and radiation exposure. Dr Mangione says they "looked hard" to determine if annual mammograms would save more lives than every-other-year screens and determined that every two years is optimal for now, while calling for more evidence.

"We worry about harms, with the main benefit of saving lives from breast cancer. So we balance that, and the majority of benefit in reducing mortality can occur if you go every other year and you have a much lower rate of false positives," Dr Mangione says. She adds that the "B recommendation" means there's "moderate benefit" to starting screening at 40 every other year, but "we can't really say exactly how much better or worse annual would be because there isn't a lot of data."

While the task force considers various mammography risks, breast imagers generally prioritize early cancer detection, notes Dr Destounis.

"Our goal is to find every tumor at its smallest. The ACR, SBI [Society of Breast Imaging], RSNA [Radiological Society of North America]—we're all in agreement, recommending annual screening beginning at age 40. The USPSTF looks at other

things such as callbacks, and considers those more important. Essentially they're putting the risk of getting a callback higher than finding a cancer," she says.

Dr Babagbemi concurs. "We have data that says if you're screening annually starting at age 40, that has the greatest reduction in mortality," she says. "The USPSTF needs to look very carefully at that data." She adds that annual mammograms for Black women could significantly reduce disparities in their survival rates compared to other groups.

Erik Anderson, division president of breast and skeletal health solutions at Hologic, based in Marlborough, MA, which manufactures mammography scanners, agrees with Dr Babagbemi.

"Every two years is inconsistent with the position of leading voices in the breast cancer community. This creates confusion for patients and providers and puts women's lives at risk by giving cancers time to grow undetected. Early detection through annual screening is especially important for Black women and Jewish women, who are at higher risk for developing more aggressive breast cancer at earlier ages," Anderson says.

Saving lives isn't the only goal of early detection; more favorable treatment courses impact quality of life, Dr Vincoff adds.

"If you wait two years instead of one [to screen], you increase the chances that your cancer will be larger and require more aggressive treatment like mastectomy and chemotherapy," Dr Vincoff says.

At-risk Considerations

The new USPSTF guidelines are for average-risk women. African Americans, women of Ashkenazi Jewish descent, and those with dense breasts all benefit from earlier and more frequent screening, Dr Babagbemi says. Without recommendations for risk assessments, however, women may not know which category they're in. In May, the ACR called for *all* women to have risk assessments by age 25 to determine if they should be screened before they turn 40.[2]

"Most people fail to recognize Black women as being in a high-risk category. So we fail to screen them early, and we fail to genetically test them," Dr Babagbemi explains, arguing that radiologists have a responsibility to educate providers and patients about the higher risks Black women carry for breast cancer.

"One of the reasons the task force lowered the age was in recognition that the old guidelines weren't serving Black women well enough," Dr Vincoff adds. "But even these guidelines may not be serving them well enough."

The USPSTF underscored the importance of equitable follow-up and treatment after screening, and urgently called for more research on how to improve the health of Black women. Similarly, the task force called for more research on the benefits and risks of screening women 75 and older.

"For women expected to live into their 80s and 90s with a high quality of life, there's no guidance for them about screening. That's unfortunate," says Dr Vincoff.

Dr Destounis adds there should be no screening upper limit, which she calls a "disservice" to older women. "What should define if a woman over 75 gets mammograms is not her age but her comorbidities—her ability to come back in for additional views, tests, or procedures. Most patients in this group do return to have additional workup," she says.

The task force acknowledges that women with dense breasts are at higher risk for breast cancer and that their mammograms are less effective. However, the USPSTF failed to make a recommendation on supplemental screening strategies as part of the new guidelines, instead calling for more research.

"We don't know the best testing strategies for women with dense breasts in terms of supplemental testing," says Dr Mangione. "Is it better to do an ultrasound? MRI? We don't know at what age, or how often. We have an urgent call for research to help us answer all those questions."

On a related note, the US Food and Drug Administration recently updated its mammography guidelines to require patient reporting of breast density, which will be enforced by next year.

"It's disappointing that women are now going to get these notifications, but then be unable to look to the task force for guidelines about what to do next," Dr Vincoff says.

Patient Education

As the incidence of breast cancer evolves over time, the body of evidence on screening will grow, leading to adjustments to guidelines by stakeholder organizations across primary care, the cancer community, and medical imaging. To patients, the

recommendations can seem like a "moving target," observes Dr Destounis, who explains that while various organizations often consider the same data and research, they approach the information differently. Educating patients and referring physicians is critical, Dr Babagbemi says.

"Empowering patients is one of the key things when it comes to care of patients. We need to provide them with the best scientific evidence we have, and allow them to make their decisions with the aid of their PCPs," she says.

Dr Vincoff agrees. "As radiologists, a big part of our job has always been educating the community. Patients and referring physicians need to know that the guidelines proposed are not the ones that will save the most lives. We're going to need to tell that story."

This includes educating patients about potential false positives, says Dr Babagbemi, who notes that many patients are less alarmed by callbacks than they are by a missed cancer.

"I'm not insensitive to the idea of the anxiety. I'm a breast imager, but I'm also a woman who has mammograms and understands the fear and anxiety associated with callbacks. Women need better education about what they involve," Dr Babagbemi says. "With this information, some of the anxiety can be reduced and women may be better able to make decisions about screening with their doctors."

Dr Mangione summarizes that the task force, across more than 100 recommendations—ranging from preventive medications to hormone therapy to autism screening—tries to strike the balance between benefit and risk to keep Americans as healthy as possible.

"Our whole decision-making is based solely on net health benefit," she says.

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Macrocystic Lymphatic Malformation

D'Shaun D. Adams; Richard B. Towbin, MD; Carrie M. Schaefer, MD; Alexander J. Towbin, MD

Case Summary

An infant presented with a large right-sided chest wall, axillary, and neck lymphatic malformation (LM), diagnosed prenatally. The patient had limited right upper extremity motion because of the large right chest wall and axillary mass.

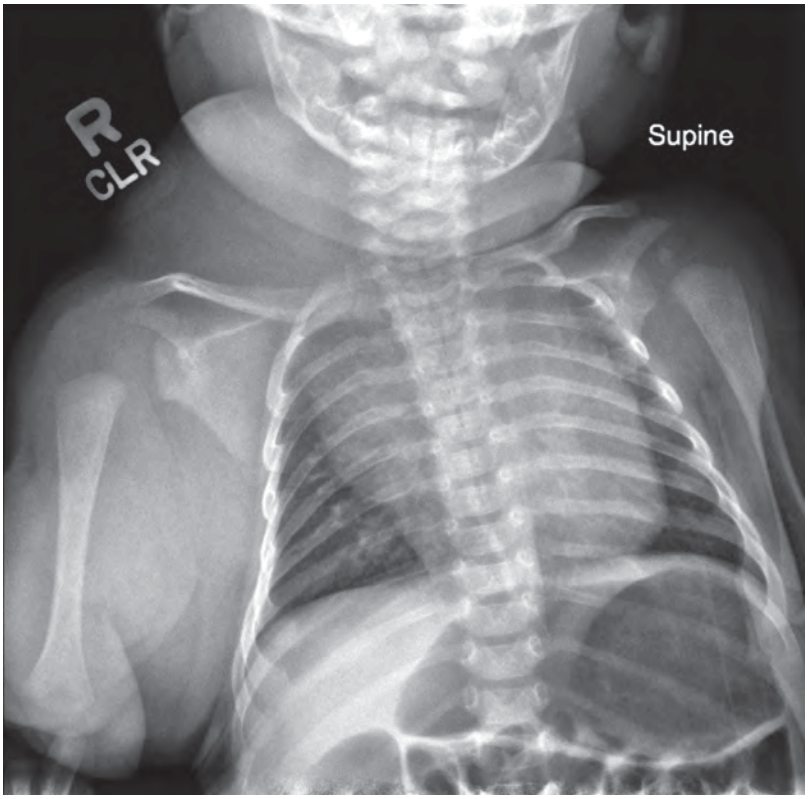
Imaging Findings

Chest radiograph (Figure 1) shows a soft-tissue mass involving the right neck and upper extremity. Chest MRI (Figure 2) revealed a large macrocystic mass extending from the base of the neck to the right upper extremity and into the mediastinum. Some of the cystic spaces had fluid-fluid levels. The LM was treated with image-guided (ultrasound and fluoroscopic) drainage and sclerotherapy (Figure 3).

Diagnosis

Macrocystic lymphatic malformation (formerly known as cystic hygroma).

Figure 1. Frontal chest radiograph shows a large soft-tissue mass affecting the neck, chest wall, and right upper extremity.



Discussion

Lymphatic malformations are congenital masses resulting from errors in the development of the lymphatic endothelium and vasculature. They may form in any location, and be separate from the primitive lymphatics from which they derive.[1] The most common location for this anomaly is within the head and neck. The axilla, chest, and perineum are the second-most common sites. Lymphatic malformations are particularly problematic because they tend to grow with the child, expand and enlarge over time, and may recur after treatment.

Affiliations: UCF College of Medicine, Orlando, Florida (Mr Adams), Department of Radiology, Phoenix Children's Hospital, Phoenix, Arizona, (Drs Schaefer, R Towbin), Department of Radiology, Children's Hospital Medical Center, Cincinnati, Ohio; Department of Radiology, University of Cincinnati College of Medicine (Dr A Towbin).

Figure 2. Chest MRI performed at 2 months of age. (A) Axial T2 image of the neck shows a large macrocystic lymphatic malformation in the right side of the neck that displaces the right common carotid artery posteriorly and leftward (red arrow), the trachea far leftward (blue arrow), and a fluid-fluid level in the microcyst (yellow asterisk). (B, C) Axial T2 image of the chest shows macrocysts extending into right axilla and mediastinum. (D) Coronal T1, fat-suppressed, postcontrast image of the neck shows the extensive macrocystic structure. There is no enhancement of the cysts.

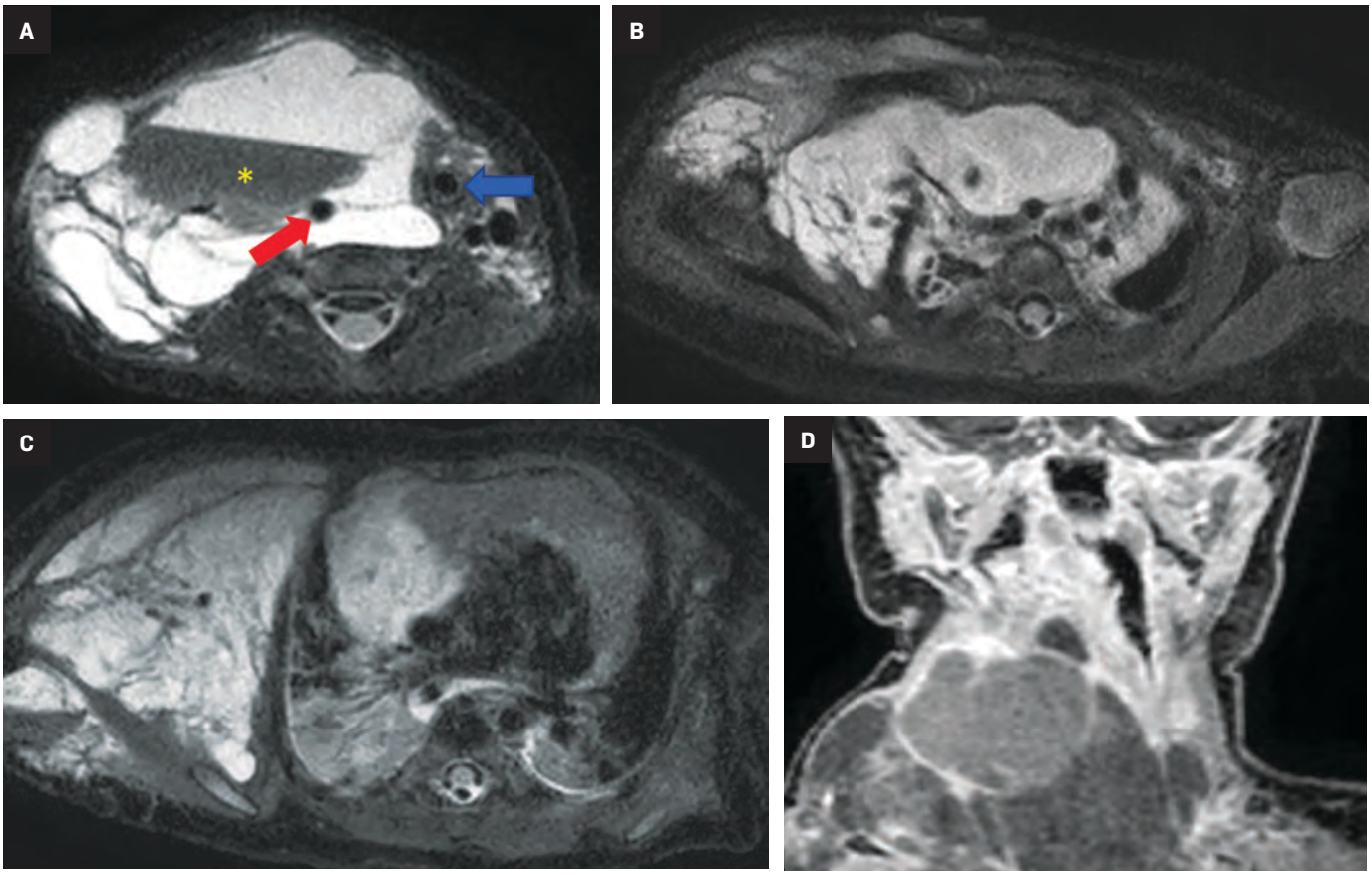
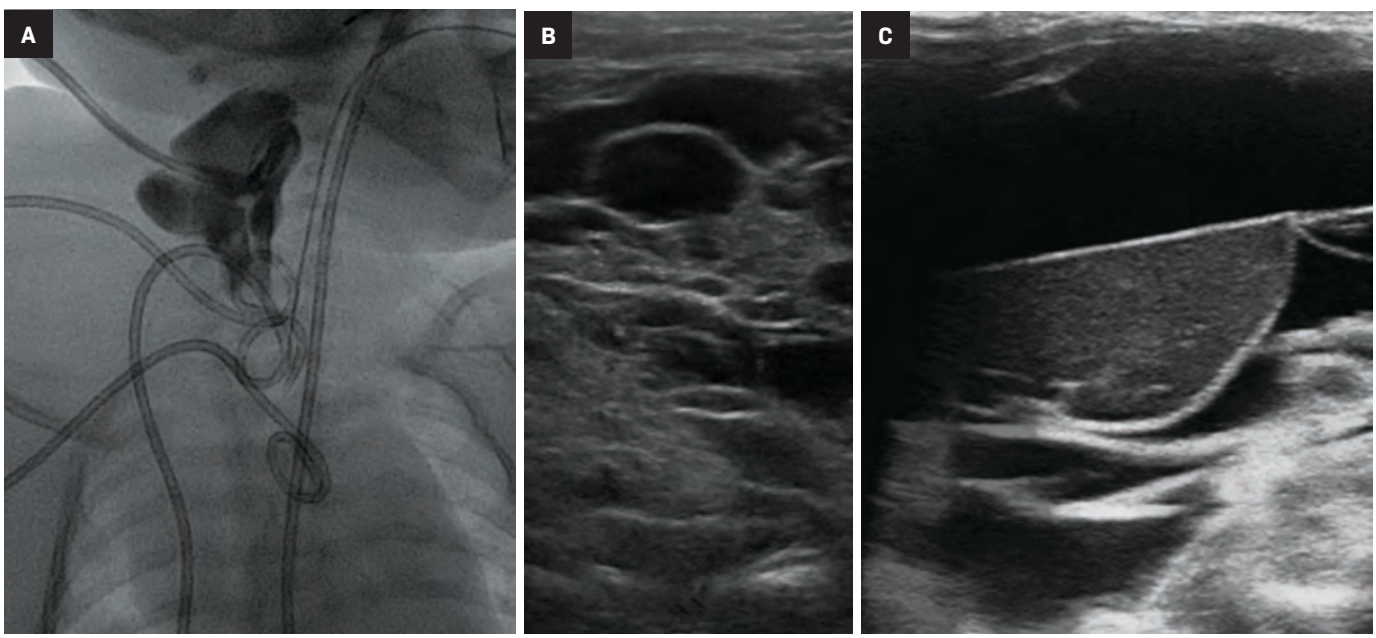


Figure 3. Images obtained during sclerotherapy of the lymphatic malformation at 2 months of age. (A) Ultrasound of a complex macrocyst highlights a fluid-debris level. (B) Ultrasound of multiple cysts in the right chest wall . (C) Percutaneous drains in four macrocysts of the lymphatic malformation, with dilute contrast instillation delineating the superior-most macrocyst.



Lymphatic malformations may be divided into macrocystic and microcystic lesions. This is important because the drugs used for therapy differ. Most LMs contain macrocystic and microcystic components, with no histological difference between the two. Macrocystic lesions measure > 2 cm in diameter and present at birth as large, translucent, soft, compressible masses covered by normal skin.

Microcystic LMs are made up of smaller cysts or soft-tissue enlargement without cyst formation. They are congenital and may be noted at birth or appear in the first few years of life, presenting as a cluster of translucent or hemorrhagic vesicles that may intermittingly leak lymphatic fluid. Both types grow with the child and manifest in a waxing and waning course, with changes in size associated with increased hormonal activity, infections, intralesional hemorrhage, inflammation, and trauma.

On ultrasound, macrocystic LMs appear as well-defined, multilocular, cystic masses with internal septa of varying thickness. The cystic contents are usually anechoic but may be hyperechoic if debris, infection, or hemorrhage complicate the malformation. These lesions are of low flow, with absent Doppler signal owing to the lack of flowing blood. The lesions are compressible and may have mobile internal debris. Microcystic LMs are frequently more poorly defined and may appear solid because of the dominant soft-tissue component.

Lymphatic malformations are often extensive and involve multiple tissue planes. They have a variable appearance on MRI because of the variable protein content within the cystic spaces. On T1 sequences, components of the malformation can be either hypointense or hyperintense. On T2 sequences, LMs are typically hyperintense. Fluid-fluid levels may be observed in macrocystic LMs due to dependent proteinaceous material, internal hemorrhage, or infection. Contrast enhancement is limited to the wall of the cyst and septations.

LMs are treated when disfiguring, symptomatic (eg, from airway compression) and complicated by bleeding or infection.

Sclerotherapy is currently the first-line therapy for both types. Sclerotherapy of macrocysts involves aspiration of the cyst contents, followed by injection of an inflammatory sclerosant (absolute alcohol, sodium tetradecyl sulfate) that causes injury to the cell lining of the cyst. Cyst wall injury is followed by thrombosis and scarring, leading to collapse of the macrocyst that occurs up to 6-8 weeks post sclerotherapy.

Sclerotherapy of microcystic LMs (doxycycline, bleomycin) consists of injecting a sclerosing agent into multiple microcysts. Owing to the progressive nature of this disease, residual LMs may grow larger. In general, one can expect a better result from sclerotherapy of macrocysts.

Sclerosants utilized for LMs in the United States include doxycycline, bleomycin, sodium tetradecyl sulfate (STS), and ethanol. Doxycycline has been shown very effective and safe, with an additional theoretical benefit of reducing postoperative infection.[2,5] However, doxycycline has potential to affect the enamel of the teeth in young children.

Bleomycin is used to treat microcystic LMs and is preferred where a reactive inflammatory response must be avoided, such as in intra-orbital microcystic LMs. Although an effective sclerosant, STS carries a higher rate of localized tissue swelling and is less effective than ethanol.

Ethanol is the most effective sclerosant but carries the highest complication rate, with large volumes (> 1cc/kg) to be avoided due to the risk of local and systemic complications, including central nervous system depression from alcohol intoxication, thromboembolism, and arrhythmias.[4]

Ethanol also can injure nerves and should not be used near important structures such as the cranial nerves.[6]

The most common complication of sclerotherapy is skin ulceration, which is more frequent with superficial lesions and the use of ethanol.[4] Skin ulceration is managed with local wound care.

Sclerotherapy alleviates symptoms and has superior efficacy, less disfigurement, and lower complication rates compared to surgical resection.[2] Resection may be indicated for small, well-localized LMs that can be removed for a cure, or symptomatic LMs after pretreatment with sclerotherapy.[1,7]

Additionally, when considering resection, the postoperative scar/deformity should be weighed against the preoperative appearance of the lesion. Wound healing may be a problem if an incomplete resection is performed because of continuous fluid leakage. For diffuse malformations, subtotal resections are preferred to complete removal, as total resections may cause a deformity worse than the initial lesion and come with a high rate of LM recurrence (35%–64%).[1,7]

Sirolimus (rapamycin) has recently emerged as an effective agent for the medical management of LMs. Sirolimus works as an mTOR inhibitor. mTOR acts as a master switch of numerous cellular processes, including cellular catabolism and anabolism, cell motility, angiogenesis, and cell growth. A 2018 systematic review by Wiegand et al found 60 of 63 patients from 20 studies of different LM subtypes had a treatment response to sirolimus.[8]

However, many of the studies included did not quantify the treatment response. Further randomized, controlled studies are required to

analyze the efficacy and long-term adverse effects of sirolimus before evaluating its potential as a medical intervention.

Conclusion

Lymphatic malformations are rare, congenital, vascular malformations that progress over time, grow with the child, and rarely regress spontaneously. They are characterized as macrocystic, microcystic, or mixed lesions. Their progression can compress nearby structures and they can be complicated by hemorrhage or infection.

Sclerotherapy is the current first-line therapy; sclerosants cause an inflammatory reaction that leads to LM collapse. Ultrasound plays an important role in the diagnosis, characterization, and image-guided treatment of LMs.

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Cosmetic Injection-induced Hypercalcemia

Roy Gottlieb, DO, FSCCT; Miriam Brookenthal

Case Summary

An elderly patient presented with ~5-year history of chronic hypercalcemia. Etiology remained unknown despite extensive radiology and laboratory work-up, including negative nuclear medicine bone and parathyroid scans, negative CT and MRI scans, and numerous laboratory tests. Relevant medical history includes a history of gluteal cosmetic injections more than five years prior.

Laboratory investigations were significant for an elevated creatinine level of 1.13 mg/dL (reference range: 0.8-1.2 mg/dL); elevated calcium level of 14 mg/dL (reference range: 8.4-10.2 mg/dL); 1,25 dihydroxy vitamin D level of 88 pg/mL (reference range: 19.9-79.3 pg/mL); 24hr urine collection 404 mg calcium (100-300 mg/24hr); low parathormone (PTH) level of 11pg/mL (reference range: 12-88 pg/mL); and high parathormone-related protein (PTHrp) at 11pmol/L (reference range: 0.0-2.3 pmol/L).

Imaging Findings

Positron emission tomography (PET)/CT maximum intensity projection image (Figure 1) demonstrated marked fluorodeoxyglucose (FDG)-avid uptake in the gluteal regions and thighs with associated mild inguinal adenopathy. Magnetic resonance imaging demonstrated nodular, low T1 and T2 masses in the subcutaneous fat and inguinal lymphadenopathy (Figure 2).

Affiliations: Rolling Oaks Radiology, Thousand Oaks, California (Dr Gottlieb); University of Washington, Seattle, Washington (Ms Brookenthal).

Diagnosis

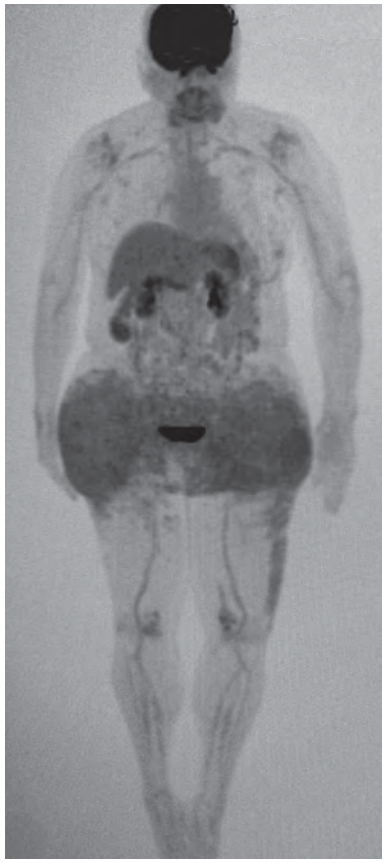
Cosmetic injection-induced granulomas causing calcitriol-mediated hypercalcemia.

Discussion

Many different varieties of cosmetic fillers are used today, several of which are not approved for use by the US Food and Drug Administration (FDA). While collagen, hyaluronic acid, and polymethacrylate (PMMA) are approved for injection,[1] liquid silicone injections were banned by the FDA in 1991 because of associated complications. Nonetheless, illicit usage of these injections remains high.[2,3] The exact numbers are unknown, but complications from silicone injections are significant enough that there are calls for enhanced state-level enforcement of penalties.[4]

The first foreign body granuloma caused by a silicone injection was described as a "siliconoma" by Winer et al in 1964.[5] The researchers described three cases of granuloma formation resulting from silicone injections and advised against itheir use. Foreign body granulomas associated with cosmetic injections may occur in up to 1% of all cases. Even when appropriately used, cosmetic injections may, albeit rarely, trigger calcitriol-mediated hypercalcemia.

Figure 1 Full body PET/CT MIP image demonstrates FDG-avid, hypermetabolic activity diffusely in the gluteal and thigh regions.



Silicone, as well as other cosmetic injections including PMMA and paraffin oil are used in plastic surgical procedures and can all cause granulomas that may induce hypercalcemia.[6]

Granulomatous conditions like sarcoidosis can lead to calcitriol-induced hypercalcemia. In these conditions, macrophages release 1-alpha-hydroxylase, which facilitates the conversion

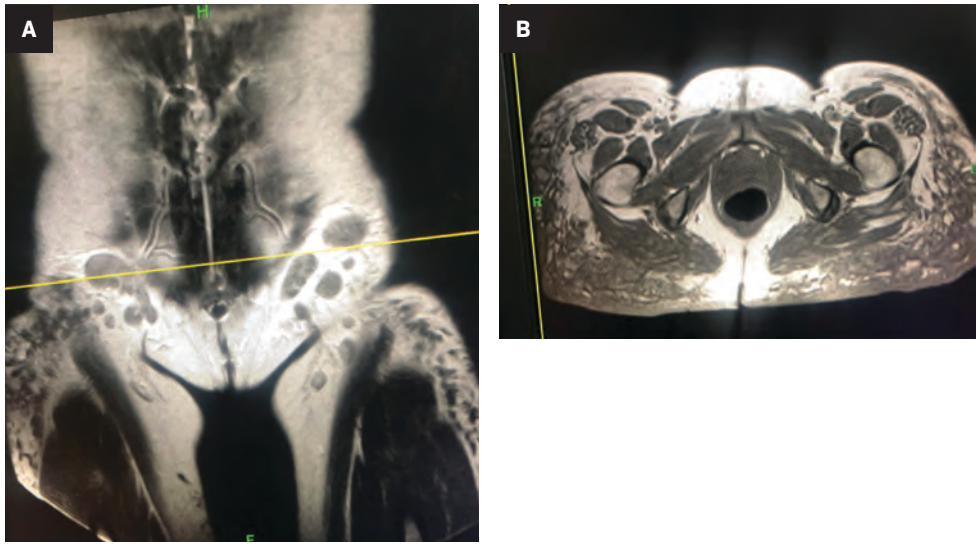


Figure 2 (A) MRI coronal T1 image demonstrates inguinal adenopathy and hypointense, nodular soft tissue granulomas in subcutaneous soft tissues of gluteal region and thighs. (B) Axial T1 MRI demonstrates decreased nodular soft tissue masses in subcutaneous soft tissues of gluteal region and thighs.

of inactive vitamin D to its active form. Calcitriol has an immunomodulatory action resulting in decreased T cell activity, most likely due to inhibition of IL-2 and γ-interferon.[6] Under normal circumstances, renal 1-alpha-hydroxylase is responsible for producing calcitriol, an active form of vitamin D. High circulating calcitriol elicits negative feedback on 1-alpha-hydroxylase production and thus inhibits further calcitriol production. This regulatory pathway is lacking in macrophages, leading to uncontrolled calcitriol production.[7]

The radiologist who identifies cosmetic induced granulomas may be the first of the patient's physicians to recognize them as a potential source of "idiopathic" hypercalcemia. This will aid in early diagnosis and may decrease the need for unnecessary medical tests.[8]

Conclusion

Cosmetic injections can cause foreign body granulomas resulting in life-threatening hypercalcemia, that may present years after initial injection. Cosmetic-induced granulomas which should be included in the differential diagnosis of causes of hypercalcemia, may first be recognized by radiologists. Hypercalcemia remains a diagnosis of exclusion after evaluating for and excluding malignancy, autoimmune disease, paraneoplastic syndromes, and other granulomatous diseases.

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Ollier Disease

Daniel Morgan, MD; Richard B. Towbin, MD; Alexander J. Towbin, MD

Case Summary

A child with no prior medical history presented for orthopedic evaluation after developing an increasing number of painless bumps over the right hand. The patient's signs began with a single bump on the right fourth digit middle phalanx. The bumps did not affect range of motion. Focused exam of the right hand revealed palpable, nontender, osseous nodules involving the proximal and middle phalanges and metacarpal of the ring finger, as well as over the proximal phalanx of the small finger. There were no additional lesions.

Imaging Findings

Radiography of the right hand (Figure 1) revealed numerous expansile lucent lesions within the bones of the right hand, most notably involving the proximal and middle phalanges of the fourth and fifth digits in addition to the metacarpal of the fourth digit. Each lesion demonstrated a ground-glass matrix and a narrow zone-of-transition. A skeletal survey revealed additional lucent lesions within the right ulna (Figure 2). Noncontrast MRI of the right hand and forearm (Figure 3) revealed multiple lobular, expansile masses that were homogeneously T2 hyperintense and T1 isointense to muscle within the metacarpal, proximal phalanx, and middle phalanx of the fourth digit, in addition to lesions within the proximal and middle phalanx of the fifth digit. Within the ulna mid-diaphysis, two centrally based lobular lesions displayed homogeneous T2 hyperintensity and T1 isointensity to muscle. All lesions were consistent with enchondromas.

Diagnosis

Ollier disease (multiple enchondromatosis). Differential diagnosis includes Maffucci syndrome.

Discussion

Ollier disease is a rare, nonhereditary disease of the appendicular skeleton that manifests as multiple enchondromas. The short, tubular bones of the hand are most commonly involved, followed by the femur, tibia, fibula, humerus, radius, and ulna. The prevalence of Ollier disease is about 1:100,000. It usually manifests within the first decade of life and has an equal incidence in males and females.[1]

In Ollier disease, the multiple enchondromas are often unilateral and may be associated with concomitant limb deformities and shortening. Pathological fractures are common sequelae of long-standing disease.

The assessment for Ollier disease begins with the physical exam, which will often reveal multiple, hard, palpable nodules within the bones of the hand. A hand radiograph should be the first imaging study; it characteristically reveals multiple, expansile, lucent lesions within the metaphyses of the short tubular bones. Bones may exhibit erosion and endosteal scalloping without significant periosteal reaction. Pathological fractures can be seen in up to 60% of patients at initial presentation.[2] An MRI exam typically reveals multiple lobulated bone lesions

Affiliations: Department of Radiology, University of Cincinnati College of Medicine, Cincinnati, Ohio (Drs Morgan, A Towbin); Department of Radiology, Phoenix Children's Hospital, Phoenix, Arizona (Dr R Towbin)

Figure 1. Radiograph of the right hand shows multiple expansile lucent lesions within the bones of the right hand. The proximal and middle phalanges of the fourth and fifth digits, in addition to the metacarpal of the fourth digit, are most severely affected.

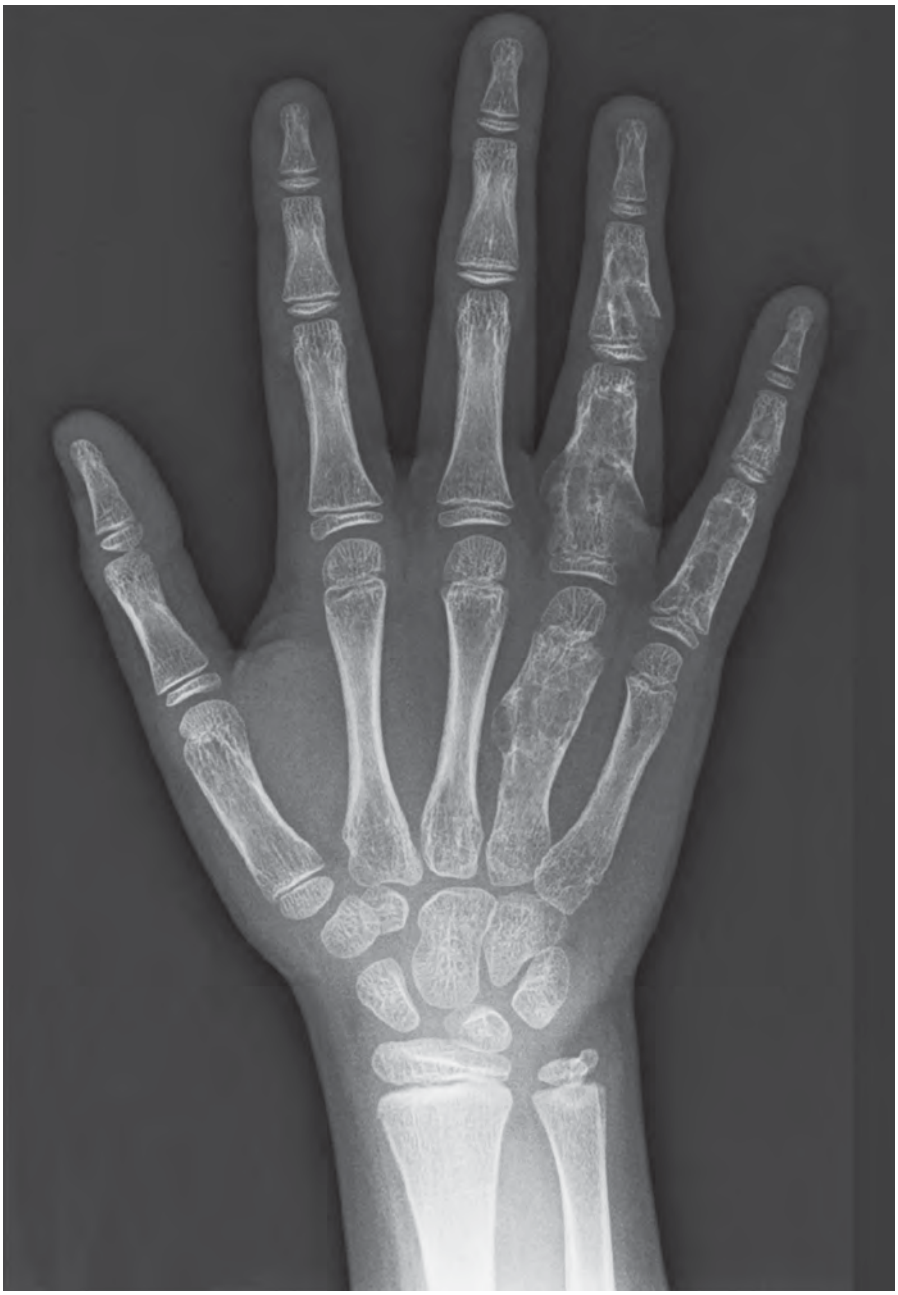
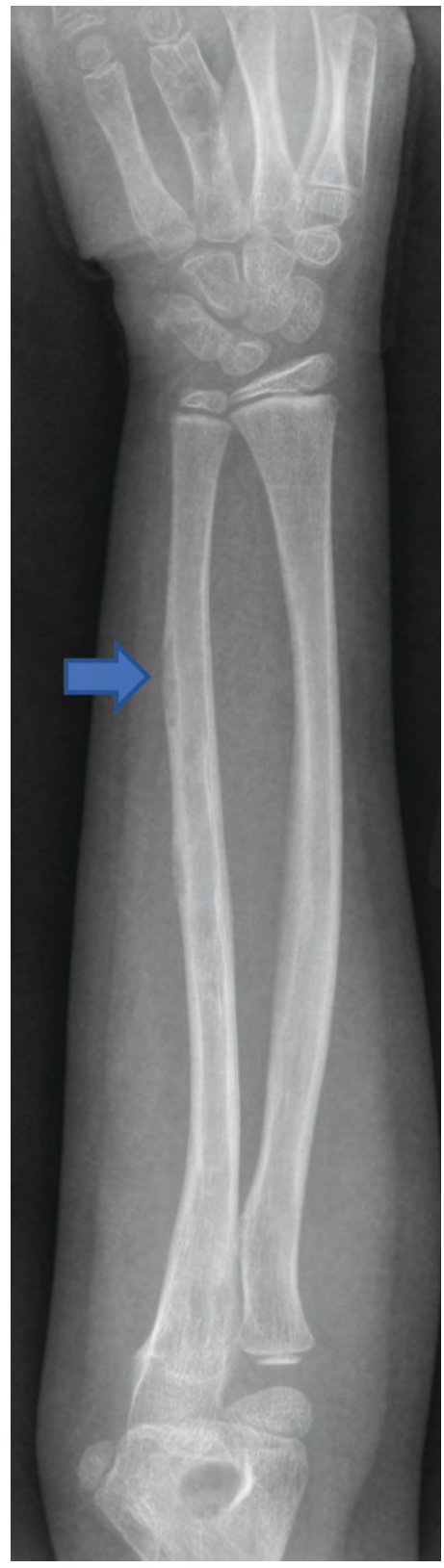


Figure 2. Radiograph of the right forearm shows expansile lucent lesions involving the mid ulna blue arrow indicating more distal lesion)

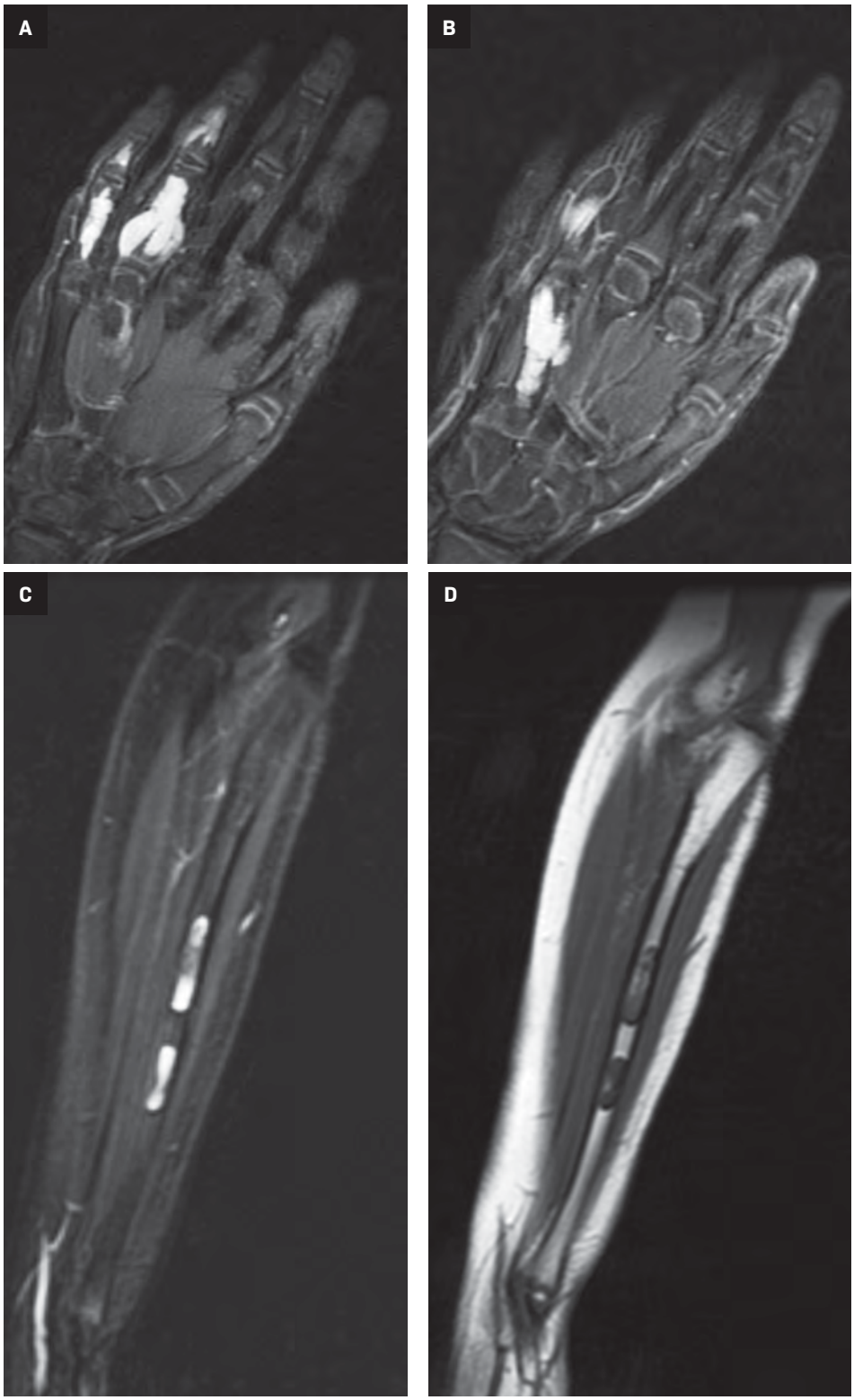


with intermediate T1 and intermediate-to-high T2 signal intensity.[3]

Definitive diagnosis, if required, is obtained through direct tissue sampling via bone biopsy. The pathological samples in this study revealed multiple fragments of hypercellular hyaline cartilage with focal perichondrium lining, bony trabeculae, and fragments of detached hypocellular bone marrow, consistent with enchondroma.

Different theories have been proposed regarding the pathogenesis of Ollier disease. One is that somatic mosaic mutations in the *IDH1* and

Figure 3. MRI of the right upper extremity. (A and B) Coronal intermediate-weighted images of the right hand at two different levels shows multiple hyperintense lesions affecting the proximal and middle phalanges of the fourth and fifth digits. (C) Coronal fast spin echo inversion recovery (FSEIR) and (D) coronal T1 images of the right forearm show two lesions within the ulna. The lesions are hyperintense to bone on the FSEIR image and hypointense to the bone on the T1 image.



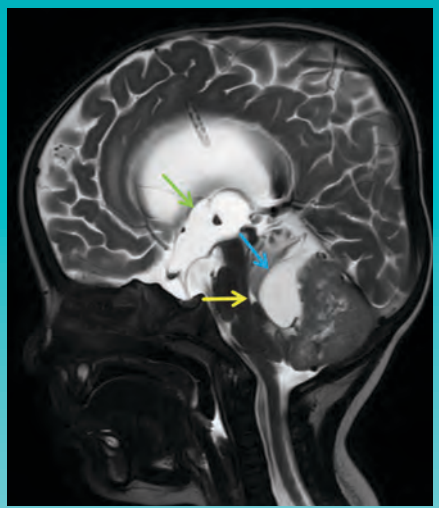
IDH2 genes, which code for isocitrate dehydrogenase (a digestive enzyme used in the citric acid cycle) and the PTHR1 (parathyroid hormone 1 receptor) play a role.[4] Depending on the patient's family history, gene sequencing may be performed at the time of diagnosis.

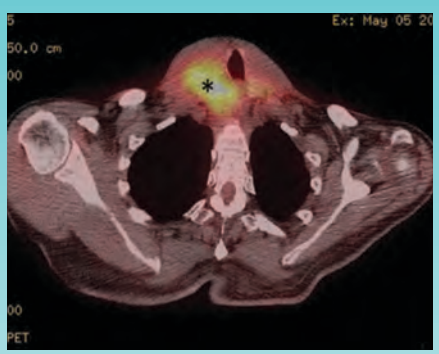
Similar to Ollier disease, Maffucci syndrome is a separate, nonhereditary syndrome characterized by multiple enchondromas. However, Maffucci syndrome also involves the coexisting presence of multiple soft-tissue hemangiomas and/or lymphangiomas, which are absent in Ollier disease.[5] These disorders share many overlapping themes, including the propensity for enchondromas to undergo malignant transformation to chondrosarcoma.

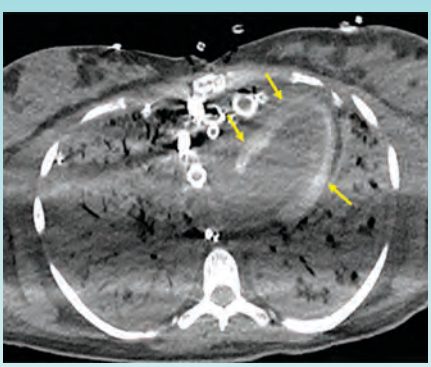
Pain in an apparent enchondroma or an abrupt increase in lesion size should prompt evaluation for malignant transformation. As the imaging modality of choice, MRI can distinguish between enchondroma and chondrosarcoma; the presence of new soft-tissue invasion or high T2 signal intensity (edema) surrounding the osseous lesion are suspicious for malignancy. Both conditions are also associated with an increased risk for the development of additional systemic malignancies, most commonly juvenile granulosa cell tumor of the ovary and gliomas.[5]

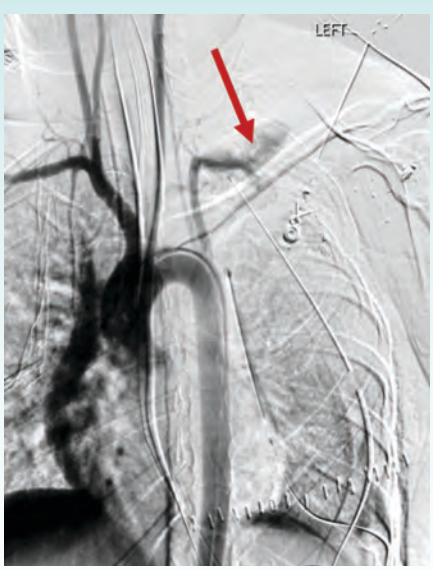
Ollier disease has no pharmacological treatment. Patients without significant deformities or functional impairment can begin with conservative "watchful waiting" and long-term follow-up. Patients with early-onset disease or complications such as limb deformities, pathological fractures, or malignant transformation require surgical treatment;[6] options include lesion resection/curettage, internal fixation of fractures with bone grafts, and/or amputation in the most advanced cases.[6]

The patient in this study was treated with right fourth digit proximal









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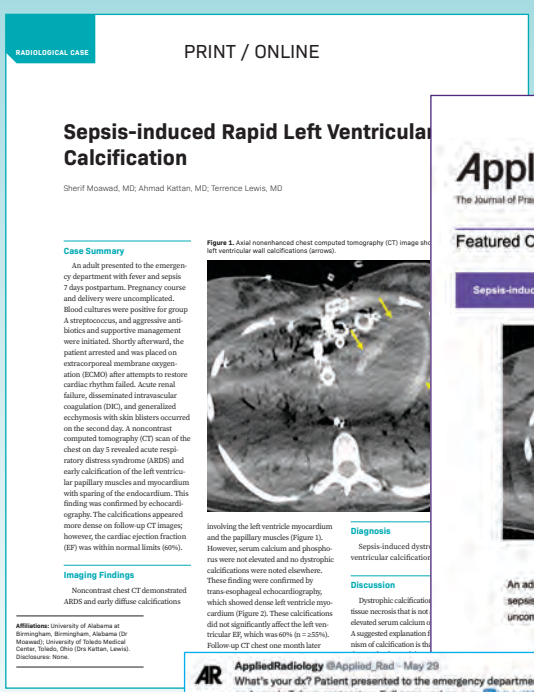
RADIOLOGICAL CASE

Sepsis-induced Rapid Left Ventricular Calcification

Sherif Moawad, MD; Ahmad Kattan, MD; Terrence Lewis, MD

Case Summary

An adult presented to the emergency department with fever and sepsis 7 days postpartum. Pregnancy course and delivery were uncomplicated. Blood cultures were positive for group A streptococcus, and aggressive antibiotics and supportive management were initiated. Shortly afterward, the patient arrested and was placed on extracorporeal membrane oxygenation (ECMO) after attempts to restore cardiac rhythm failed. Acute renal failure, disseminated intravascular coagulation (DIC), and generalized ecchymosis with skin blisters occurred on the second day. A noncontrast computed tomography (CT) scan of the chest on day 5 revealed acute respiratory distress syndrome (ARDS) and early calcification of the left ventricular papillary muscles and myocardium with sparing of the endocardium. This finding was confirmed by echocardiography. The calcifications appeared more dense on follow-up CT images; however, the cardiac ejection fraction (EF) was within normal limits (60%).

Imaging Findings

Noncontrast chest CT demonstrated ARDS and early diffuse calcifications involving the left ventricle myocardium and the papillary muscles (Figure 1). However, serum calcium and phosphorus were not elevated and no dystrophic calcifications were noted elsewhere. These finding were confirmed by trans-esophageal echocardiography, which showed dense left ventricle myocardium (Figure 2). These calcifications did not significantly affect the left ventricular EF, which was 60% (n = ≥55%). Follow-up CT chest one month later

Figure 1. Axial nonenhanced chest computed tomography (CT) image sho left ventricular wall calcifications (arrows).

Diagnosis

Discussion

Affiliations: University of Alabama at Birmingham, Birmingham, Alabama (Dr Moawad); University of Toledo Medical Center, Toledo, Ohio (Drs Kattan, Lewis).
Disclosures: None.

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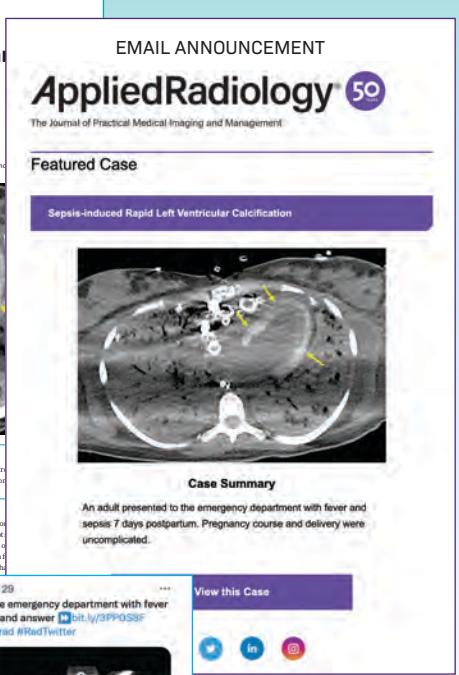
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Sepsis-induced Rapid Left Ventricular Calcification

Case Summary

An adult presented to the emergency department with fever and sepsis 7 days postpartum. Pregnancy course and delivery were uncomplicated.

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phalanx enchondroma curettage with distal radius bone grafting. Patients with corresponding limb deformities can benefit from bone lengthening techniques, but they often require multiple procedures owing to a high rate of recurrence and angular deformities.[7]

Conclusion

Ollier disease is a rare disease of the appendicular skeleton characterized by multiple enchondromas, most often in the small tubular bones of the hand. Common sequelae include limb deformities, pathological fractures, and malignant transformation of enchondromas to chondrosarcomas. The physical exam and radiological imaging remain paramount to proper diagnosis. Treatment options should be considered on a patient-to-patient basis, with the most invasive interventions (resection/curettage, internal fixation with bone grafts, limb amputation) reserved for patients with advanced or transformed malignant disease.

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Giant Breast Hamartoma

Sheeza Imtiaz, MBBS, FCPS, EDIRI

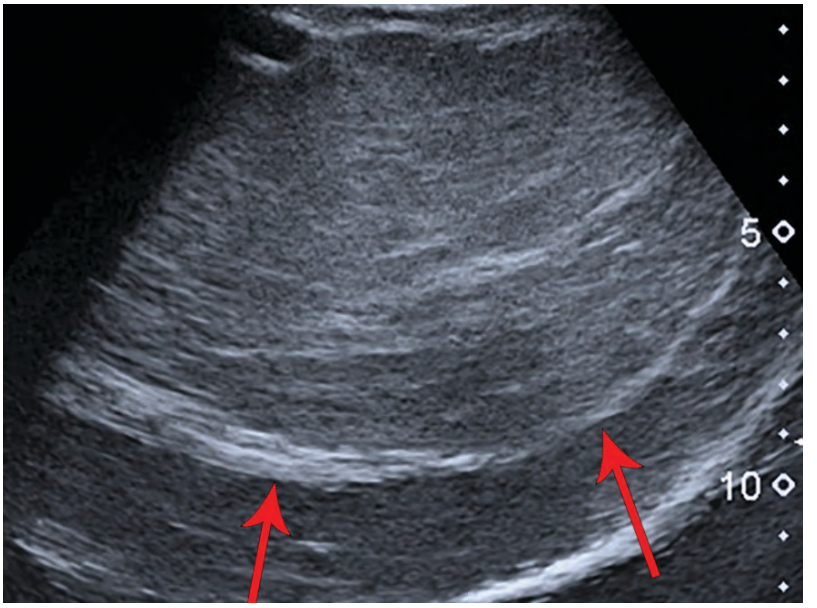
Case Summary

An adult lactating patient presented with complaints of asymmetric enlargement of the left breast accompanied by occasional mild pain. The patient had delivered their first child four months prior and initially attributed the enlargement to lactation. The patient's right breast was unremarkable, and they reported no history of fever, discharge, erythema, or nipple changes. The patient also reported no significant personal medical history and no family history of breast carcinoma. Clinical examination demonstrated a soft, freely moveable lump in the left breast. The axillary lymph nodes were not palpable bilaterally.

Imaging Findings

Ultrasound revealed an encapsulated iso- to hyperechoic, large lesion within the left breast parenchyma with a few, focally ectatic ducts showing internal moving echoes/inspissated secretions. No significant vascularity was present, nor were any calcific foci or posterior shadowing seen (Figure 1). Findings were suggestive of a benign etiology with hamartoma as the leading diagnostic consideration. A subsequent mammogram revealed a large, encapsulated lesion occupying almost the entire left breast. The lesion was of mixed density, with both fat and soft-tissue components, resulting in a "breast within a breast" appearance. No internal calcification was seen (Figure 2).

Figure 1. Ultrasound of left breast using a curvilinear probe demonstrates a large, encapsulated (arrows) lesion with mixed echogenicity.



Diagnosis

Giant breast hamartoma

Discussion

Breast hamartomas are rare, benign, slow-growing lesions that account for 0.1 – 0.7% of benign breast lesions. First defined by Arrigoni et al in 1971,[1] they are most frequently seen in women during perimenopause, but can also be found in men.[2,3] Hamartomas consist of a mixture of tissues, including epithelial, fibrous, glandular, and adipose. Diagnosis can usually be made by combining the clinical examination with radiological findings and histological features. Hamartomas are not considered premalignant lesions, but cases of invasive ductal carcinoma within a hamartoma have been reported.[4]

Hamartomas are well-encapsulated breast lesions that usually range from 2 to 5 cm in size but can grow larger. They usually present as a painless mass or asymmetrical enlargement of the breast without any palpable lump; they may, rarely, develop in the axillary region. Hamartomas are

Affiliation: Dr Ziauddin University Hospital, Karachi, Pakistan.

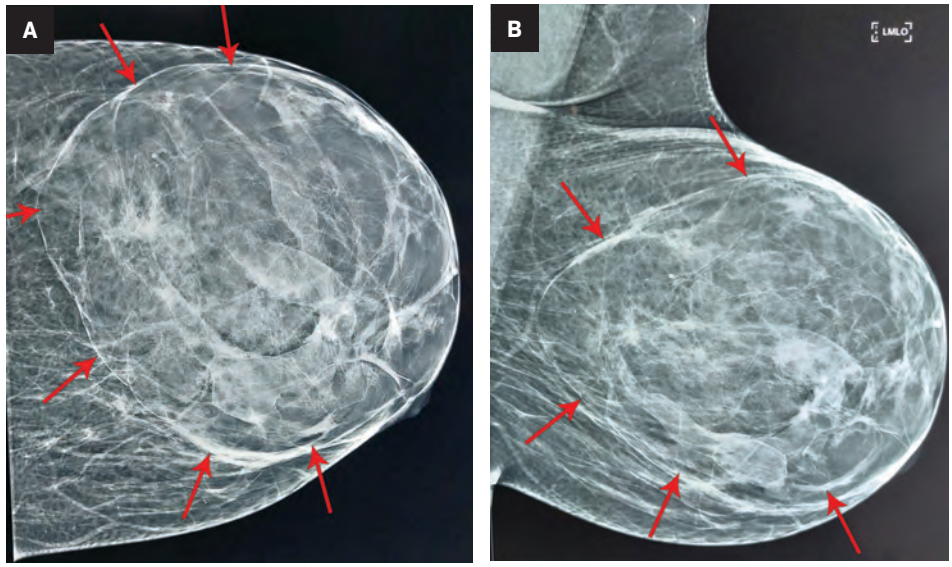


Figure 2. (A) Craniocaudal and (B) mediolateral oblique view mammograms of left breast reveals a large, encapsulated, mixed-density lesion with the typical "breast within a breast" (arrows) appearance of hamartoma.

usually soft, mobile, painless lumps on physical examination and can be mistaken for other benign masses.[5] Up to 60% are subclinical and missed on palpation.

Ultrasound features of hamartomas vary, owing to their variable amount of fibrous, adipose, and glandular tissue. They usually appear as round or oval, well-circumscribed and -encapsulated masses of inhomogeneous internal echotexture, and without any significant vascularity on Doppler examination. Retrotumor acoustic phenomena are absent, and a thin halo usually separates the lesion from the surrounding breast parenchyma.[6]

On mammography, hamartomas present as the classic "breast within a breast" appearance, with a thin, radiopaque pseudocapsule formed by surrounding, compressed breast tissue. Hamartomas rich in fibrous tissue appear homogeneously dense, mimicking a fibroadenoma, while hamartomas abundant in adipose tissue may be misdiagnosed as lipomas or fat necrosis. Calcifications are relatively rare.[7]

Magnetic resonance imaging is not routinely used to diagnose hamartoma. However, MRI might be performed in cases with atypical features on mammography and ultrasound. They usually exhibit type I time-signal intensity curve on postcontrast images.[8]

Hamartomas do not exhibit specific diagnostic histological features; therefore, the utility of fine needle aspiration cytology and needle core biopsy is limited. Combined clinical and radiological assessment is necessary to avoid misdiagnosis.[9]

The prognosis for a hamartoma is good with or without surgical excision, but excision is usually recommended, as associated malignancies have rarely been reported. The incidence of recurrence is 8%, and postoperative follow-up is recommended every six months for up to two years.[10]

Conclusion

Hamartomas are rare, benign breast lesions with a distinctive appearance on ultrasound and mammography. These entities are not considered premalignant, but because of the presence of glandular breast tissue, they may rarely undergo malignant changes similar to normal breast tissue.

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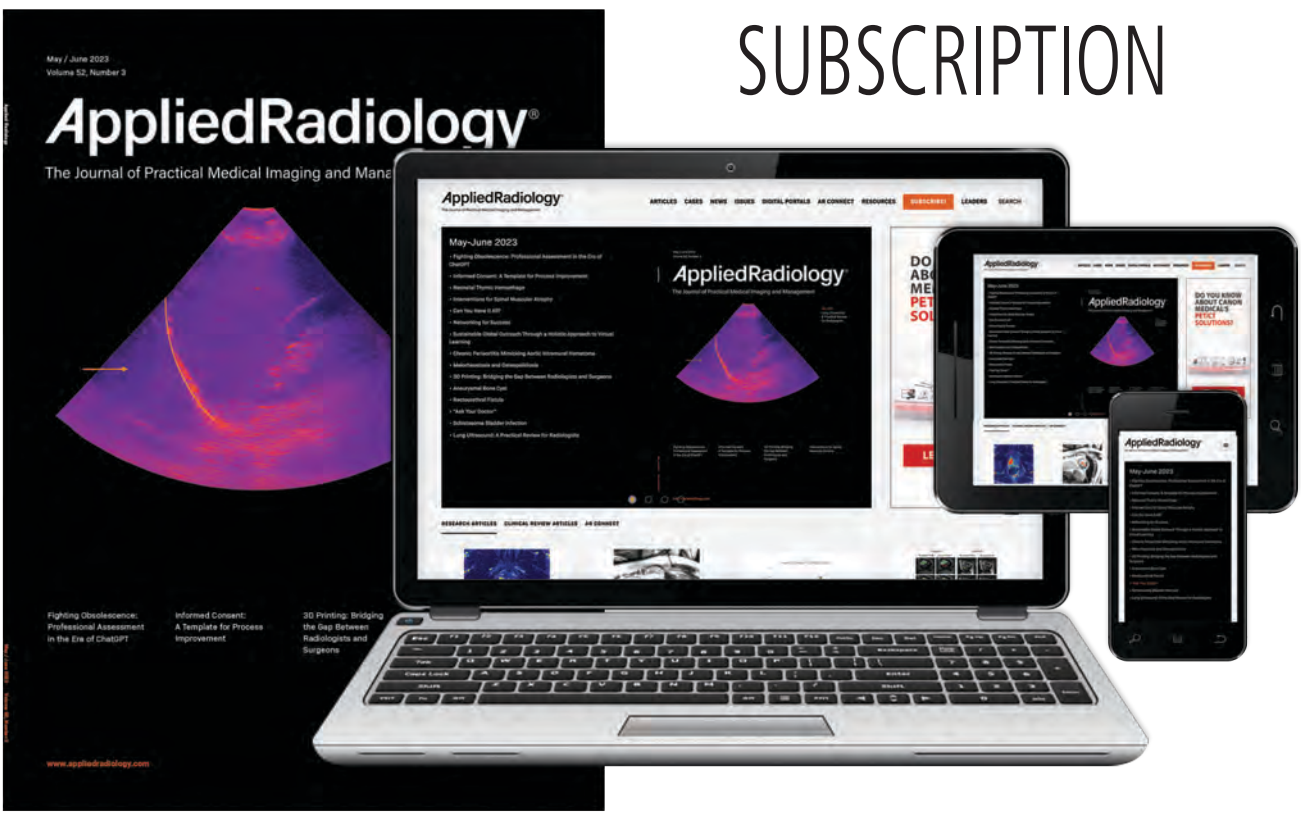

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Removal of Subdermal Contraceptive Device

Navpreet Kaur Khurana, MBBS; Theresa M. Caridi, MD, FSIR

Case Summary

An adult with an etonogestrel 68 mg subdermal implant (Nexplanon) placed in the left arm three years previous presented for removal of the implant due to irregular menstrual cycles. On physical examination, the device was difficult to palpate and likely embedded in the fascia or muscle wall.

Imaging Findings

Radiographs of the left humerus demonstrated 4 cm linear Nexplanon implant in the soft tissues of the upper arm (Figure 1). The patient was referred to interventional radiology for image-guided removal. The position of the contraceptive implant in the superficial soft tissues of the medial upper arm was confirmed using ultrasound (Figure 2). Preprocedure localization was performed (Figure 3) and the device was removed under image-guidance using blunt dissection (Figure 4). Complete removal was confirmed under fluoroscopy.

Affiliations: Department of Radiology, University of Pennsylvania, Philadelphia, Pennsylvania (Dr Khurana); Division of Vascular and Interventional Radiology, Department of Radiology, University of Alabama at Birmingham, Birmingham, Alabama (Dr Caridi).

Diagnosis

Deeply implanted subdermal contraceptive device

Discussion

According to a 2021 Guttmacher Institute report, approximately 1.5 million women in the United States use a contraceptive implant. Nexplanon (Merck, Kenilworth, New Jersey), a 4 cm linear and radio-opaque etonogestrel contraceptive, is highly effective, safe, and nonteratogenic with a Pearl Index of 0. The Pearl Index measures the number of pregnancies per 100 women per year using the contraceptive method.[1] The device is placed sub-dermally in the medial aspect of the nondominant arm 8-10 cm above the medial epicondyle of the humerus and 3-5 cm posterior to the sulcus. Located between the biceps and triceps, the sulcus contains the median nerve, ulnar nerve, basilic vein, and brachial artery. Nexplanon is long-acting, reversible, and effective for up to three years.[1]

Appropriately positioned subdermal implants are typically easily palpable. Nonpalpable implants are usually placed deep, have migrated (most commonly to the bicep or axillary region), or because of weight gain. Such implants should be localized using ultrasound or radiography.

The Nexplanon Observational Risk Assessment study reported the incidence of incorrect placements to be 12.6 per 1000 insertions.[2] Incorrectly placed implants can lead to vascular injury, median and ulnar neuropathy, and migration to the pulmonary artery (3.17 per 100,000 implants). Migration to pulmonary vasculature, a very rare occurrence, can be life threatening. Patients may present without any symptoms or with chest pain and/or dyspnea.[1]

Abnormal menstrual bleeding is the most common reason for early removal of Nexplanon, although insertion-site pain, cellulitis, neurovascular injury, and hematoma are some other reported complications. The device is contraindicated in patients with breast cancer, severe liver disease, and deep vein thrombosis.[1]

Appropriately placed subdermal implants are usually removed under local anesthesia without image-guidance. Nonpalpable implants may be removed surgically or under imaging guidance. Interventional radiologists are increasingly being integrated in the multidisciplinary management of malpositioned implants.

Patients undergo preprocedure radiography to ensure the device is

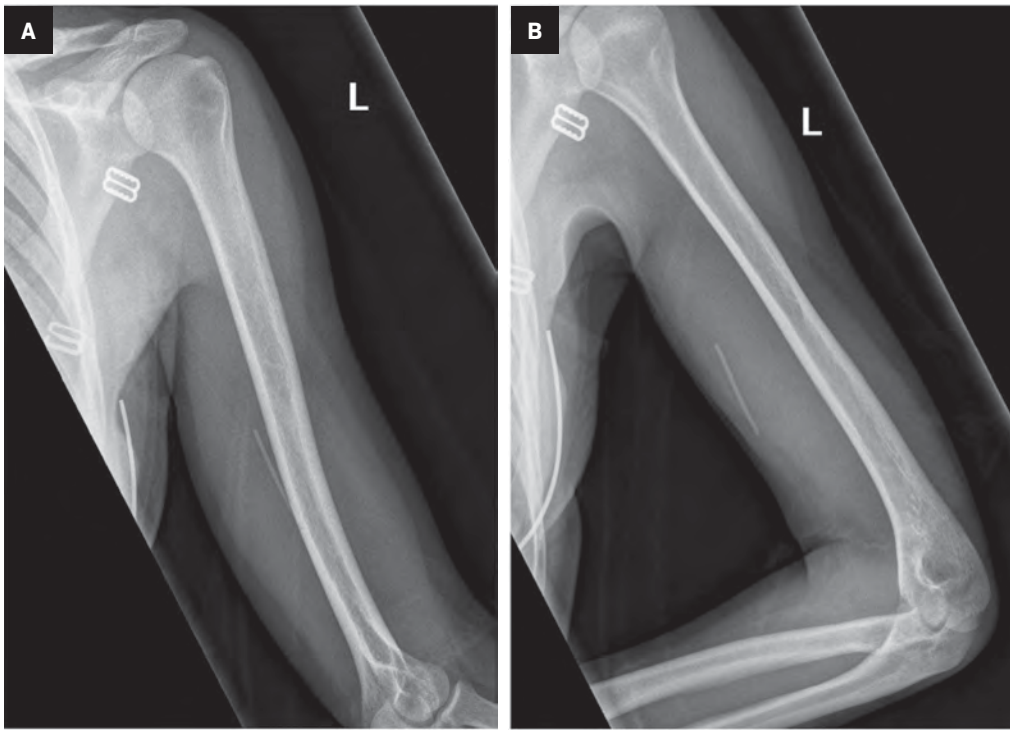


Figure 1. Anteroposterior (A) and lateral (B) view radiographs of the left humerus demonstrate a linear radiopaque foreign body in the medial soft tissues of the upper left arm measuring 4 cm in length.

Figure 2. Ultrasound demonstrates a hyperechoic elongated foreign body in the superficial soft tissues of the medial upper arm.

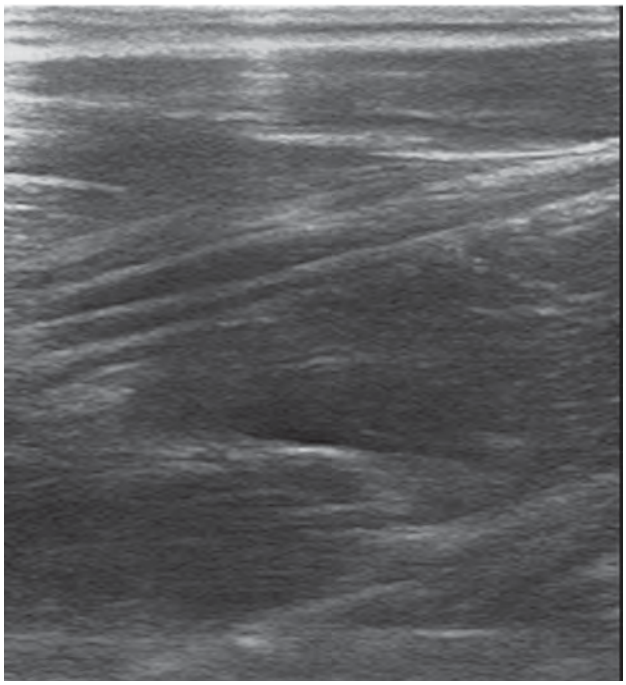


Figure 3. Fluoroscopic image demonstrates pre-procedure localization of the implant.

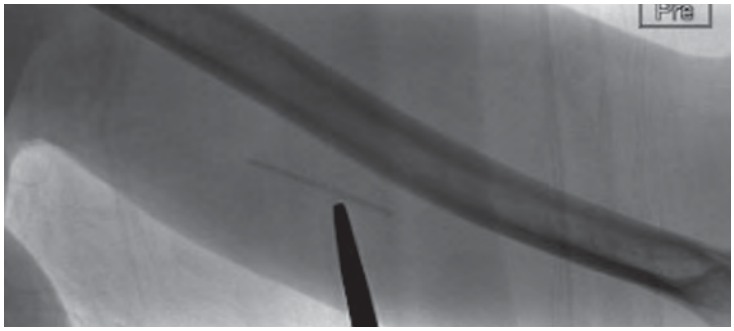
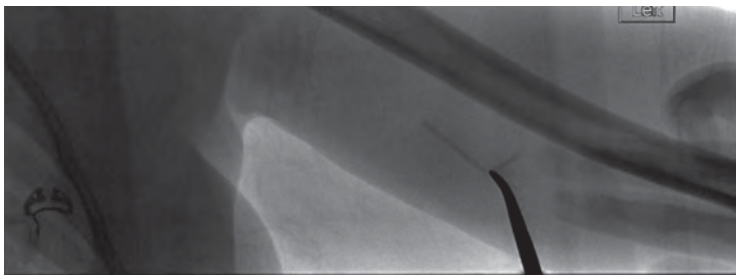


Figure 4. Fluoroscopic image demonstrates retrieval of the foreign body using blunt dissection.



in the upper arm. The implant is localized under fluoroscopic guidance, and a small incision (~1cm) is made over the peripheral aspect of the implant. The implant is retrieved using blunt dissection. The procedure is usually performed with mild/moderate sedation but can also be performed with local anesthesia only.

Injecting lidocaine around an implant located next to vital structures permits easy removal, decreases the risk of damage to surrounding structures, and provides additional anesthesia.[3] Both measuring the length of the removed implant and postprocedure fluoroscopy are essential to confirm complete removal. Although surgical removal has been described in the literature,[4] fluoroscopy-guided removal allows for precise localization, confirmation of complete removal, and decreased risk of injury to surrounding structures.

If the device is not evident at radiography or ultrasound, serum etonogestrel levels can be obtained before proceeding with other imaging modalities, such as CT or MRI, to ensure that the implant is present. In the rare cases of migration to the pulmonary artery, endovascular retrieval can be attempted. Early detection is key, as endothelialization of the device makes retrieval more difficult and may warrant surgical intervention.[3] Nonradiopaque implants (Implanon, Merck; Norplant, Wyeth Pharmaceuticals) may be localized using US, CT, MRI, and compression film mammography.

Conclusion

Imaging of nonpalpable contraceptive implants is essential for appropriate localization and development of a management plan. Interventional radiologists should be a part of multidisciplinary management of deep implant removals. Fluoroscopy-guided removal should be considered as a therapeutic option in patients with deep or migrated implants.

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LIFE FROM INSIDE

Woke up, fell out of bed
Dragged a comb across my head
—A Day in the Life, *The Beatles*

A Day in the Life (of an 80s Radiologist)

C. Douglas Phillips, MD, FACR

I read those end-of-year, survey-type filler articles from lots of sites with detailed breakdowns of how Joe and Jane Average are doing. What do they do during the day? How do they view global warming? Personally, I hate them. How easy it is to lie, eh? And, who enjoys filling out those more than someone who is disgruntled? I understand the genre. I just totally disbelieve it.

I was thinking, for this piece, I'd do a typical day in the life of someone who does what we do, but back in the 80's, when radiology was a bit of a different field. Here goes...

0600. Wake up, quick shower, and get some coffee. Out to the car for the drive to the hospital.

0715. Arrive at hospital. Park in the (now-crowded) lower section of the lot (out near the railroad tracks). Damned administrators get the front spots near the hospital. Not a one of them here yet. Surgeons get the second tier of parking. Their spots are mostly full, also.

0730. Start reading the overnight chest films and the three CT studies from the ED. Busy night for the ED. Make four phone calls to the units about chest film findings, second cup of coffee, say hi to a few people wandering through the department to look at films. Curbside consult on an abdominal film — looks like a bowel obstruction and help get them on the schedule for a GI study.

0830. A bit late getting to the IR suite. Doing angiography today. Start with a run-off on an elderly patient. Did the prelim radiographs and finally got access. Took way too long to time it out and then missed the lower calf on one side on the first attempt. Have to do it all over again. That puts a hurting on my schedule. Plus, held the groin for about a half hour and still oozing. Need to check them mid-day and tonight.

1230. Finish three arches, a renal for diagnosis (no stenosis) and help a colleague do an embolization of an active pelvic bleed. Break for lunch.

1345. The afternoon is crazy. One of the surgeons wants to see something a little better on an abdominal study from the day before. Spend 20 minutes getting subtractions done. Why can't these folks just make do with regular film? If only you could just have subtractions of everything, wouldn't that be novel? Oh, well. You can dream.

1730. Finish the scheduled patients. Have to get through these three add-ons. That's great; they are all short cases. Should finish early. Oops, fourth add-on. Well, not too late, anyway.

1945. Finished. Heading upstairs to see patients for the day. Fortunately, all the groins are dry and clean. Everyone should be able to go home tomorrow. Stop by to chat with a few of my colleagues in their offices. I pity the two folks reading chests today. With all the consults and a full hospital census, they might not get done for another hour. Sometimes, you just can't get ahead.

Times change, eh?

Keep doing that good work. Mahalo.

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

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