SA-CME CREDIT

**Anterior Cruciate Ligament and Meniscal Tears: A Multi-modality Review**
M Schwenke, M Singh, and B Chow, Santa Barbara Cottage Hospital, Santa Barbara, CA

**MRI of Toxic, Metabolic, and Autoimmune Encephalopathies: A Review**
J Gavito-Higuera; C Mullins; LI Gutierrez-Villalobos; H Sandoval; and L Ramos-Duran, Texas Tech University Health Sciences Center, El Paso, TX; and J Shewchuk, University of British Columbia, Vancouver, BC

**Post-Traumatic Retrograde Urethrography: A Review of Acute Findings and Chronic Complications**
P Hota; H Patel; C Conn; ME Sterling; M Metro; and O Agosto; Temple University Hospital, Philadelphia, PA; and T Patel, Atlantic Medical Imaging, Galloway, NJ
Gadavist® (gadobutrol) Injection
The Power to Decide

**Indications**
Gadavist® (gadobutrol) injection is a gadolinium-based contrast agent indicated for use with magnetic resonance imaging (MRI):

- To detect and visualize areas with disrupted blood brain barrier and/or abnormal vascularity of the central nervous system in adult and pediatric patients including term neonates.
- To assess the presence and extent of malignant breast disease in adult patients.
- To assess myocardial perfusion (stress, rest) and late gadolinium enhancement in adult patients with known or suspected coronary artery disease (CAD).

Gadavist® is indicated for use in magnetic resonance angiography (MRA):

- To evaluate known or suspected supra-aortic or renal artery disease in adult and pediatric patients including term neonates.

**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 of NSF appears highest among patients with:
  - Chronic, severe kidney disease (GFR <30 mL/min/1.73m²), 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 (for example, age >60 years, hypertension or diabetes), estimate the glomerular filtration rate (GFR) through laboratory testing.
- For patients at highest risk for NSF, do not exceed the recommended GADAVIST dose and allow a sufficient period of time for elimination of the drug from the body prior to any re-administration.

Please see brief summary on adjacent pages.
GADAVIST IS THE FIRST AND ONLY gadolinium-based contrast agent (GBCA) approved for cardiac magnetic resonance (MR) imaging to assess known or suspected coronary artery disease (CAD).

Visit Gadavist.com to learn more

Important Safety Information (continued)

Contraindication and Important Information about Hypersensitivity Reactions: Gadavist® is contraindicated in patients with history of severe hypersensitivity reactions to Gadavist®. Anaphylactic and other hypersensitivity reactions with cardiovascular, respiratory, or cutaneous manifestations, ranging from mild to severe, including death, have uncommonly occurred following Gadavist® administration. Before Gadavist® 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 Gadavist®.

Gadolinium Retention: Gadolinium is retained for months or years in several organs. Linear GBCAs cause more retention than macrocyclic GBCAs. At equivalent doses, retention varies among the linear agents. Retention is lowest and similar among the macrocyclic GBCAs. Consequences of gadolinium retention in the brain have not been established, but they have been established in the skin and other organs in patients with impaired renal function. 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 and minimize repetitive GBCA studies, when possible.

Acute Kidney Injury: In patients with chronic renal impairment, acute kidney injury sometimes requiring dialysis has been observed with the use of GBCAs. Do not exceed the recommended dose; the risk of acute kidney injury may increase with higher than recommended doses.

Extravasation and Injection Site Reactions: Ensure catheter and venous patency before the injection of Gadavist®. Extravasation into tissues during Gadavist® administration may result in moderate irritation.

Overestimation of Extent of Malignant Disease in MRI of the Breast: Gadavist® MRI of the breast overestimated the histologically confirmed extent of malignancy in the diseased breast in up to 50% of the patients.

Low Sensitivity for Significant Arterial Stenosis: The performance of Gadavist® MRA for detecting arterial segments with significant stenosis (>50% renal, >70% supra-aortic) has not been shown to exceed 55%. Therefore, a negative MRA study alone should not be used to rule out significant stenosis.

Adverse Reactions: The most frequent (≥0.5%) adverse reactions associated with Gadavist® in clinical studies were headache (1.7%), nausea (1.2%) and dizziness (0.5%).

Please see brief summary on adjacent pages.

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Printed in the USA. PP-GADA-US-0280-1 December 2019
**INDICATIONS AND USAGE**

1.1 Magnetic Resonance Imaging (MRI) of the Central Nervous System (CNS)

Gadavist is indicated for use with magnetic resonance imaging (MRI) in adult and pediatric patients, including term neonates, to detect and visualize areas with disrupted blood brain barrier and/or abnormal vascularity of the central nervous system.

1.2 MRI of the Breast

Gadavist is indicated for use with MRI in adult patients to assess the presence and extent of malignant breast disease.

1.3 Magnetic Resonance Angiography (MRA)

Gadavist is indicated for use in magnetic resonance angiography (MRA) in adult and pediatric patients, including term neonates, to evaluate known or suspected supra-aortic or renal artery disease.

1.4 Cardiac MRI

Gadavist is indicated for use in cardiac MRI (CMRI) to assess myocardial perfusion (stress, rest) and late gadolinium enhancement in adult patients with known or suspected coronary artery disease (CAD).

**CONTRAINDICATIONS**

Gadavist is contraindicated in patients with history of severe hypersensitivity reactions to Gadavist.

**WARNINGS AND PRECAUTIONS**

5.1 Nephrogenic Systemic Fibrosis

Gadolinium-based contrast agents (GBCAs) increase the risk for 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-contrasted MRI or other modalities. The GBCA-associated NSF risk appears highest for patients with chronic, severe kidney disease (GFR < 30 mL/min/1.73m²) as well as patients with acute kidney injury. The risk appears lower for patients with chronic, moderate kidney disease (GFR 30 to 59 mL/min/1.73m²) and little, if any, for patients with chronic, mild kidney disease (GFR 60 to 89 mL/min/1.73m²). NSF may result in fatal or debilitating fibrosis affecting the skin, muscle and internal organs. Report any diagnosis of NSF following Gadavist administration to Bayer Healthcare (1-888-842-2937) 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 (for example, 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 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 Gadavist dose and allow a sufficient period of time for elimination of the drug prior to re-administration. For patients receiving hemodialysis, 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)]. The usefulness of hemodialysis in the prevention of NSF is unknown [see Clinical Pharmacology (12.3)].

5.2 Hypersensitivity Reactions

Anaphylactic and other hypersensitivity reactions with cardiovascular, respiratory or cutaneous manifestations, ranging from mild to severe, including death, have uncommonly followed Gadavist administration [see Adverse Reactions (6)].

- Before Gadavist 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 Gadavist.
- Administer Gadavist only in situations where trained personnel and therapies are promptly available for the treatment of hypersensitivity reactions, including personnel trained in resuscitation.

Most hypersensitivity reactions to Gadavist have occurred within half an hour after administration. Delayed reactions can occur up to several days after administration. Observe patients for signs and symptoms of hypersensitivity reactions during and following Gadavist administration.

5.3 Gadolinium Retention

Gadolinium is retained for months to years in several organs. The highest concentrations (nanomoles per gram of tissue) have been identified in the bone, followed by other organs (for example, 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 Omniscan (gadodiamide) and Optiray (gadoversetamide) causing greater retention than other linear agents [Eovist (gadoxetate disodium), Magnevist (gadopentetate dimeglumine), Multihance (gadobenate dimeglumine)]. Retention is lowest and similar among the macrocyclic GBCAs [Dotarem (gadoterate meglumine), Gadavist (gadobutrol), ProHance (gadoteridol)].

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)]. 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 retention [see Adverse Reactions (6.2)].

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.

5.4 Acute Kidney Injury

In patients with chronic renal impairment, acute kidney injury sometimes requiring dialysis has been observed with the use of some GBCAs. Do not exceed the recommended dose; the risk of acute kidney injury may increase with higher than recommended doses.

5.5 Extravasation and Injection Site Reactions

Ensure catheter and venous patency before the injection of Gadavist. Extravasation into tissues during Gadavist administration may result in moderate irritation [see Nonclinical Toxicology (13.2)].

5.6 Overestimation of Extent of Malignant Disease in MRI of the Breast

Gadavist MRI of the breast overestimated the histologically confirmed extent of malignancy in the diseased breast in up to 50% of the patients [see Clinical Studies (14.5)].

5.7 Low Sensitivity for Significant Arterial Stenosis

The performance of Gadavist MRA for detecting arterial segments with significant stenosis (>50% renal, >70% supra-aortic) has not been shown to exceed 55%. Therefore, a negative MRA study alone should not be used to rule out significant stenosis [see Clinical Studies (14.3)].

**ADVERSE REACTIONS**

The following serious adverse reactions are discussed elsewhere in labeling:

- Nephrogenic Systemic Fibrosis (NSF) [see Boxed Warning and Warnings and Precautions (5.1)].
- Hypersensitivity reactions [see Contraindications (4) and Warnings and Precautions (5.2)].

**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 adverse reactions described in this section reflect Gadavist exposure in 7,713 subjects (including 184 pediatric patients, ages 0 to 17 years) with the majority receiving the recommended dose. Approximately 52% of the subjects were male and the ethnic distribution was 62% Caucasian, 28% Asian, 5%
Hispanic, 2.5% Black, and 2.5% patients of other ethnic groups. The average age was 56 years (range from 1 week to 93 years).

Overall, approximately 4% of subjects reported one or more adverse reactions during a follow-up period that ranged from 24 hours to 7 days after Gadavist administration.

Adverse reactions associated with the use of Gadavist were usually mild to moderate in severity and transient in nature.

Table 2 lists adverse reactions that occurred in ≥ 0.1% subjects who received Gadavist.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>1.7</td>
</tr>
<tr>
<td>Nausea</td>
<td>1.2</td>
</tr>
<tr>
<td>Dizziness</td>
<td>0.5</td>
</tr>
<tr>
<td>Dysgeusia</td>
<td>0.4</td>
</tr>
<tr>
<td>Feeling Hot</td>
<td>0.4</td>
</tr>
<tr>
<td>Injection site reactions</td>
<td>0.4</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0.4</td>
</tr>
<tr>
<td>Rash (includes generalized, macular, papular, pruritic)</td>
<td>0.3</td>
</tr>
<tr>
<td>Erythema</td>
<td>0.2</td>
</tr>
<tr>
<td>Paresthesia</td>
<td>0.2</td>
</tr>
<tr>
<td>Pruritus (includes generalized)</td>
<td>0.2</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>0.1</td>
</tr>
<tr>
<td>Urticaria</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Adverse reactions that occurred with a frequency of < 0.1% in subjects who received Gadavist include: hypersensitivity/anaphylactic reaction, loss of consciousness, convulsion, parosmia, tachycardia, palpitation, dry mouth, malaise and feeling cold.

6.2 Postmarketing Experience

The following additional adverse reactions have been reported during postmarketing use of Gadavist. Because these reactions are reported voluntarily from a population of uncertain size, it is not possible to reliably estimate their frequency or establish a causal relationship to drug exposure.

- Cardiac arrest
- Nephrogenic Systemic Fibrosis (NSF)
- Hypersensitivity reactions (anaphylactic shock, circulatory collapse, respiratory arrest, pulmonary edema, bronchospasm, cyanosis, ophthalmic swelling, laryngeal edema, blood pressure increased, chest pain, angioedema, conjunctivitis, hyperhidrosis, cough, sneezing, burning sensation, and pallor) [see Warnings and Precautions (5.2)].
- General Disorders and Administration Site Conditions: Adverse events with variable onset and duration have been reported after GBCA administration [see Warnings and Precautions (5.3)]. These include fatigue, asthma, pain syndromes, and heterogeneous clusters of symptoms in the neurological, cutaneous, and musculoskeletal systems.
- Skin: Gadolinium associated plaques

8 USE IN SPECIFIC POPULATIONS

8.1 Pregnancy

Risk Summary

GBCAs cross the placenta and result in fetal exposure and gadolinium retention. The human data on the association between GBCAs and adverse fetal outcomes are limited and inconclusive (see Data). In animal reproduction studies, although teratogenicity was not observed, embroyolethality was observed in monkeys, rabbits and rats receiving intravenous gadobutrol during organogenesis at doses 8 times above the recommended human dose. Retardation of embryonal development was observed in rabbits and rats receiving intravenous gadobutrol during organogenesis at doses 8 and 12 times, respectively, the recommended human dose (see Data). Because of the potential risks of gadolinium to the fetus, use Gadavist 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 is unknown. 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 is 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) 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

Embryolethality was observed when gadobutrol was administered intravenously to monkeys during organogenesis at doses 8 times the recommended single human dose (based on body surface area); gadobutrol was not maternally toxic or teratogenic at this dose. Embryolethality and retardation of embryonal development also occurred in pregnant rats receiving maternally toxic doses of gadobutrol (≥ 7.5 mmol/kg body weight; equivalent to 12 times the human dose based on body surface area) and in pregnant rabbits (≥ 2.5 mmol/kg body weight; equivalent to 8 times the recommended human dose based on body surface area). In rabbits, this finding occurred without evidence of pronounced maternal toxicity and with minimal placental transfer (0.01% of the administered dose detected in the fetuses).

Because pregnant animals received repeated daily doses of Gadavist, their overall exposure was significantly higher than that achieved with the standard single dose administered to humans.

8.2 Lactation

Risk Summary

There are no data on the presence of gadobutrol 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 present in breast milk and there is limited GBCA gastrointestinal absorption in the breast-fed infant. Gadobutrol is present in rat milk (see Data). The developmental and health benefits of breastfeeding should be considered along with the mother’s clinical need for Gadavist and any potential adverse effects on the breastfed infant from Gadavist or from the underlying maternal condition.

Data

In lactating rats receiving 0.5 mmol/kg of intravenous [153Gd]-gadobutrol, 0.01% of the total administered radioactivity was transferred to the pup via maternal milk within 3 hours after administration, and the gastrointestinal absorption is poor (approximately 5% of the dose orally administered was excreted in the urine).

8.4 Pediatric Use

The safety and effectiveness of Gadavist have been established in pediatric patients, including term neonates, for use with MRI to detect and visualize areas of disrupted blood brain barrier and/or abnormal vascularity of the central nervous system and for use in MRA to evaluate known or suspected supra-aortic or renal artery disease. Use of Gadavist in these indications is supported by adequate and well-controlled studies in adults and supportive imaging data in two studies in 135 patients 2 to less than 18 years of age and 44 patients less than 2 years of age with CNS and non-CNS lesions, and pharmacokinetic data in 130 patients 2 to less than 18 years of age and 43 patients less than 2 years of age, including term neonates (see Clinical Pharmacology (12.3) and Clinical Studies (14.1)). The frequency, type, and severity of adverse reactions in pediatric patients were similar to adverse reactions in adults [see Adverse Reactions (6.1)]. No dose adjustment according to age is necessary in pediatric patients [see Dosage and Administration (2.1), Clinical Pharmacology (12.3), and Clinical Studies (14.1)]. The safety and effectiveness of Gadavist have not been established in preterm neonates for any indication or in pediatric patients of any age for use with MRI to assess the presence and extent of malignant breast disease, or for use in CMRI to assess myocardial perfusion (stress, rest) and late gadolinium enhancement in patients with known or suspected coronary artery disease (CAD).

NSF Risk

No case of NSF associated with Gadavist or any other GBCA has been identified in pediatric patients ages 6 years and younger. Pharmacokinetic studies suggest that clearance of Gadavist is similar in pediatric patients and adults, including pediatric patients age younger than 2 years. No increased risk factor for NSF has been identified in juvenile animal studies of gadobutrol. Normal estimated GFR (eGFR) is around 30 mL/min/1.73m² at birth and increases to mature levels around 1 year of age, reflecting growth in both glomerular function and relative body surface area. Clinical studies in pediatric patients younger than 1 year of age have been conducted in patients with the following...
minimum eGFR: 31 mL/min/1.73m² (age 2 to 7 days), 38 mL/min/1.73m² (age 8 to 28 days), 62 mL/min/1.73m² (age 1 to 6 months), and 83 mL/min/1.73m² (age 6 to 12 months).

**Juvenile Animal Data**

Single and repeat-dose toxicity studies in neonatal and juvenile rats did not reveal findings suggestive of a specific risk for use in pediatric patients including term neonates and infants.

**8.5 Geriatric Use**

In clinical studies of Gadavist, 1,377 patients were 65 years of age and over, while 104 patients were 80 years of age and over. No overall differences in safety or effectiveness were observed between these subjects and younger subjects, and other reported clinical experience has not identified differences in responses between the elderly and younger patients. In general, use of Gadavist in elderly patients should be cautious, reflecting the greater frequency of impaired renal function and concomitant disease or other drug therapy. No dose adjustment according to age is necessary in this population.

**8.6 Renal Impairment**

Prior to administration of Gadavist, screen all patients for renal dysfunction by obtaining a history and/or laboratory tests [see Warnings and Precautions (5.1)]. No dosage adjustment is recommended for patients with renal impairment. Gadavist can be removed from the body by hemodialysis [see Warnings and Precautions (5.1) and Clinical Pharmacology (12.3)].

**10 OVERDOSAGE**

The maximum dose of Gadavist tested in healthy volunteers, 1.5 mL/kg body weight (1.5 mmol/kg; 15 times the recommended dose), was tolerated in a manner similar to lower doses. Gadavist can be removed by hemodialysis [see Use in Specific Populations (8.6) and Clinical Pharmacology (12.3)].

**13 NONCLINICAL TOXICOLOGY**

**13.1 Carcinogenesis, Mutagenesis, Impairment of Fertility**

No carcinogenicity studies of gadobutrol have been conducted.

Gadobutrol was not mutagenic in in vitro reverse mutation tests in bacteria, in the HGPRT (hypoxanthine-guanine phosphoribosyl transferase) test using cultured Chinese hamster V79 cells, or in chromosome aberration tests in human peripheral blood lymphocytes, and was negative in an in vivo micronucleus test in mice after intravenous injection of 0.5 mmol/kg.

Gadobutrol had no effect on fertility and general reproductive performance of male and female rats when given in doses 12.2 times the human equivalent dose (based on body surface area).

**13.2 Animal Toxicology and/or Pharmacology**

Local intolerance reactions, including moderate irritation associated with infiltration of inflammatory cells was observed after paravenous administration to rabbits, suggesting the possibility of occurrence of local irritation if the contrast medium leaks around veins in a clinical setting [see Warnings and Precautions (5.5)].

**17 PATIENT COUNSELING INFORMATION**

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

**Nephrogenic Systemic Fibrosis**

Instruct patients to inform their physician if they:
- Have a history of kidney disease and/or liver disease, or
- Have recently received a GBCA

GBCAs increase the risk of NSF among patients with impaired elimination of drugs. To counsel patients at risk of NSF:
- Describe the clinical manifestation of NSF
- Describe procedures to screen for the detection of renal impairment

Instruct the patients to contact their physician if they develop signs or symptoms of NSF following Gadavist 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.

**Common Adverse Reactions**

Inform patients that they may experience:
- Reactions along the venous injection site, such as mild and transient burning or pain or feeling of warmth or coldness at the injection site
- Side effects of headache, nausea, abnormal taste and feeling hot

**General Precautions**

Gadolinium Retention

- Advise patients that gadolinium is retained for months or years in brain, bone, skin, and other organs 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)].

Instruct patients receiving Gadavist to inform their physician if they:
- Are pregnant or breastfeeding
- Have a history of allergic reaction to contrast media, bronchial asthma or allergic respiratory disorder

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Manufactured for:

Bayer HealthCare
Bayer HealthCare Pharmaceuticals Inc.
Whippany, NJ 07981
Manufactured in Germany

6905905BS
10 MRI of Toxic, Metabolic, and Autoimmune Encephalopathies: A Review
Symptoms of encephalopathies are often nonspecific and range from seizures, focal neurological deficits, and movement disorders, to coma, permanent sequelae and death. MRI is the imaging modality of choice and recognition of distinct MRI enhancement patterns in regard to symmetry and topographic distribution can help identify the underlying pathology.
Jose Gavito-Higuera, MD; Carola Mullins, MD; Lisa Ivette Gutierrez-Villalobos, MD; Hugo Sandoval, PhD; Jason Shewchuk, MD; and Luis Ramos-Duran, MD

24 Post-Traumatic Retrograde Urethrography: A Review of Acute Findings and Chronic Complications
Urethral injury can be seen in 4-24% of male patients with pelvic fractures. Although rarely life threatening, urethral injuries can lead to significant long-term morbidity and mortality. RUG continues to be the best initial diagnostic study for evaluating acute male urethral trauma and post-traumatic complications.
Partha Hota, DO; Tejas Patel, MD, MBA; Harshad Patel, MD; Coleen Conn, RT; Matthew E. Sterling, MD; Michael Metro, MD; and Omar Agosto, MD

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Anterior Cruciate Ligament and Meniscal Tears: A Multi-modality Review
Injuries to the ACL are increasing, with an estimated cost of almost a billion dollars per year in the United States. Radiographs may show indirect signs of ACL and meniscal injuries; however, US, MRI, and CT are being utilized more often in the workup of these conditions as an initial screening tool and as an adjunct to physical exam.
Matthew Schwenke, MD; Manu Singh, MD; and Bernard Chow, MD

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Vesicouterine Fistula
Jennifer Evans, DO; Roland E. Gazaille III, DO; Ana Keppke, MD; Patrick Pagur, DO; Dhananjay Paranjpe, MD; Kyle Tharp, MD; Jason Broomhall; and Ankif Mohla, OMS IV
We all know that screening is the best way to detect breast cancer earlier and digital breast tomosynthesis (DBT) improves image quality for better detection. But now it’s time to get smarter about it. ASPIRE Cristalle with DBT is built with insight into image quality, operational excellence, and a better patient experience.

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We’re Embarking on a New Direction

Erin Simon Schwartz, MD, FACR

The Applied Radiology crew is expanding and sailing into new waters. As we endeavor to continue providing you with the highest quality content, it has become clear that we can use more hands on deck to develop a growing cargo of review articles, cases, depart ments, and columns.

Indeed, in an effort to better reflect modern radiological practice, we are renaming or eliminating some technology-based imaging categories and replacing them with body system-based categories. The CT/MRI category, for example, is being eliminated, while Gastrointestinal Imaging is now Body Imaging and Chest Imaging is now Cardiopulmonary Imaging.

We are also in the midst of building upon our Editorial Board with a panel of specialty-specific Associate Editors to help strengthen our peer review process and to enhance the breadth and depth of our offerings. I am delighted to announce the first of these consulting Associate Editors:

• Lawrence N Tanenbaum, MD, FACR, will oversee our new Artificial Intelligence section. Understanding this fast-moving field is becoming vital for all radiologists. You can expect an “Eye on AI” column in every issue of Applied Radiology, delivering valuable, applicable insights into AI and all it promises for medical imaging.

• David C Youmans, MD, FACR, a new board member, will oversee a new board section on Advocacy and Governmental Affairs, providing important, practical information on legal, regulatory, and other issues impacting the radiological community.

• Jennifer Cranny, MD, long the unofficial champion, along with Thomas Pope, MD, of our popular Radiological Cases, will officially assume the role of Associate Editor for Radiological Cases.

• Charles S White, MD, will oversee our newly renamed section of Cardiopulmonary Imaging. The revised title will more accurately reflect the comprehensive content we will offer under Charlie’s direction.

• Alexander J Towbin, MD, will oversee Pediatric Imaging. You may recognize Alex, along with his father, Richard B Towbin, MD, FACR, as the longtime leaders of AR’s website-based Pediatric Digital Community. Thanks to their outstanding leadership and the sponsorship of our corporate partner, Guerbet, LLC, the community is celebrating its fifth anniversary! Nearly 50 pediatric Radiological Cases reside in the Community, as well as in the print edition of Applied Radiology, and there are more to come.

We are also thrilled to welcome several new Editorial Board members:

• Sonia Gupta, MD — Artificial Intelligence;
• Seth M Hardy, MD, MBA, FACP — Advocacy and Governmental Affairs;
• K Elizabeth Hawk, MS, MD, PhD — Nuclear Medicine;
• Saurabh Jha, MD — Cardiopulmonary Imaging;
• Minhaj S Khaja, MD, MBA — Interventional Radiology;
• Ryan K Lee, MD, MBA — Advocacy and Governmental Affairs; and,
• Kristen K Porter, MD, PhD — Body Imaging.

Rest assured, we’re just getting started. We are working to identify additional associate editors and editorial board members, and we will share them with you in the coming months. In the meantime, please take a moment to review our masthead for more information on our new appointees.

I am excited and honored to be working with our entire Editorial Board to continue providing you with the most up-to-date and valuable medical imaging relevant to your daily practice. As always, I look forward to your feedback.
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Encephalopathies encompass a wide range of etiologies, including intoxications, autoimmune disorders, and metabolic imbalances. Symptoms are often nonspecific and range from seizures, focal neurological deficits, and movement disorders, to coma, permanent sequelae and death. MRI is the imaging modality of choice and is often the first indicator of an encephalopathy as a possible cause of symptoms. Recognition of distinct MRI enhancement patterns in regard to symmetry and topographic distribution can help identify the underlying pathology.

This article highlights the vital role the radiologist plays in identifying these manifestations, which in some cases are reversible. We also illustrate the most common toxic, autoimmune, and metabolic encephalopathies to create an understanding and awareness of typical imaging appearances the radiologist may encounter (Table 1).

**Toxic Etiologies**

**Thermatrim Encephalopathy**

Thermatrim, a thermogenic dietary supplement marketed to promote weight loss, has been associated with anxiety, insomnia, cardiovascular disorders, and central nervous stimulation. Imaging findings are characteristic for extensive symmetric involvement of the corpus callosum, pons, and the subcortical white matter, with hyperintensities on T2-weighted imaging (T2-WI) and restricted diffusion on Diffusion Weighted Imaging (DWI) with reduced Apparent Diffusion Coefficient (ADC) values (Figure 1).

**Methanol Encephalopathy**

The clinical presentation usually involves visual disturbances as a first symptom followed by headaches, dizziness, malaise, seizures, stupor, and coma after a latent period. Intoxication can be fatal unless treated early and characteristically involves bilateral necrosis of the putamina with or without hemorrhage. Variable signal intensities on T1-weighted imaging (T1-WI) with enhancement after contrast administration, hyperintensities on T2-WI, and Fluid Attenuation Inversion Recovery (FLAIR) sequences, and restricted diffusion on DWI, are typical imaging findings (Figure 2).

**Carbon Monoxide Encephalopathy**

Carbon-monoxide intoxications may be accidental or intentional and present with nonspecific symptoms and signs ranging from headaches and confusion to coma and death. Exposure can be acute or chronic, and bilateral symmetric involvement of the globi pallidi with or without involvement of the caudate and putamina is characteristic. Hypointensities on T1-WI and hypertintensities on T2-WI are distinct imaging findings and their extent correlates with clinical outcome (Figure 3).

**Heroin Encephalopathy**

Heroin can be administered through multiple routes, including intravenous injection, oral use, and vapor inhalation, also referred to as “chasing the dragon.” Leukoencephalopathy related to heroin vapor inhalation progresses from cerebellar signs and motor restlessness to pyramidal and pseudobulbar signs and eventually to spasms, paresis, and death. Symmetric high signal intensity...
MRI OF TOXIC, METABOLIC, AND AUTOIMMUNE ENCEPHALOPATHIES

Table 1. Acquired encephalopathic processes

<table>
<thead>
<tr>
<th>Toxic</th>
<th>Autoimmune</th>
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on T2-WI MRI and FLAIR sequences with involvement of the cerebellum and posterior limbs of the internal capsules are characteristic (Figure 4). Heroin encephalopathy is typically associated with ischemia, and 5-10% of all heroin users have infarcts of the globi pallidi. High signal intensities in the subcortical and periventricular white matter on T2-WI are also characteristic imaging findings (Figure 4).

Tacrolimus Encephalopathy

The calcineurin inhibitor tacrolimus is administered in the prophylaxis of graft-versus-host disease. About 40-60% of all treated patients suffer from headaches, paresthesia, tremor, and sleep disturbances, and 5-8% exhibit signs of confusion, lethargy, dysarthria, seizures, and coma. Bilateral edema in the subcortical white matter is characteristic and corresponds to hyperintensities on T2-WI and FLAIR sequences (Figure 5).

Autoimmune Etiologies

Hashimoto Encephalopathy

Hashimoto encephalopathy, associated with autoimmune disease involving the thyroid, can present either as neurological deficits or as progressive cognitive decline with dementia or psychosis. Seizures are usually present in both forms, and anti-thyroid antibodies, in particular antithyroid peroxidase (anti-TPO) and antithyroglobulin (anti-TG), can be detected. Imaging findings are potentially reversible and are characteristic for bilateral symmetric involvement of the temporal lobes and basal ganglia, with diffuse increased signal intensities on T2-WI and FLAIR sequences (Figure 6).

Anti-N-Methyl-D-Aspartate Receptor (NMDA R) – Encephalopathy

NMDA R-encephalopathy is associated with serum or cerebrospinal fluid autoantibodies against subunits of the NMDA receptor. Signs include auditory and visual hallucinations, behavior changes, impaired consciousness, seizures, movement disorders, and

FIGURE 1. A 19-year-old taking Thermatrim as a weight loss supplement presented with headaches and photophobia. (A) Axial DWI and ADC map demonstrate abnormal hyperintensity and corresponding restricted diffusion of the corpus callosum (yellow arrows). (B) Sagittal T2-WI demonstrates diffuse abnormal hyperintensity of the corpus callosum (white arrowheads) and of the pontine tegmentum (blue arrow). (C) Two-month follow-up sagittal T2-WI demonstrates near complete interval resolution of the hyperintensities of the corpus callosum and pons.
autonomic dysfunction. In 59% of cases, an ovarian tumor can be identified and the overall associated mortality is up to 25%. Diagnostic imaging is often normal but may demonstrate hyperintensities of the hippocampi, cerebellar and cerebral cortex, basal ganglia, brainstem, fronto-basal, and insular regions, and should include appropriate studies to rule out an ovarian teratoma (Figure 7).

Limbic Encephalitis (LE)

LE can be the paraneoplastic manifestation of an underlying, often undetected, malignancy associated with various antibodies against neuronal and tumor cells or it can be non-neoplastic, and in that case most commonly identifiable through the presence of voltage-gated, potassium channel antibodies (VGKC). Onset is generally subacute with temporal lobe seizures, memory loss, and confusion. Temporomesial changes with uni- or bilateral swelling are visible on T2-WI and FLAIR sequences and may progress to atrophy (Figure 8).

Metabolic Etiologies

Hypoxic Encephalopathy

Hypoxic encephalopathy occurs because of either hypoperfusion or hypoxia, and the duration of the insult, the degree of perfusion, temperature, and glucose levels determine the extent of the cerebral injury. Structures of the gray matter, such as cerebral cortex, basal ganglia, or hippocampi, are usually
FIGURE 5. 49-year-old under tacrolimus treatment after bone marrow transplant presented with headaches and visual disturbances. (A) Axial FLAIR demonstrates bilateral hyperintense signal in the occipital subcortical white matter (yellow arrows). (B) ADC and (C) DWI show facilitated, not restricted, diffusion (yellow arrows).

FIGURE 6. 45-year-old with a history of severe headaches, visual hallucinations, and cognitive dysfunction. Anti-TPO-AB and anti-TG-AB were elevated in CSF, indicating Hashimoto encephalopathy. (A) Coronal T2WI demonstrates abnormal hyperintense signal in the left insula (yellow arrow) and hippocampus (green arrow). (B) Axial FLAIR image demonstrates abnormal hyperintense signal in the left insula, subinsular white matter (yellow arrow), posterior putamen (blue arrow), and ipsilateral thalamus (yellow asterisk). (C) Axial FLAIR image shows abnormal hyperintense signal of the isthmus of the cingulate gyrus (yellow arrow).

FIGURE 7. A 30-year-old female patient with acute psychosis and Anti-–NMDA R–Encephalopathy. (A) Axial FLAIR demonstrates a small hyperintense lesion in the left hippocampus without volume loss (yellow arrow). (B) Corresponding axial T1-WI postcontrast shows no enhancement. Contrast-enhanced CT of the pelvis in axial (C) and coronal reformatted (D) planes show a complex cystic lesion in the right adnexa (asterisk) with fat and internal calcification (yellow arrows) consistent with an ovarian teratoma.
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FIGURE 8. 60-year-old with history of small cell lung carcinoma presented with altered mental status and seizures, diagnosed with limbic encephalitis. (A) Axial and (B) coronal FLAIR images show abnormal signal hyperintensities in the left orbitofrontal (blue arrow), left insula (yellow arrowhead) and bilateral medial temporal lobes (yellow arrows). (C) DWI and corresponding ADC map (D) demonstrate bright signal due to T2 shine-through and increased diffusivity, respectively (yellow arrows).

FIGURE 9. 33-year-old was brought to the hospital after a motorcycle collision, cardiac arrest and prolonged CPR, resulting in hypoxic encephalopathy. (A) Axial DWI and ADC map (B) demonstrate restricted diffusion of bilateral frontal and parietal cortices (yellow arrows). (C) Axial susceptibility weighted imaging demonstrates symmetrical bi-hemispheric pseudo-diminished cortical veins, and faint cortical low signal attenuation representing cortical laminar necrosis (yellow arrows).

FIGURE 10. 57-year-old with uncontrolled diabetes mellitus presented to hospital after 1 week of involuntary movements of the right arm, diagnosed with nonketotic hyperglycemic hemichorea. (A) T1-WI postcontrast in axial view shows asymmetric abnormal hyperintensity mainly in the left putamen (yellow arrow). (B) Corresponding axial T2 gradient echo sequence demonstrates low signal intensity in the left putamen (yellow arrow).

Nonketotic hyperglycemic hemichorea
Nonketotic hyperglycemic hemichorea is a rare treatable manifestation of diabetes mellitus usually involving the unilateral or, more commonly, bilateral caudate nuclei and the putamina. It clinically presents with involuntary movements with elevated blood glucose levels and absence of ketones. T1-WI shows increased signal intensities of the involved structures with variable imaging findings on T2-WI (Figure 10).
FIGURE 11. 35-year-old patient was brought to the hospital after trauma and hypoglycemia, diagnosed with hypoglycemic encephalopathy. (A) Axial T2-WI, and (B) FLAIR demonstrate abnormal hyperintense signal and corresponding restricted diffusion on (C) DWI and (D) ADC map in the cortical aspect of the bilateral hippocampi (yellow arrows).

FIGURE 12. A 57-year-old with history of hepatitis C complicated by cirrhosis with altered mental status, diagnosed with hepatic encephalopathy. (A) Sagittal T1-WI and (B) axial T1-WI non-contrast, with fat suppression demonstrate diffuse symmetric abnormal hyperintensities in the bilateral caudate (yellow arrows) and lentiform nuclei (globi pallidi and putamina) (green arrows).

FIGURE 13. 44-year-old patient with a history of chronic alcohol use was admitted to the hospital with an acute alcohol intoxication, elevated serum ammonia levels (170 µg/dL), and diagnosed with hepatic encephalopathy. (A) Axial DWI, (B) ADC map, and (C and D) FLAIR images demonstrate abnormal symmetric hyperintense signal of the bilateral corticospinal tracts, corona radiata (asterisk), cerebral peduncles (arrow head) and the splenium of the corpus callosum (arrows).

Hypoglycemic Encephalopathy
Decreased serum glucose levels lower than 50 mg/dl are most commonly associated with an unintentional overdose of sulfonylurea drugs or insulin in diabetics. Cerebral structures affected are the cortex, hippocampus, and basal ganglia, but involvement may be limited to white matter structures of the corpus callosum, internal capsule, and corona radiata in milder cases. Bilateral T2 hyperintensity with restricted diffusion on DWI are characteristic imaging findings and involvement of the basal ganglia yields a less optimistic prognosis of this potentially reversible condition (Figure 11).

Hepatic Encephalopathy (HE)
HE, which entails a wide range of symptoms owing to liver dysfunction such as cirrhosis and subsequent increase...
MRI OF TOXIC, METABOLIC, AND AUTOIMMUNE ENCEPHALOPATHIES

FIGURE 14. 65-year-old patient with decompensated hepatitis C cirrhosis was admitted to the hospital with seizures and decreased level of consciousness. Serum ammonia levels were elevated (330 µmol/L), and diagnosis of hyperammonemic encephalopathy was made. (A) Axial T2-WI, (B) FLAIR, (C) DWI, and (D) ADC map demonstrate abnormal T2 hyperintensity and restricted diffusion, respectively, of the insular cortex (yellow arrows), thalamus, and temporal-occipital cortical regions (blue arrows).

FIGURE 15. 4-year-old patient aggressively treated with fluids and bicarbonate due to metabolic acidosis after cardiac arrest, which resulted in hypernatremia and development of central pontine myelinolysis. MR images were obtained a few days after event. (A) Axial T2-WI shows a trident-shaped hyperintensity in the central pons (yellow arrow). (B) DWI demonstrates abnormal hyperintense signal in the central pons (yellow arrow). (C) ADC map with no signal dropout, findings are consistent with T2 shine-through (yellow arrow).

FIGURE 16. A 23-year-old with decreased vision and history of alcohol use, diagnosed with Wernicke encephalopathy. (A) Axial FLAIR images and (B) axial T2-WI images demonstrate abnormal bilateral hyperintensities involving the ventromedial aspect of the thalami (yellow arrows) and the inferior cerebellar peduncles infratentorially (blue arrows).

of usually metabolized substances, can present as an acute or chronic manifestation. Acute HE is often fatal, while chronic HE can be relapsing or persistent with dementia, parkinsonism, and myelopathy dominating the clinical picture. Involvement of the globi pallidi, subthalamic regions, and midbrain corresponding to hyperintensities on T1-WI, and T2 hyperintensity of the corticospinal tracts, the periventricular white matter, thalami, and internal capsules are characteristic imaging findings (Figures 12, 13).

Hypermmonamemic Encephalopathy
Ammonia may be elevated in advanced liver disease, manifesting as bilateral symmetric involvement of the insular cortex with restriction on DWI subsequent to astrocyte swelling, cell death, and edema (Figure 14).
Central Pontine Myelinolysis / Osmotic Demyelination

The overly rapid correction of hyponatremia is the classic association, which initially presents as an altered sensorium and progresses to spasticity, and pseudo-bulbar palsy, as well as locked-in-syndrome, after 2-7 days. Structures involved are the central pons, thalamus, putamen, and lateral geniculate bodies, with early restriction on DWI followed by hyperintensities on T2-WI and FLAIR sequences (Figure 15).1, 4

Wernicke Encephalopathy (WE)

WE is related to thiamine (vitamin B1) deficiency, and the spectrum of affected patients includes alcoholics, as well as non-alcoholics with malabsorption syndromes or dietary deficits. Onset is usually acute; however, only 16-38% of all patients present with the typical triad of ophthalmoplegia, ataxia, and altered consciousness. Structures involved are the medial thalami, mammillary bodies, the periaqueductal region, the floor of the fourth ventricle, and the tectal plate corresponding to hyperintensities on T2-WI (Figure 16).1

Summary

The brain is highly susceptible to toxins, autoimmune disorders, and metabolic changes, which can result in a broad range of encephalopathies. Signs are often nonspecific and can range from a hyper-alert agitated state, to coma, and death. Therefore, clinical assessment alone is often inconclusive. MR imaging is the modality of choice and frequently provides the first indication an encephalopathy as a possible cause of symptoms. By recognizing distinct imaging features, such as symmetry, characteristic topographic distribution, and enhancement patterns of the lesions, the radiologist plays a crucial role in narrowing the diagnosis to help improve patient outcome in an interdisciplinary approach.

References

People traditionally think of artificial intelligence (AI) as a means of using computer-generated neural networks to mirror the intellectual thought processes of human beings. In reality, however, humans are not so interested in thought duplication; they are much more interested in thought augmentation.

We want computers to elevate and augment human capacity and improve efficiency. Computers are now sophisticated enough to quickly analyze large volumes of high dimensional data and recognize patterns. Computers are actually better than humans at pattern detection. Through deep learning algorithms, computers can be taught to answer questions that augment human capabilities. Deep learning (DL) is a form of machine learning (ML) employing convolutional neural networks, which has shown great potential in medical imaging applications. AI is the future not just of medicine, but of all occupational sectors because of its power to enhance efficiency, accuracy, value and quality.

The goal of many AI companies is to expand their narrow use products into broader comprehensive AI suites, which not only elevates the value of the software, but also makes them more marketable to end-users. AI tools are continuing to evolve and improve at a rapid pace and can be employed before, during, or after image acquisition.

Mining patient notes, improving billing, preventing no-shows

Before patients even enter the imaging suite, AI tools can mine electronic health records to extract key clinical notes and present them in a dashboard summary for the radiologist’s review, such as IBM Watson Imaging Patient Synopsis (IBM, Cambridge, MA, distributed through Guerbet). RadNet’s AI division has recently integrated the AI company NuLogix (Santa Monica, CA) which will have several roles, including improvements in billing. RadNet is also working with Philips on a project using ML to analyze and prevent “no shows.”

Accelerating acquisition, improving quality, lowering dose

AI tools can optimize quality by standardizing patient head angulation, reducing noise, and minimizing artifacts. Real-time patient motion correction is the goal of tools such as the (not yet FDA cleared) visual biofeedback application of FIRMM™ (Nous, St. Louis, MO). One of the most exciting current applications of AI for MRI and PET-CT image acquisition is the utilization of tools employing deep learning algorithms to markedly enhance image quality and reduce scan acquisition time, by as much as 75%, as with Subtle Medical’s (Palo Alto, CA) FDA-cleared SubtleMRTM and SubtlePET™. Studies have shown that the shorter the scan, the higher patients rank their imaging experience. These tools also improve scanner efficiency and offer opportunities for better image quality. Canon has commercialized AiCE™ for both their CT and MR products providing the same potential benefits. Similarly, iQMR™, an FDA-cleared, vendor-agnostic ML boosted iterative reconstruction image-enhancement add-on from Medic Vision (Tirat Carmel, Israel), can achieve 40% faster MRI scanning with higher resolution. Medic Vision also has a SafeCT™ iterative reconstruction product which allows (up to 60%) dose reduction without compromising image quality. GE Healthcare has a deep learning AI product in the pipeline (510K pending) which leverages k-space data to sig-
AI applications are quickly becoming embedded in the fabric of advanced, state-of-the-art neuroimaging, creating value, enhancing quality, and saving time.

–Suzie Bash, MD

Significantly improve image quality and create the opportunity for significant scan time reduction. Subtle Medical is also developing a DL based tool to reduce gadolinium contrast dose (Subtle-GAD™, not yet FDA approved) to only 10% of that typically required, while preserving the intensity of contrast enhancement, which is a promising product, particularly in light of known gadolinium deposition in the brain with repetitive contrast-enhanced MRI exams.

**Flagging urgent findings, quantitative volumetric and metabolic analysis**

AI tools are also being used by physicians post-acquisition. Among these are triage apps such as Aidoc’s (Tel Aviv, Israel) FDA-cleared, “always on” technology that analyzes CT scans of the head and spine in the background, and then identifies the urgent acute findings (intracranial hemorrhage and cervical spine fractures) and flags these cases for expedited reading. This type of prioritization software reduces report turn-around time so the most critical patients can be identified and treated first. Other FDA-cleared AI tools such as icometrix’ icobrain (Leuven, Belgium), maxQ AI™ (Tel Aviv, Israel) and Zebra Medical (Providence, RI) can also identify (and for icobrain, quantify) intracranial hemorrhage.

Meanwhile, large vessel occlusions (LVOs) are being automatically identified with FDA-cleared tools like Viz.ai’s Viz LVO™ (Tel Aviv, Israel) which not only flags the LVO on the CT angiogram (CTA), but also alerts the entire stroke team (neuroradiologist, interventional radiologist and neurologist) via transmission of pertinent DICOM images through a secure mobile app to their personal cellphones, with less than 6 minutes from acquisition to alarm notification. Additionally, Viz.ai’s companion tool, Viz CTP™, can measure perfusion in affected areas of the brain. In the pipeline, Aidoc is shepherding a new ischemic stroke module (CE marked, FDA pending) to flag LVOs for faster treatment.

Quantitative volumetric MRI tools add diagnostic value, accuracy and efficiency. They assist in eliminating reader subjectivity and provide objective longitudinal assessment of disease. Products like NeuroQuant™ and LesionQuant™ (CorTechs Labs, San Diego, CA) and icobrain (icometrix, Leuven, Belgium), leverage machine learning to enhance segmentation. By calculating the volume of substructures of the brain (such as hippocampal atrophy in patients with dementia), these applications augment the evaluation of dementia, seizures, multiple sclerosis and brain trauma by highlighting statistically significant variations from an age and sex matched normative database. In patients with multiple sclerosis, the software calculates the volume of new, enlarging or shrinking plaques, overall plaque burden and interval change from prior studies. FDA cleared MIMneuro™ (MIM Software, Cleveland, OH) and 510K pending PETQuant™ (CorTechs Labs, San Diego, CA) aid in the quantitative interpretation of brain FDG PET and amyloid PET studies in patients with memory loss. The software aligns the PET images into a built-in atlas (MIM) or native patient brain (CorTechs) space, providing quantitation of standardized uptake values (SUVs) by anatomical region. The software also calculates the statistical significance of variations in regional metabolic activity or amyloid deposition by reference to a normative database, which helps establish whether a true neurodegenerative syndrome, such as Alzheimer’s disease, is present.

AI applications are quickly becoming embedded in the fabric of advanced, state-of-the-art neuroimaging by creating value, enhancing quality and saving time. Transformational innovation through AI is actively expanding our human capabilities, unlocking the potential of digital technology and ultimately making a meaningful difference in our patients’ lives.
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**CONTRAINDICATIONS**

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- **Before DOTAREM 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 DOTAREM.**

- **Adverse Reactions**

  - **The most common adverse reactions associated with DOTAREM in clinical trials were nausea, headache, injection site pain, injection site coldness and rash.**

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  - **Adverse Reactions in the Postmarketing experience have been reported with DOTAREM. These serious adverse reactions include but are not limited to: arrhythmia, cardiac arrest, respiratory arrest, pharyngeal edema, laryngospasm, bronchospasm, coma and convulsion.**

**USE IN SPECIFIC POPULATIONS**

- **Pregnancy:** GBCAs cross the human placenta and result in fetal exposure and gadolinium retention. Use only if imaging is essential during pregnancy and cannot be delayed.

- **Lactation:** There are no data on the presence of gadoterate meglumine 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 present in breast milk.

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*Dotarem was launched globally in 1989 and approved by the FDA for use in the US in 2013.*

**REFERENCES**

2. Internal data as of May 2019
Post-traumatic Retrograde Urethrography: A Review of Acute Findings and Chronic Complications

Partha Hota, DO; Tejas Patel, MD, MBA; Harshad Patel, MD; Coleen Conn, RT; Matthew E. Sterling, MD; Michael Metro, MD; Omar Agosto, MD

While injuries to the urethra are relatively rare compared to other segments of the genitourinary tract, urethral injury can be seen in 4-24% of male patients with pelvic fractures.1,4 Although rarely life-threatening, urethral injuries can lead to significant long-term morbidity.1,2 Retrograde urethrography (RUG) continues to be the best initial diagnostic study for evaluating acute male urethral trauma and post-traumatic complications.5,6 Accurate technique in performing these procedures in both the pre- and postoperative settings can be challenging, and knowledge of normal and abnormal findings is essential to guiding management and treatment. This review article will highlight normal urethral anatomy, describe the appropriate techniques for conducting RUG examinations, accompanied by practical troubleshooting strategies; and review post-traumatic pathologies.

Normal Anatomy

The male urethra extends from the external meatus to the urinary bladder with a length ranging from 17 to 24 cm (reported mean 22 ± 2.4 cm).7 The urethra is divided into anterior and posterior segments separated by the urogenital diaphragm (Figure 1). The anterior urethra extends from the external meatus to the urogenital diaphragm and is subdivided into a proximal bulbo- penile segment, and a distal penile segment, spanning approximately 16 cm. The distal-most aspect of the anterior urethra is termed the fossa navicularis; it is approximately 1 to 1.5 cm in length. The Cowper’s glands, located within the urogenital diaphragm, drain into the proximal bulbous segment. The periurethral Littré glands are located in the dorsal aspect of the penile urethra and distal bulbous urethra.

The posterior urethra extends from the urogenital diaphragm to the urinary bladder, measuring approximately 5 cm. It is subdivided into a proximal prostatic segment and a distal membranous segment. The verumontanum is a 1 cm-long ovoid mound located in the posterior wall of the prostatic urethra, the center of which contains the prostatic utricle. The prostatic utricle is flanked bilaterally by the ejaculatory ducts. The internal urethral sphincter spans the length of the bladder neck to just proximal to the verumontanum. The intrinsic urethral sphincter is located distal to the verumontanum within the distal prostatic urethra. The extrinsic sphincter arises from the levator ani complex and surrounds the membranous urethra.

Indications

Indications for RUG include trauma, lower urinary tract structural abnormalities, urethral masses, and postoperative evaluation (Table 1). The most common indication is trauma, which on physical examination traditionally presents with blood within the urethral meatus or a mobile prostate gland in the case of urethral disruption.8,9 Lower urinary tract structural pathologies that warrant RUG include abnormalities such as urethral strictures, urethral diverticulum, or urethral fistula which may present with urinary urgency, weak urinary stream, and poor bladder emptying.10

Contraindications

While no absolute contraindications for RUG exist, there are several relative contraindications (Table 1). Allergy to iodinated contrast is one, and while a properly performed RUG should not result in contrast entry into the vascular system, it may result in venous intravasation.11 In cases of reported allergy to iodinated contrast, institutional protocols should be followed, which often include premedication with corticosteroids and antihistamines is recommended.11
Active urinary tract infection is also considered a relative contraindication, and in a non-emergent setting, urine laboratory analysis and urine culture should be performed prior to RUG.

Unstable trauma patients may require life-saving procedures to address more emergent injuries prior to urethral evaluation. Lastly, recent instrumentation is a relative contraindication and a thorough clinical and surgical history should be obtained prior to the examination.

Technique

At our institution, we use a 14 French Foley catheter for most RUGs. Smaller catheters, ranging from 8 to 12 French, may be used with smaller urethras.

With distal-most penile urethral strictures, such as those at the meatus, we employ pediatric 5 French feeding tubes, although these lack inflatable balloons for adequate anchoring and must be held in place by the radiologist during the examination. Prior to beginning a RUG, the physician should perform a preoperative equipment check. Inflate the Foley catheter balloon with 2 cc of air using a 5 cc Luer lock syringe, and then flush the catheter with contrast to ensure patency and remove air bubbles. The use of lubricating jelly with the Foley catheter is controversial and is not recommended by some authors. We do not use lubrication, as it is likely to dislodge the catheter. Moreover, the contrast itself used to flush the Foley catheter acts as a lubricant, to reduce patient discomfort.

Next, place the patient in a supine, 45-degree oblique position with the penis situated in a plane oriented laterally over the proximal thigh. Sterilize the urethral meatus with an antiseptic iodine-based solution. Then insert the catheter gently into the fossa navicularis and inflate the balloon with 2 cc of air. Inform the patient prior to balloon inflation that some discomfort may result.

A pre-injection scout radiograph should be obtained (Figure 2). Using...
POST-TRAUMATIC RETROGRADE URETHROGRAPHY

Table 2. RUG Relative Contraindications

<table>
<thead>
<tr>
<th>Relative Contraindications</th>
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<tbody>
<tr>
<td><strong>Contrast Allergy</strong></td>
</tr>
<tr>
<td>Relative contraindication in the presence of an allergy to iodinated contrast.</td>
</tr>
<tr>
<td>While a properly performed RUG should not have contrast within the vascular system, this may result in the setting of contrast intravasation.</td>
</tr>
<tr>
<td>Premedication with H1/H2 blockers and steroids may be performed, as per institutional protocol.</td>
</tr>
<tr>
<td><strong>Active Urinary Tract Infection</strong></td>
</tr>
<tr>
<td>Relative contraindication with urinalysis and urine culture should be obtained in the outpatient setting prior to examination.</td>
</tr>
<tr>
<td><strong>Unstable Patient</strong></td>
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<tr>
<td>Relative contraindication with the patient possibly needing other procedures performed in the emergent setting.</td>
</tr>
<tr>
<td>Recent instrumentation.</td>
</tr>
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FIGURE 2. A pre-injection scout radiograph is obtained to confirm the position of the catheter as well as to evaluate for intrinsic radio-opacities that may confound diagnosis.

FIGURE 3. (A, B) The Foley catheter balloon is positioned within the fossa navicularis. Following hand-injection of contrast, the balloon has fallen out of the urethra with spillage of contrast (solid arrow). (C, D) Following contrast injection, there is disconnection of syringe (solid arrow) and spillage of contrast throughout the examination bed (dashed arrows) secondary to improperly sealed tubing.

Gentle pressure, we hand inject 18% iodinated, water-soluble contrast through the catheter in a retrograde fashion with the penis in slight traction while concurrently obtaining static radiographs. The volume and pressure needed for contrast injection depends on the degree of obstruction; the examiner should determine volume and pressure while evaluating spot radiographs throughout the study. The physician should instill enough contrast to visualize a full column of contrast spanning the urethra from the fossa navicularis to the urinary bladder (Figure 1). If overlapping structures obscure pathology, position the patient in a more oblique fashion. Following imaging, deflate the balloon and remove the catheter. Instruct the patient to stand in an oblique position and void into a urinal container, and obtain additional images to assess for pathology at the distal-most urethra and fossa navicularis. Finally, obtain a post-voiding image of the bladder to document the presence of residual contrast.

Troubleshooting Strategies

Balloon slippage may occur when pressure from hand injection displaces the balloon and expels the catheter from the penis. This may be secondary to an inadequately sized catheter. Should this occur, insert a larger Foley catheter to reduce future slippage (Figure 3). In the setting of a narrow stricture, hand injection may cause increased intracatheter
pressures, disconnecting the syringe from the catheter. If this occurs, ensure proper sealing of the tubing before hand-injecting with the catheter held firmly in place (Figure 3).

Increased extrinsic sphincter contraction secondary to spasm may result in non-opacification of the posterior urethra. In this event, instruct the patient to deeply inhale and exhale, and hand inject contrast with gentle pressure. In the absence of pathology, contrast should freely cross the posterior urethra into the urinary bladder (Figure 4). Improper penile positioning may result in a foreshortened and distorted urethral anatomy appearance that may mimic strictures and other urethral pathology. By applying moderate traction to the penis and obtaining images in the urethral long axis, distortion should resolve (Figure 4).

Complications

Allergy to iodinated contrast is a relative contraindication. In a properly performed RUG, contrast should enter the vascular system; however, an anaphylactoid reaction may result from the rare case of intravascular contrast intravasation, identified as opacification of the corpora and draining veins. Closely monitor the patient for an anaphylactoid reaction when such intravasation is identified. As a prophylactic measure, follow institutional protocols which often include premedication of patients with allergies to iodinated contrast, and may include the use of antihistamines and corticosteroids prior to RUG.

Urinary tract infections are also rare following RUGs performed with proper sterile technique. Patients may experience dysuria, a burning sensation while urinating, or fever. Workup includes urinalysis and urine culture, with symptomatic patients undergoing empiric antibiotic therapy.

Iatrogenic urethral injury is an extremely rare complication of RUG in patients with a structurally normal urethra. With distal urethral tears, attempting to insert the Foley catheter beyond the tear may cause tear propagation or urethral perforation; the examination should be promptly discontinued.

Normal Studies

A normal RUG study should demonstrate a continuous contrast column extending from the fossa navicularis to the urinary bladder (Figure 1). The penile urethra should be mostly uniform in caliber with the bulbous urethra slightly larger than the penile urethra. At the bulbomembranous junction there should be a smooth change in caliber of the smaller membranous urethra into the larger bulbous urethra. With inadequate distention of the urethra, the
verumontanum is visualized as an ovoid filling defect in the posterior prostatic urethra approximately 1.5 cm proximal to the bulbomembranous junction. Following voiding, the urethra and urinary bladder should be essentially free of contrast.

Urethral Trauma

Blunt Urethral Trauma

Blunt urethral trauma accounts for most traumatic urethral injuries, and generally occurs in the anterior urethra, owing to its unprotected nature and increased mobility.8,14 Anterior urethral injuries are also associated with pelvic fracture and are the result of straddle perineal injuries secondary to bulbous urethra impaction onto the pubis symphysis.14,15 In penile fractures, anterior urethral injury has an incidence of up to 20%.14

Unlike anterior urethral injuries, most posterior urethral trauma occurs in the setting of pelvic fractures, with an incidence of 4 – 24%.15,16 With pelvic fractures, the blunt urethral trauma is typically secondary to direct injury.17 In the absence of pelvic fracture, posterior urethral injuries usually result from shearing forces, causing urethral stretching between points of relative fixation, including the puboprostatic ligament or the fascia of the urogenital diaphragm.14,17

Urethral contusions represent a low-grade injury and are typically occult on RUG, with patients traditionally treated conservatively, including pain management.12 Higher-grade blunt urethral injuries have a variety of imaging characteristics and can be categorized using the Goldman Classification, which divides urethral injury into subtypes based on the anatomic segment(s) involved (Table 2). Accurate classification is crucial to guiding optimal treatment planning.

Type I injuries are relatively uncommon, accounting for 10-15% of blunt urethral trauma.13 Injury is isolated to the posterior urethra, which is stretched but remains intact without evidence of extraluminal contrast extravasation. Treatment is conservative, with suprapubic or urethral catheterization.12,13,18

Type II injuries also account for 10-15% of blunt urethral trauma.13 Tearing is present, and isolated to the posterior urethra, resulting in contrast extravasation. Treatment usually consists of suprapubic or urethral catheterization for partial (< 25% thickness) tears, and realignment or urethroplasty for high-grade (> 75% thickness) tears.5,12,13,18

Type III injuries are most common, accounting for 66 – 85% of all blunt urethral trauma.5 They are defined as combined anterior and posterior urethral injury with involvement of the urogenital diaphragm, resulting in contrast extravasation from these areas (Figure 5). Treatment for type III injuries is similar to type II injuries.5,12,13,18 Type IV injuries are relatively rare and are defined as bladder neck injury with extension into the urethra.12,13,18 Patients with type IV injuries may present with incontinence secondary to injury to the detrusor musculature. Type IVa injuries should not be confused with type IV injuries; Type IVa injuries are defined as a pure extraperitoneal injury to the bladder base and have lesser association with incontinence than type IV injuries.12,13,18

Type V injuries are isolated to the anterior urethra and typically involve the bulbous urethra as a result of straddle injury (Figure 5).12,13,18,19 If the Buck fascia is intact, extravasation is limited to the space between the Buck fascia and tunica albuginea. If the Buck fascia is disrupted, extravasation will be present and located between the confines of the Colle fascia. Treatment is similar to type II and III injuries.13,18,19

Penetrating Urethral Injury

Penetrating urethral trauma usually results from knife or firearm injury and most commonly affects the anterior urethra. RUG examinations are indicated in patients with any penetrating penile injury, as up to 50% will have a urethral injury.12 Late complications of penetrating urethral trauma include periurethral abscess formation, post-traumatic stricture, and fistula formation.12,20 RUG will demonstrate contrast extravasation at the site of urethral injury (Figure 6). Extravasated contrast may be confused with urethral diverticulum when blunt or penetrating urethral injuries are being evaluated. In such scenarios, voiding images are particularly helpful as persistent contrast or a change in morphology is suggestive of urethral injury.

In the setting of complete urethral transection, retrograde instilled contrast will extravasate at the site of injury with non-opacification of the urethra proximal to the site of injury (Figures 6, 7).

After debridement of the urethral edges, urethral transections can be
directly anastomosed over a Foley catheter (Figure 6). Long defects (> 2 cm) in penetrating trauma should not be repaired emergently; instead, they should be reconstructed at a later date, with urinary diversion in the interim. Injuries secondary to gunshot trauma also should not be repaired emergently secondary to a potentially delayed thermal injury; they should similarly be repaired in a delayed fashion.

**Post-Traumatic Urethral Stricture**

Urethral strictures are defined as narrowing of the urethra resulting from scar tissue formation from collagen and fibroblast proliferation, ultimately causing obstruction of the lower urinary tract. Etiologies for urethral strictures are multifactorial. The vast majority are secondary to traumatic, iatrogenic (indwelling catheter, cystoscopy, prior hypospadias correction, prostate surgeries), and idiopathic etiologies that encompass approximately 75% of all cases.

Strictures manifest as narrowing of the contrast column on RUGs. Post-traumatic strictures may be single or multifocal and are typically variable in length (Figure 8). Most strictures involve the anterior urethra, with the bulbous segment most commonly affected. Posterior urethral strictures or stenoses are more prevalent in pelvic fractures, post-radiation treatment, or prior prostate surgery. During complete obstruction, retrograde instilled contrast will not be observed opacifying the segment of urethra more proximal to the stricture. In these cases, the urethra proximal to the obstruction may be evaluated with a combined antegrade and retrograde urethrogram (Figure 8).

Treatment options for post-traumatic strictures include urethroplasty, urethral dilatation, urethrotomy, or suprapubic...
catheter placement. \(^{24,25,26}\) Post-urethroplasty RUGs demonstrate improved caliber of the affected segment compared to preoperative films (Figure 9). In the immediate postoperative setting, a voiding cystourethrogram (VCUG) should be performed and careful attention should be paid to assessing for evidence of a leak. Urethral stents may be visualized as a radiopaque tubular device over the expected course of the urethra (Figure 9). However, these are no longer used due to complications of long-term patency secondary to intra-stent fibrosis.

**Urethral Fistula**

Urethral fistulas are most commonly acquired. Acquired causes include trauma, prior surgeries (up to 10% of complex hypospadias repair), prior infection, and post-radiation treatment-related changes. \(^{28,29}\) While fistulas have been reported to be spontaneous in the setting of diabetes, they remain quite rare. \(^{28}\) Common acquired subtypes of urethral fistulas include urethrocystal and urethrocortaneous fistulas. Rarely, a urethrocortosomal diverticulum may form. \(^{30}\) Urethrocortaneous fistulas have been reported in penile fractures. \(^{31}\)

RUGs demonstrate an opacified fistulous tract extending from the urethra to the communicating organ. In cases of urethrocystal fistulas, the rectum will appear as an opacified structure with transverse folds distinct from the urinary bladder (Figure 10). Urethrocortaneous fistulas will demonstrate contrast extending to the skin surface; this may be readily evident on physical examination. In cases of urethrocortosomal diverticulum, contrast will opacify and distend the sac (Figure 10). \(^{30}\)

Urethral fistulas are generally treated with urethroplasties, which take down the fistula, close the urethra, and fix any associated obstruction. \(^{29}\) Postoperative VCUG examinations following urethroplasty demonstrate nonopacification of}

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**FIGURE 8.** (A) Short single segment high-grade stricture of the membranous urethra (solid arrow) with no contrast identified proximally in the setting of prior pelvic fracture as indicated by the orthopedic hardware. (B) Smooth luminal narrowing of the bulbous and penile urethral segments (solid arrows) in keeping with multifocal strictures following remote history of trauma. (C, D) Combined antegrade retrograde urethrogram (C) with no contrast identified in the region of stricture (solid arrow) in the posterior urethra. Contrast in the urinary bladder is from intravenously instilled contrast in an antegrade fashion. Following voiding (D), opacification of the proximal non-obstructed urethra is visualized demonstrating the true extent of the stricture (solid arrow).

**FIGURE 9.** Non-opacification of the membranous urethra (dashed circle) in keeping with a high-grade stricture following remote pelvic trauma (A). Following urethroplasty (B), the posterior urethra has regained its normal caliber (dashed circle). (C) Urethral stent manifesting as a radiopaque tubular foreign body at the bulbomembranous junction. Caliber of the contrast within the urethral stent is decreased in keeping with stenosis secondary to intra-stent fibrosis.
previously noted fistulous tracts. A small opacified urethral outpouching at the fistula site may be observed corresponding to a small stump.

Conclusion

Retrograde urethrography continues to represent a cost-effective tool that remains the gold-standard for initial diagnostic evaluation of acute male urethral trauma, as well as post-traumatic pathologies, including strictures and fistula formation. With recent advances and complexity of lower urinary-tract surgical procedures, appropriate technique and interpretation of these examinations remains a crucial part of the radiologist’s skillset.

REFERENCES

At the 2019 Radiological Society of North America’s scientific exhibition in Chicago in December, nearly every company highlighted new artificial intelligence (AI) initiatives and enhancements to their diagnostic imaging systems. From AI developments in machine learning (ML) to deep learning (DL) technologies, these advanced systems are being designed to effectively address clinical conditions, while simplifying physician workflows and departmental throughput.

Following is a recap of some of the most exciting AI-based tech that could make an appearance in medical imaging departments and clinics in the months ahead:

After entering the U.S. market in 2018, United Imaging Healthcare (UIH) announced several FDA-pending AI capabilities across multiple modalities with DELTA, a DL enhancement to its uCT 7 series computed tomography system; HYPER Deep Learning Reconstruction in the routine PET/CT workflow of its uMI 550 system; and AI-Assisted Compressed Sensing (ACS) full-coverage image acceleration for its uMR 780 system.

“The Delta algorithm can be applied to lower-dose datasets in order to recreate something that is similar to a higher-dose dataset. This has a big application for lowering dose, which is obviously on the hearts and minds of everybody who uses CT,” said Jeffrey M. Bundy, PhD, Chief Executive Officer of UIH.

United Imaging also announced a new strategic partnership with BAMF Health, which is achieving AI-enabled precision medicine through molecular imaging and theranostics. Powered by UIH’s proprietary AI platform, BAMF Health clinics will diagnose and deliver personalized treatment to patients with cancer, while leveraging United Imaging’s PET/CT and PET/MR technology.

Gaining access to the huge volumes of data required to train AI models while protecting patient privacy is a key issue for healthcare facilities. NVIDIA is addressing this challenge with NVIDIA Clara Federated Learning (FL), which uses distributed training across multiple hospitals to develop robust AI models without sharing personal data.

iCAD showcased Profound AI for digital breast tomosynthesis (DBT), or 3D mammography, the first and only FDA-cleared AI solution to support breast cancer detection in DBT.

ProFound AI helps increase cancer detection rates while also reducing false positives and reading time to enhance clinical performance. According to a recent study, ProFound AI is clinically proven to increase sensitivity by 8%, reduce false positives by 7%, and slash radiologist reading time by 52%.

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“With ProFound AI for DBT, radiologists are still in the driver’s seat – they’re just getting
help with prioritizing which lesions to look at, which essentially cuts reading time in half,” said Jeff Hoffmeister, MD, MSEE, vice president and medical director of iCAD. “It’s especially helpful on challenging cases where a radiologist might need extra insight.”

**Hologic** debuted the 3DQuorum Imaging Technology, powered by Genius AI, a breakthrough AI-powered algorithm to expedite mammography exam reading time without compromising image quality, sensitivity, or accuracy. 3DQuorum uses analytics enhanced by Genius AI to uniquely reconstruct high-resolution 3D data to produce 6 mm “SmartSlices.” The company says this expedites reading time by reducing the number of images for radiologists to review without compromising image quality, sensitivity, or accuracy. These analytics identify clinically relevant regions of interest and preserve important features during reconstruction of the SmartSlices.

**Canon Medical Systems USA, Inc.**, is bringing AI to routine imaging with Advanced intelligent Clear IQ Engine (AiCE) Deep Learning Reconstruction, an innovative approach to CT reconstruction that uses DL to distinguish true signal from noise to deliver sharp, clear, and distinct images at fast speeds. Trained with vast amounts of high-quality image data, the FDA-pending AiCE provides enhanced anatomical resolution across the central nervous, respiratory, cardiac, and musculoskeletal systems.

This technology is already cleared by the FDA for use on the Aquilion ONE/GENESIS Edition and Aquilion Precision CT systems. It is pending FDA 510(k) clearance for use on the Aquilion ONE/PRISM Edition and the Aquilion Prime SP CT systems, as well as on the Vantage Galan 3T MR and Vantage Orian 1.5T MR systems.

**Siemens Healthineers** expanded its AI-Rad Companion family with two AI-based software assistants designed to free radiologists from routine activities during MRI examinations.

The AI-Rad Companion Brain MR for Morphometry Analysis automatically segments the brain in MRI images, measures brain volume, and marks volume deviations in result tables used by neurologists for diagnosis and treatment. AI-Rad Companion Prostate MR for Biopsy Support also automatically segments the prostate on MRI images and enables radiologists to mark lesions, facilitating targeted prostate biopsies.

**GE Healthcare** introduced several new digital applications built on Edison, the company’s
digital intelligence platform, which was unveiled at RSNA 2018. The first, AIR Recon DL, is a new FDA-pending MR image reconstruction technology that delivers TrueFidelity Images. It’s designed to deliver greater image accuracy by leveraging advanced neural networks, or DL algorithms trained from a database of more than 10,000 images, to identify and remove artifacts, allowing users to optimize images and improve clinical diagnostics.

The new Edison Open AI Orchestrator manages imaging workflows. It simplifies implementation, deployment, support, and scaling of multiple AI applications, including those from partners iCAD and MaxQ, to seamlessly integrate clinical applications into the radiology PACS reading workflow. With this, Edison Open AI Orchestrator can help reduce the complexity of multiple systems and algorithms working together, potentially leading to fewer errors.

Edison Open AI Orchestrator seamlessly integrates multiple AI applications into the radiology PACS reading workflow.

Fujifilm’s FDR AQRO mini mobile DR system can be used in the ER with AI-powered recognition algorithms that could help physicians more clearly identify suspicious findings. AI recognition will search and map images to help identify pathologies such as pneumothorax.

Fujifilm’s FDX Console, also pending FDA clearance, will leverage AI in the OR with its ability to highlight foreign objects, such as surgical gauze, in images acquired during or post-surgery. AI for positioning navigation includes a camera built into the collimator of a Fujifilm X-ray unit to ensure proper patient positioning prior to exposure.

Royal Philips announced the launch of IntelliSpace AI Workflow Suite, which enables healthcare providers to seamlessly integrate AI into the imaging workflow. The AI workflow suite provides a full set of applications to integrate and centralize workflow management of AI algorithms, delivering structured results wherever they’re needed across the healthcare enterprise.

It automatically orchestrates the routing of clinical data to the appropriate AI application, analyzes the data without user interaction, then displays the results – allowing providers to capitalize on AI applications without adding complexity. IntelliSpace AI Workflow Suite is launching with more than 20 applications from both Philips and its partners.

Guerbet showcased IBM Watson Imaging Patient Synopsis, a radiologist-trained AI tool that aims to extract patient information and sum-
IBM Watson Imaging Patient Synopsis is a radiologist-trained AI tool that aims to extract relevant patient information and summarizes into a tailored and specific dashboard to help inform diagnostic decisions.

“The AI engine searches for all relevant data in patients’ records and brings in data from unstructured reports to give a more holistic view of the patient,” said Leeann Essai, North American head of marketing. “Now clinicians don’t have to click through an EMR – the system surfaces relevant data so they can make a better decision quickly and efficiently.”

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CorTechs Labs’ CEO, Chris Airriess, PhD, said the future of AI in healthcare will be powered by smart technology that can aid physicians in faster, more accurate diagnosis of neurodegenerative diseases. He called out NeuroQuant, an MR software that provides volumetric measurements of brain structures and compares them to a normative database adjusted for age, sex, and intracranial volume. It can help replace time-consuming manual processes with leading-edge automated technology that accelerates analysis so clinicians can spend more time focusing on patients.

“NeuroQuant can help doctors follow disease progression with reports tailored to diseases, such as epilepsy and multiple sclerosis,” he said. “Over time, with NeuroQuant, doctors can see how therapies for multiple sclerosis are really making a difference in their brains. It supports diagnosis through treatment follow up, which is huge.”

Konica Minolta Healthcare Americas, Inc., continued to highlight its focus on bringing precision medicine to primary imaging with Dynamic Digital Radiography (DDR) on the KDR Advanced U-Arm (AU) for orthopedic imaging featuring “X-ray that Moves.” Although DDR and the KDR AU have regulatory approvals, the combination of the two technologies is pending FDA clearance. When the two technologies are applied to musculoskeletal (MSK) imaging, clinicians can assess changes in the relationship of bones, ligaments, and other anatomical structures through full range of motion to evaluate the shoulders, knees, wrists, and spine.

Konica Minolta previously launched DDR for pulmonary imaging through a partnership with Shimadzu Medical Systems. In addition to producing dynamic sequences, the KDR AU also provides standard medical images for all anatomies. “DDR provides a new level of information using the common X-ray and allows the clinician to see things that they have never seen before,” says President and CEO David Widmann. “It is Smart X-ray and the foundation upon which we
will continue to add advanced analytics to provide an even greater level of insight.”

KDR AU with DDR from Konica Minolta Healthcare captures a cine loop of rapidly acquired, diagnostic-quality images depicting full views of articulatory mobility.

The company also launched Rede PACS, a new PACS designed for specialty practices including orthopedic, urgent care and family practice. The Insights dashboards, initially available for Konica Minolta Healthcare’s AeroDR flat panel detectors, is now extended to provide analytics on the digital radiography CS-7 and Ultra systems and the Exa Enterprise Imaging platform. Also announced was the development of an AI platform that will host multiple algorithms across vendors to provide a single worklist and workstation through the company’s Exa Enterprise Imaging platform.

Aidoc released its AI package for identifying and triaging stroke in CT scans will now include the CE-marked Large Vessel Occlusion AI module. The package prioritizes ischemic and hemorrhagic stroke patients in worklists by analyzing scans continuously in the background to reduce “door-to-needle” time.

Several companies announced collaborations with IBM Watson Health. Circle Cardiovascular Imaging’s cvi42, an AI-embedded single-platform solution for cardiac imaging, reading, and reporting, is now part of the IBM Imaging AI Marketplace. The platform for cardiac MR and CT, along with interventional planning and electrophysiology, provides tools to quantify and diagnose complex cardiovascular diseases. 

DiA Imaging Analysis Ltd announced it will introduce LVivo EF on the IBM Imaging AI Marketplace. LVivo is an AI-based quantification solution providing automated clinical data such as ejection fraction and global longitudinal strain.

MaxQ AI announced new partnerships with various original equipment manufacturers and marketplaces. Besides expanding its partnership with GE Healthcare’s PACS and Universal Viewing platforms (the solution is already available on GE’s Edison ecosystem), MaxQ’s AI ACCIPIO ICH and Stroke Platform will be integrated with Philips’ CT systems. The company also announced the availability of this solution on the Arterys Marketplace, the Nuance AI Marketplace, and the Blackford Platform.

SubtleGAD, a product of Subtle Medical, is under development for reducing gadolinium dose in MR exams. Supported by a $1.6 million National Institutes of Health Fast-Track Small Business Innovation Research (SBIR) grant, the company says the solution will use deep learning to deliver safer MRI exams without sacrificing clinical quality.
Several AI-driven cloud innovations are now available in the newest release of PowerScribe One from Nuance. Ambient Mode automatically converts free-form dictation into structured reporting, and makes possible real-time, bi-directional data synchronization with third-party platforms. A virtual assistant lets radiologists use voice commands to execute common commands, while new administrator dashboards provide real-time access to system and radiologist performance data. The company also introduced a new interface, and PowerScribe One now integrates with Nuance AI Marketplace through the solution’s image-sharing network.

For interventional fluoroscopy or cine imaging, the newly FDA-cleared FluoroShield from Omega Medical Imaging automatically collimates during a procedure to reduce field-of-view, and subsequent lower exposure to ionizing radiation. Auto ROI automatically follows device movement to minimize input requirements for the interventionalist. FluoroShield is compatible with the company’s 2020 Cardiac Flat Panel Detector.

Oxipit introduced Dynamics for its ChestEye CAD suite, which enables comparison of X-rays and provides automatically generated reports to address changes in images over time. The solution will initially support longitudinal comparison for pneumothorax, consolidation, mass, nodule, pleural effusion, pulmonary edema, and lung congestion radiological findings.

Several products under development at Care Mentor AI are designed to assist radiologists with interpretation of X-rays of the chest, foot, knee, and breast. In the breast, a neural network performs screening tasks and classifies results based on the BI-RADS algorithm. In the foot, the neural network determines the angle of the foot arch and compares it to a reference standard. Chest X-rays are screened for radiological abnormalities; recommendations are made for additional diagnostic procedures. In the knee, bone and cartilage structures, along with the width of the articular cavity, are analyzed to determine extent of osteoarthritis.

Fovia, Inc., introduced solutions that the company says will help clinicians access AI results in their existing workflows. The F.A.S.T. AI Suite provides PACS and universal viewer OEMs a way to integrate and visualize AI results within existing workflows. Also released were XStream aiCockpit, which provides access to customized, AI-driven workflows and visualizations launched from PACS, and XStream aiPlatform, a vendor-neutral ecosystem that connects AI developers, PACS and hospital systems for delivery of AI-driven tools to radiologists.

RTI-MRI+ from HealthLytix uses AI and a tissue-microstructure model to increase MR diffusion imaging visibility of restricted water in body tissue. “A key innovation of RSI-MRI+ is that it can better characterize the complexity of water diffusion in cancerous tissue, resulting in better performance,” said Nathan White, PhD, CEO of HealthLytix and coinventor of RSI. “With early-stage aggressive cancer, we need more sophisticated approaches to separate what’s important from what’s not important. In cancer, that means separating restricted diffusion from other sources of water diffusion that are less relevant.” The solution received FDA marketing clearance right before RSNA 2019.

Meanwhile, Laurel Bridge AI Workflow Suite, designed to simplify AI algorithm integration into existing clinical workflows, can manage such tasks as identifying, fetching, anonymizing, and delivering current and prior studies for use in AI algorithms or postprocessing applications. The suite can also reidentify…
and store AI algorithm results in an archive and provide interoperability between facilities and cloud-based AI algorithms.

**TeraRecon** introduced AI Sync results interchange technology for delivering interactive findings into the radiology report and downstream systems. AI Sync is an enhancement to the company’s EnvoyAI platform that prepares and presents AI results for verification before, during, or after interpretations are completed. The company also announced multiple AI-enabled workflow subscription offerings for stroke and trauma, TAVR, and cardiac MR.

**Kheiron** and the University of California-San Francisco (USCF) will collaborate on AI imaging research and development in UCSF’s new Center for Intelligent Imaging. Kheiron will work with UCSF’s breast imaging group to study whether the Mia breast cancer screening software can be deployed in ethnically diverse populations.

For lung CT imaging, LungPrint Discovery, from **Vida**, is an automated, AI-powered analysis of an inspiratory chest CT scan that flags abnormalities that may indicate emphysema, COPD, or interstitial lung disease. It includes patent-pending airway visualization for reviewing and reporting lung CT abnormalities. Designed for thin-slice, noncontrast standard chest CT scans, including those for lung screening, it is part of the company’s VIDAvision suite of applications for lung visualization.

**Volpara** showcased its newly redesigned VolparaScorecard+, which provides access to three key patient risk insights: breast density assessment, an indication of suspicious findings in the mammogram, and lifetime risk of developing breast cancer. The solution incorporates Screenpoint Medical’s Transpara, an AI software that helps radiologists interpret screening mammograms. According to Volpara’s Chief Medical Officer, Monica Saini, MD, MS, the solution will “help radiologists design a personalized breast care plan for patients without disrupting their workflow.”

A new indication was cleared by the FDA for **Zebra Medical Vision’s HealthCXR** as part of the company’s A11 bundle. The device can now identify and triage pleural effusions on chest X-rays.

“Based on the real-world application of this product, we saw that Zebra-Med’s automatic identification of pleural effusion on chest X-rays can play a significant role in triage,” says Dr. J.J. Visser, Radiologist and Head of Imaging IT and Value-Based Imaging at Erasmus MC University Medical Center (Netherlands). “It could be a relevant indicator for acute cardiopulmonary disease, so that clinical management can be adopted, as soon as possible, in order to provide optimal patient care.”
Sphenoclival Intraosseous Lipoma

Christopher C. Zarour, MD, Bronson Yaldoo, DO; and Jeremy Kendra, MD

CASE SUMMARY
An 18-year-old presented with a history of chronic sinusitis and migraine headaches. Due to ongoing symptomatology, a CT sinus exam was ordered, which demonstrated findings consistent with acute sinusitis and a lytic lesion located in the anterior portion of the clivus. A subsequent MRI exam with and without contrast was recommended for further evaluation of the lytic lesion. Combined CT and MRI findings were consistent with an intraosseous lipoma.

IMAGING FINDINGS
A noncontrast CT sinus exam demonstrated the presence of small air-fluid levels within the sphenoid sinuses containing reticular densities/debris consistent with acute sinusitis. There was minimal mucoperiosteal thickening of bilateral maxillary sinuses. An expanse lytic lesion involving the anterior aspect of the clivus extending to the posterior wall of the sphenoid sinuses and containing septations with loss of cortex was identified to the right, measuring approximately $2.0 \times 2.0 \times 2.4$-cm in anterior-posterior, transverse and craniocaudal dimensions, respectively (Figure 1).

MRI demonstrated a lobulated mass surrounding the sella turcica having signal characteristics of a sphenoclvial intraosseous lipoma. MRI signal characteristics included: hyperintense signal on T1- and T2-weighted images, fat suppression, and no discernable contrast enhancement. In review of the prior CT exam, fat density within the lesion was demonstrated. There was normal parenchymal signal intensity (Figure 2).

DIAGNOSIS
Sphenoclvial intraosseous lipoma

DISCUSSION
Intraosseous lipoma (IL) is a rare, benign, fat-containing tumor that can occur throughout the skeleton, most commonly in the lower limbs and specifically, in the calcaneus and femur. However, the incidence of an IL variant located intracranially is extremely rare. There have been only five sphenoclvial intraosseous lipoma cases published in literature. IL has no age predilection, affecting individuals between ages of 5 and 90. IL occurs in the medullary cavity, which is the central part of bone where red and yellow (adipose tissue) bone marrow is stored. Due to its slow-growing, fat-containing, and benign characteristics, a sphenoclvial IL is usually found incidentally on CT or MR scans.

A study by Milgram investigated 61 patients with IL. After examination, a conclusion was made to divide the lipoma into three stages. Stage 1 represents a solid fatty lesion of strictly viable fat. Stage 2 demonstrates a fatty lesion with necrosis or calcifications located centrally. Lastly, stage 3 represents advanced lipomas with characteristics of multiple regions of necrosis, cystic formations, and calcified fat material. In stage 1, CT demonstrates a trabecular bone resorption with expansion, whereas T1- and T2-weighted MR imaging reveals signal intensity characteristic of adipose tissue. Furthermore, on CT imaging Stage 2 lesions will show attenuated fat that corresponds to obvious adipose tissue with calcification or necrosis. On MRI, T1- and T2-weighted imaging will show hypointense (calcified fat or ossification) presences of fat intensity; or may appear hyperintense densities (necrosis). Lastly, in stage 3 with the addition of stage 2 findings will represent adipose calcified attenuation on CT. The presence of a circumferential lip of attenuated fat and calcification supports a diagnosis.
of an IL rather than bone infarction. T2-weighted MRI will demonstrate a hyperintense signal that represents central necrosis and granulation tissue formation.

Removal of an IL is rarely needed, as most are asymptomatic and an incidental finding. Treatment is usually conservative, with continued observation and scanning roughly every six to eight months. There are exceptions, however, when the IL is located intracranially. If an intracranial IL becomes symptomatic, surgical removal is warranted. Currently, our patient did not require surgery as of this writing.

**CONCLUSION**

Intraosseous lipoma is a rare, benign, fat-containing tumor of the bone that occurs throughout the body, but most commonly in the lower limbs. In rare cases, these entities can be found intracranially, specifically within the sphenoclival region. Its characteristic features of fatty attenuation with or without calcifications or necrosis allows for certain diagnosis. Furthermore, a direct diagnosis can be made using T1 MR imaging with fat suppression. Surgical intervention is not required in the absence of symptoms.

**REFERENCES**


Prepared while Dr. Zarour was a Diagnostic Radiology Resident at St. Joseph Mercy Oakland Hospital, Pontiac, MI; Dr. Yaloo was a Diagnostic Radiology Resident at McLaren Oakland Hospital in Pontiac, MI; and Dr. Kendra was a Radiologist at McLaren Macomb Hospital, Mount Clemens, MI.
Injuries to the anterior cruciate ligament (ACL) are increasing over time, with younger women at elevated risk. Meniscal tears are also a significant source of morbidity in both the younger and older populations. Surgical repair of both conditions may alleviate symptoms and allow resumption of athletic activities. Understanding of the pathogenesis, associated findings, and appearance of these injuries on all imaging modalities is critical to their accurate diagnosis and timely treatment. Radiographs may show indirect signs of ACL and meniscal injuries. Ultrasonography is being utilized more often in the workup of these conditions as an adjunct to physical exam and as an initial screening tool. Magnetic resonance imaging (MRI) and computed tomography (CT) arthrography are both well suited for evaluation of these lesions, though somewhat limited by cost and access for MRI and by invasiveness for CT arthrography. ACL and meniscal tears can also be graded and classified according to their appearance on imaging which helps guide the surgeon during arthroscopy.

Learning Objectives
After completing this activity, the participant will be able to:
• Explain how the pathophysiology of ACL and meniscal tears differ according to age and injury mechanism, and how those differences can aid in injury detection;
• Identify the direct and indirect signs of ACL and meniscal tears on radiographs, CT, MRI, and ultrasound; and,
• Correctly describe and classify the various types of ACL and meniscal tears.

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Description

Authors
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Target Audience
• Radiologists
• Related Imaging Professionals

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Disclosures
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Injuries to the anterior cruciate ligament (ACL) are increasing with time with an estimated cost for these injuries of almost a billion dollars per year in the United States alone. Women, in particular, appear to be at greater risk of ACL injury than men, especially during activities that involve pivoting and jumping such as lacrosse, and soccer. Patients presenting with instability after ACL injury are at increased risk of osteoarthritis, but ACL reconstruction can resolve the objective and subjective joint instability, allowing patients to return to preinjury levels of athletic activities. Meniscal tears are also a significant source of morbidity in both the younger and older populations. Thankfully, meniscal repair is beneficial for patients with viable meniscal tissue and an injury pattern that is amenable to intervention and arthroscopic partial meniscectomy (APM) will improve symptoms in those not eligible for repair. Understanding of the pathogenesis, associated findings, and appearance of these injuries on all imaging modalities is critical to their accurate diagnosis and timely treatment. Radiographs may show indirect signs of ACL and meniscal injuries. Recently, ultrasonography is being utilized more often in the workup of these conditions as an adjunct to physical exam and as an initial screening tool. Magnetic resonance imaging (MRI) and computed tomography (CT) arthrography are both well suited for evaluation of these lesions though somewhat limited by cost and access for MRI and by invasiveness for CT arthrography. Accurate detection, description, and classification of these injuries are of paramount importance as they indicate the need for orthopedic evaluation as well as help guide the surgeon during arthroscopy.

**Pathogenesis**

**ACL Tears**

Nearly three quarters of all ACL injuries are non-contact injuries. A variety of theories have been proposed for the precise mechanism of ACL tears, including axial compressive forces on the lateral aspect of the joint, inadequate dampening of ground reaction forces, whole-body kinematics, and valgus forces. Axial compressive forces on the tibiofemoral joint during the transition from non-weight bearing to weight bearing cause anterior translation of the tibia which has been shown to lead to ACL rupture in cadaveric studies. Inadequate dampening of ground reaction forces and particular whole-body kinematics such as torso, hip, and ankle positioning also increase the risk of ACL injury by increasing the compressive and anterior forces at the tibiofemoral joint. Valgus forces may also play a part in ACL injuries as increased knee abduction places greater axial forces on the lateral side of the knee than on the medial side leading to an amplification of lateral compressive forces and increased internal rotation of the joint.

**Meniscal Tears**

Like ACL tears, most of the mechanisms of injury for most meniscal tears are non-contact in nature. These occur while cutting, decelerating, or landing from a jump. Older patients are often unable to pinpoint the inciting event that caused the injury, but instead are only aware of the symptoms themselves. This is due to age-related degeneration of the meniscus leading to a lower threshold for injury. Specific mechanisms of meniscal tears can be divided into two categories based on the aforementioned scenarios: abnormally large forces on a...
normal meniscus resulting in longitudinal or radial tears, and normal forces on a degenerative meniscus resulting in horizontal tears, usually in the posterior half of the meniscus. Medial meniscal tears are more common than lateral meniscal tears, likely due to the medial meniscus being less mobile and thus bearing more force during weight bearing. Some 56% of all tears involve the posterior horn of the medial meniscus, with anterior meniscal tears representing only 2% of medial and 16% of lateral meniscal tears. Lateral meniscal tears occur more frequently in younger patients in whom tears are more frequently related to sporting events and concomitant ACL tears.

Diagnostic Imaging: ACL Tears

Radiographs

As the ACL is not well visualized on radiographs, only indirect signs of ACL injury are used. The most common radiographic signs of ACL tears are Segond fractures, avulsion fractures of the anterior tibial spine.
(Figure 1), impacted lateral femoral condyle fractures, and fractures of the posterior lateral tibial plateau. If any of these abnormalities are found, additional imaging should be acquired to identify the extent of the ACL injury and any additional injuries to the other components of the knee joint.

Ultrasound

Ultrasound can aid the examiner in determining the presence of an ACL injury. Studies have been performed using both dorsal and ventral approaches to the ultrasound-guided examination, with both demonstrating good sensitivity and specificity (dorsal approach: 85-97% sensitivity and 87.5-98% specificity; ventral approach: 70-91.9% sensitivity and 95.6-98% specificity). Though the techniques vary between studies, in general, the examiner assesses anterior translation of the tibia in both knees and compares the unaffected knee to the knee in question. Then, the translation in the unaffected knee is subtracted from the total translation in the injured to give a side-to-side difference (Figure 2). Some studies have used only the side-to-side difference with cutoffs at 1 to 5 mm to determine whether there is a positive result from the test. Other tests also include total translation of the affected knee in the algorithm, which helps to improve specificity. In general, ultrasound can help to make the physical examination more quantitative; however, like all physical examinations in the diagnostic period, pain may interfere with the
FIGURE 5. (A) Meniscal degeneration and protrusion of the lateral meniscus with horizontal tear (white arrow) and bulging of the lateral collateral ligament (open black arrow). (B) Meniscal cyst (black arrow) and a horizontal tear in the medial meniscus (notched white arrows). Reprinted with permission from UltrasoundCases.info, Case 6.6.14 Meniscus, Case 1/23, 7/23, and 8/23, http://www.ultrasoundcases.info/Case-List.aspx?cat=392, Accessed December 11, 2018.17

FIGURE 6. (A) Coronal reformat from a CT arthrogram shows a horizontal tear (white arrow) in a small medial meniscus. A meniscal fragment (arrowheads) is found in the intercondylar notch and indicates an unstable meniscal tear. (B) Sagittal reformat shows a blunted anterior horn of the medial meniscus (arrow) flipped anteriorly and laterally in the intercondylar notch (double PCL sign [arrowheads]).18

FIGURE 7. (A) Three-dimensional model (left) and cross-sectional diagram (right) show a horizontal tear (black arrows) that courses between the longitudinal collagen bundles (blue cylinders) without disrupting them and separates the meniscus into upper and lower halves. (B) Coronal reformat from an PDFS MRI shows linear T2 signal in the medial meniscus compatible with a horizontal tear (white arrow). The lateral meniscus is slightly extruded and demonstrates intrasubstance T2 signal representing meniscal degeneration (open arrowhead).24
patient’s ability to move the knee joint freely. It is also worth noting that ultrasound may be a good choice for patients with metallic implants, as MRI artifacts can interfere with accurate assessment of the ACL.9

**CT Arthrography**

CT arthrography is infrequently used for patients with suspected ligamentous injury due to MRI’s superior visualization of soft tissues. Additionally, MRI does not expose the patient to radiation nor does it necessitate the use of iodinated contrast. As such, CT arthrography may be avoided in children and patients with known allergic reactions to iodinated products. However, CT arthrography is still utilized where MRI is unavailable, in patients with contraindications to MRI, or those with ferromagnetic implants.10 When CT arthrography is used to assess ACL injuries, it has been shown to be quite accurate for diagnosing ACL tears (sensitivity 84-94%, specificity 91-98%) and concomitant injuries to the menisci (sensitivity 80-97%, specificity 75-95%).10 The ACL can generally be considered normal on cross-sectional imaging if it appears as a continuous tubular structure on contiguous coronal and sagittal reformations. On axial reformats, the ACL will appear oval in structure and can be located medial to the lateral femoral condyle. It should appear to attenuate immediately at approximately the same level as the patellar tendon and lower than that of the iodinated contrast material.10 Signs of ACL tear on CT arthrography are the same as those on MRI: ligament discontinuity, abnormal contours, and abnormal course (Figure 3).10 Indirect signs include anterior translocation of the lateral tibial plateau, abnormal depression of the lateral femoral condyle notch, and fracture of the posterior margin of the lateral tibial plateau.10

**Magnetic Resonance Imaging**

MRI is widely considered the best modality for evaluating the ACL in the acutely injured, chronically injured, and reconstructed states.11 Multiple meta-analyses have been performed on the diagnostic accuracy of MRI in suspected ACL injuries, with sensitivity of 86.5-94.5% and specificity of 93-95.5%.12 On MRI, the ACL has low T1- and T2-weighted signal and can be found within the lateral aspect of the tibial plateau, abnormal depression of the lateral femoral condyle notch, and fracture of the posterior margin of the lateral tibial plateau.10

**Meniscal Tears**

**Radiographs**

As with ACL tears, meniscal tears are poorly visualized on radiographs. Similarly, they must be identified indirectly...
with signs such as cortical avulsion fractures. As with ACL tears, additional imaging will be required to assess the extent of meniscal injuries.14

Ultrasound

Ultrasound is an infrequently utilized tool in the initial assessment of meniscal tears. However, recent studies have found that ultrasound has a sensitivity of 86.2-86.4% and a specificity of 69.2-84.9% in diagnosing meniscal tears.12,15 To assess the anterior horn and the middle zone of the medial and lateral meniscus, dynamic coronal images of the knee in question should be obtained with the patient in the lateral decubitus position with the knee at 30 degrees of flexion. To assess the posterior horns, place the patient in the prone position with the knee extended. All images from the affected knee should be compared against those in the unaffected knee.12 Real Time Compound Sonography (RTCS) is a relatively new technique that has been found to be superior to conventional grayscale images. RTCS is also beneficial specifically in the assessment of menisci, and should be utilized where available.16 Additionally, both linear and convex probes should be used, if available.13 To identify meniscus tears, look for evidence of a hypoechoic area within the meniscus itself; take care not to misinterpret the popliteal hiatus as a lateral meniscal tear (Figure 5).17 Comparing the anatomy with that of the unaffected knee should help to reduce error. Then, during dynamic examination, look for any extrusion of the meniscus, again comparing the findings to those in the unaffected knee (Figure 5).12

Limitations of ultrasound include reduced visualization of tears in the inner portion of the meniscus, particularly small inner tears. Bucket handle tears are also hard to diagnose via ultrasound, owing to decreased visualization of the portion of the meniscus in the intercondylar notch. Additionally, MRI is more accurate in degenerative meniscal tears and allows a more accurate characterization of concomitant intra- and extracapsular injuries, such as bone bruises, that are not well visualized on ultrasound.12 Traditionally, it has been thought of as more experimental and limited in terms of its clinical applications owing to multiple studies with poor results in the 1990s.15 However, given the promising statistics in recent studies, the high cost of MRI and arthroscopy, and the sometimes limited availability of MRI, ultrasound may be more heavily utilized in the coming years.12

CT Arthrography

CT arthrography, like ultrasound, is infrequently utilized to evaluate meniscal injuries. There are several reasons for this, including its invasiveness, exposure of the patient to radiation, and the improved bone and soft tissue visualization of MRI. However, as in ACL assessment, CT arthrography is useful for patients where MRI is unavailable or in patients with contraindications to MRI (eg, ferromagnetic implants).18 In cases where CT arthrography has been studied, it has been shown to be quite accurate in the assessment of meniscal injury, with high sensitivity (93-99%), specificity (87-98%), and interobserver agreement (0.899 kappa coefficient for presence of a meniscal lesion).18

Both menisci are roughly triangular in cross-section. The outer rims are convex and attach to the joint capsule, while the inner rims are concave, thin, and free. The medial meniscus can generally be considered normal on cross-sectional imaging if it appears as a C-shaped structure that is larger posteriorly in the anteroposterior dimension. It is attached to the tibia anteriorly, along the outer rim, and posteriorly. Its anterior attachment is anterior to the tibial attachment of the ACL, the outer rim attachment is at the edge of the joint capsule, and the posterior attachment is immediately anterior to the posterior cruciate ligament (PCL).

The lateral meniscus is considered normal on cross-sectional imaging if
it appears more circular and uniform in width than the medial meniscus. It is also attached to the tibia anteriorly, along its outer rim, and posteriorly. Anteriorly, it attaches to the medial meniscus via the intermeniscal ligament. Posteriorly, it has a more complex attachment with connections to the PCL and the medial femoral condyle through the ligaments of Wrisberg (posterior meniscal-femoral ligament) and Humphrey (anterior meniscal-femoral ligament). Also of note, the lateral meniscus is also attached to the popliteus tendon, but it is not attached to the lateral collateral ligament (LCL) and is more mobile than the medial meniscus.5,7,19,20 Generally, meniscal abnormalities can be identified via contour irregularities, peripheral separation, or the observation of a meniscal tear. Contour irregularities are defined as altered meniscal shape with truncation, blunting, flattening, or rounding of the inner borders (Figure 6).19 Peripheral meniscal separation is defined as extrusion of the meniscus more than 1-3 mm from the tibial margin or visible separation of the meniscus from the joint capsule, and in the case of CT arthrography this space would be filled with contrast material. Likewise, meniscal tears can be seen in CT arthrography as contrast material tracking into the substance of the meniscus.5,18

**MRI**

MRI is a well-established modality for diagnosing meniscal injuries. Meta-analyses have shown it to have a pooled sensitivity and specificity for diagnosing meniscal injury of 91-93% and 81-88%, respectively, for medial meniscus tears and 76-79% and 93-95%, respectively, for lateral meniscus tears.5,21,22 A normal, healthy meniscus will show low intensity on all imaging sequences. Short echo time (TE) sequence imaging such as proton density and T1-weighted imaging are the most sensitive for detecting meniscal tears whereas T2-weighted abnormalities are very specific.20,21 Direct signs of meniscal tear include unequivocal surfacing signal (ie, hyperintensity extending to the articular surface), missing meniscal tissue, and a displaced meniscal fragment.5,20 Indirect signs include meniscal cysts, torn or absent popliteomeniscal fascicle, edema-like pattern in the subarticular marrow, and subchondral bone contusions in patients with concomitant ACL tears.5

**Classification**

**ACL Tears**

ACL injuries can range from low-grade sprains without tearing of the ligament (Grade I sprain), to partial-thickness tears in which some of the fibers of the ACL have torn (Grade II sprain), to full-thickness tears of the ACL (Grade III sprain). In younger patients, the ACL may avulse from the tibial attachment site, as well.11 These tears can be located in the proximal, midsubstance, distal, or they may involve the femoral or tibial attachment. Most tears tend to occur in the mid- to proximal aspect of the ligament and will appear with increased T2-weighted signal and an abnormal contour. In some full-thickness tears fluid or an amorphous mass replaces the discrete ACL fibers. In partial tears, the anteromedial bundle is most commonly involved.11 MRI cannot accurately determine clinically stable and unstable ACL injuries, but the presence of significant anterior tibial translation, uncovering of the posterior horn of the lateral meniscus, and a hyperbuckled PCL may aid in diagnosis of an unstable tear.23

**Meniscal Tears**

There are several types of meniscal tears; each is described in terms of location and morphology. There are two menisci in each knee: lateral and medial. There are three regions within each meniscus: the anterior horn, the body, and the posterior horn. Combining these, a specific location can be determined—for example, the posterior horn of the lateral meniscus.24 No specific MRI-based
arthrography is sensitive and specific for ACL and meniscal tears, but it is usually reserved for cases in which the patient cannot undergo MRI or where MRI is unavailable. Since its advent, MRI has been the mainstay for diagnosing both types of injuries, as it has good sensitivity and specificity for diagnosing and classifying both ACL and meniscal tears.

**References**

CASE SUMMARY
A 59-year-old female with a weight of 153 lbs. (69 kg) and no significant medical history presented with acute left shoulder pain and limited range of motion that began fewer than 24 hours after receiving the tetanus and diphtheria (Td) vaccine for routine prophylaxis. The patient denied fever, prior shoulder pain, trauma, excessive lifting, pulling or exercising. On physical exam, the patient experienced limited range of motion, pain with active and passive movement, and tenderness over the deltoïd tuberosity. The patient’s reflexes, strength, and sensation were intact. After minimal relief with nonsteroidal anti-inflammatory drugs (NSAIDs), nonenhanced magnetic resonance imaging (MRI) of the left humerus was obtained.

An MRI performed 6 weeks from the start of symptoms demonstrated extensive edema surrounding the teres minor myotendinous junction and tendon (Figure 1). There was an associated high-grade partial-thickness tear of the teres minor tendon (Figure 2). Accompanying reactive humeral subcortical edema at the teres minor tendon insertion was also noted (Figure 2).

DIAGNOSIS
Isolated teres minor tear, a shoulder injury related to vaccine administration

DISCUSSION
Transient pain, erythema, and induration are commonly experienced symptoms following vaccine administration in the shoulder. Infrequently, however, vaccines may result in an entity documented as shoulder injury related to vaccine administration (SIRVA) by the National Vaccine Injury Compensation Program. Symptoms of SIRVA include persistent shoulder and arm pain, restricted motion, bursitis, and brachial palsies. Few reported cases in the literature define the imaging findings related to this entity. To the best of our knowledge, we report the first case of an isolated teres minor rotator cuff tear following administration of the Td vaccine.

Temporary shoulder pain following vaccine administration is a commonly encountered phenomenon. Significant subcutaneous soft tissue swelling in the injected arm can be seen on ultrasound. These findings are due to a local inflammatory response following immunizations. However, prolonged shoulder pain and restricted motion after vaccine administration may be related to SIRVA, a rare entity described as a complication of incorrect vaccine administration, often-times at an injection site located too highly on the shoulder. The result is an immune-mediated inflammatory reaction locally within the shoulder. The prolonged immune mediated inflammatory response appreciated
in SIRVA is an example of a type III hypersensitivity (Arthus) reaction. This phenomenon is due to the body’s reaction to previously residing antibodies (a previous Td injection in our patient’s case) against the newly injected antigens. In our patient, the humeral head edema and teres minor tear depicted on the MRI reflects sequela of direct needle impact and prolonged immune response.

Fewer than 30 cases related to SIRVA are reported in the literature. The largest study, by Atanasoff et al, incorporated 13 cases in which patients received a vaccination against influenza, Td, Tdap, or human papillomavirus and developed prolonged shoulder pain with associated bursitis, tenosynovitis, and/or rotator cuff tears as seen on MRI. Cases of SIRVA have also been reported following other vaccines including pneumococcal and hepatitis.

Nearly all the reported cases demonstrate similar radiographic findings related to SIRVA, including subacromial and subdeltoid bursitis, tenosynovitis, supraspinatus and infraspinatus rotator cuff tears, and bone marrow edema. Only one report involving teres minor pathology has been described in the literature. In this study, a 60-year-old female experienced prolonged left shoulder pain after receiving the Tdap vaccine. Subsequent MRI revealed a 0.6 x 0.8 cm partial thickness tear of the infraspinatus tendon extending inferiorly to involve the superior portion of the teres minor tendon.

Isolated tears of the teres minor tendon are rare. They occur more commonly in the setting of traumatic posterior shoulder dislocation or in combination with supraspinatus and infraspinatus tendon tears. We report a previously undescribed case of an isolated teres minor rotator cuff tear following administration of the Td vaccine. The intent of this study is not to foster vaccine hesitancy but to broaden the differential diagnosis of prolonged shoulder pain in the context of recent immunization and to discuss technique.

Our patient experienced signs and symptoms consistent with previously reported cases of SIRVA. The patient...
developed persistent shoulder pain and limited range of motion in the setting of recent vaccination and no past medical history of shoulder dysfunction. Furthermore, her symptoms began to improve 6 weeks after onset. These findings are similar to those described by Dumonde et al, who proved that antigen injected within synovial tissues resulted in a prolonged immune response lasting 6 weeks, after which symptoms began to improve.8

A decision on needle length and injection site must be made for each person on the basis of the volume of vaccine to be administered, injection technique, size of the deltoid muscle, thickness of adipose tissue at the injection site, and depth below the muscle surface into which the material is to be injected. Most vaccines are administered via an intramuscular route into the deltoid or anterolateral aspect of the thigh. The deltoid muscle is recommended for use with small volume injections, for example vaccinations. This enhances the immunogenicity of the vaccine and minimizes adverse reactions at the injection site. For intramuscular injections, the needle should be long enough to reach the muscle mass and prevent the vaccine from seeping into the subcutaneous tissues, but not so long as to involve the underlying nerves, blood vessels, or osseous structures. Intramuscular injections should be administered at a 90-degree angle to the deltoid muscle using a 22-25-gauge needle. According to the Centers for Disease Prevention and Control (CDC), for men and women <130 lbs (<60 kg), a 5/8-1 inch needle is sufficient to ensure intramuscular injection into the deltoid muscle. For men and women who weigh 130-152 lbs (60-70 kg), a 1-inch needle is adequate.9

The potential risks of under-penetration of vaccines are well known, including local dermatologic reactions and decreased immunogenicity. However, less well known are the adverse effects related to over-penetration and risk of injury deep to the deltoid muscle using needle lengths recommended by the CDC. Lippert et al demonstrated that patients who receive vaccinations in the shoulder utilizing the CDC’s recommended 5/8, 7/8, and 1-inch needle lengths would experience 11% (16 of 150), 55% (83 of 150), and 61% (92 of 150) risk of over-penetration, respectively.10 The authors suggested a weight based vaccination model, wherein a 1/2 inch needle be used in females ≤70 kg and males ≤75 kg, 5/8-inch needle in females 70-115 kg and males 75-140 kg, and 7/8-inch or longer needle in females 115 kg or more and males 140 kg or more. Furthermore, the authors claimed that these weight-based needle lengths could potentially allow for a 0% over-penetration and 10% under-penetration rate. Bodor et al used ultrasound to determine that the sub-deltoid bursa extended 3-6 cm beyond the lateral border of the acromion and 0.8-1.6 cm deep to the skin surface.3 The authors concluded that the subdeltoid bursa is easily accessible by a 1-inch needle thereby making it a potential site of injury during vaccine administration.

Given these recommendations, our patient at a weight of 153 lbs (69 kg) would require a 1/2-inch needle, significantly decreased in length as compared to that recommended by the CDC, thereby, potentially preventing SIRVA from occurring. However, in this patient with a small muscle mass, a 1-inch needle length was used. Hence, it is very plausible that there was over-penetration of the vaccine through the deltoid into the teres minor tendon at its insertion onto the posterior aspect of the greater tuberosity of the humerus with resultant partial tear of the teres minor tendon.

CONCLUSION

Prolonged shoulder pain and restricted movement following vaccine administration should prompt clinicians to rule out SIRVA as a culprit. It is imperative when administering vaccines to remain within the deltoid muscle and avoid over-penetration into the rotator cuff tendons as this may lead to SIRVA. Lastly, SIRVA should be considered as a plausible cause when faced with isolated teres minor tendon pathology in the appropriate clinical setting.

REFERENCES


Prepared by Dr. Bansal while a PGY-4 Radiology Resident and Dr. Di Lorenzo while the section head of Musculoskeletal Radiology, at MetroHealth Medical Center/Case Western Reserve University, Cleveland, OH.
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CASE SUMMARY
A 65-year-old man presented with right forearm pain. Several years earlier, he felt discomfort from the right shoulder through the back of the right hand, and the discomfort changed to pain in the right forearm. The physical examination revealed no significant abnormalities, and his muscle strength and deep tendon reflexes were normal.

IMAGING FINDINGS
Cervical MRI revealed a right intradural, extramedullary mass lesion at the level of the C4–C5 vertebrae. The mass was isointense on T1-weighted images and slightly hyperintense on T2-weighted images. The mass was hyperintense on diffusion-weighted images and hypointense on an apparent diffusion coefficient map, enhancing slightly after gadolinium injection. Cervical CT imaging revealed cervical spondylosis and vertebral canal stenosis at the right C4–C5. (Figures 1–3)

DIAGNOSIS
A traumatic neuroma is reactive, proliferative overgrowth of axons, Schwann cells and fibroblasts at the proximal end of an injured nerve. However, there are a few reports of traumatic neuroma without a history of injury/direct trauma. The etiology for a traumatic neuroma with no history of direct trauma is unknown. Our patient’s case revealed vertebral canal stenosis at the level of the mass lesion. Our literature search did not identify a report indicating that cervical spondylotic radiculopathy as the cause of a traumatic neuroma of an intradural cervical nerve root without a trauma episode. Our patient’s case revealed vertebral canal stenosis at the level of the mass lesion. Our literature search did not identify a report indicating that cervical spondylotic radiculopathy as the cause of a traumatic neuroma of an intradural cervical nerve root without a trauma episode.

CONCLUSION
We suggest that cervical spondylotic radiculopathy may present as one of the causes of a traumatic neuroma of an intradural cervical nerve root without an episode of trauma.

REFERENCES

Prepared by Dr. Doai, Dr. Tonami, and Dr. Matoba while with the Department of Radiology; Dr. Tamase while with the Department of Neurosurgery; and Dr. Aikawa while with the Department of Pathology and Laboratory Medicine, Kanazawa Medical University, Ishikawa, Japan.
FIGURE 1. Cervical MRI revealed a mass lesion on the right intradural extramedullary at the level of the C4-C5 vertebrae, isointense on T1-weighted images (A) and slight hyperintense on T2-weighted images (B), showing hyperintense on diffusion-weighted images (C), and hypointense on an apparent diffusion coefficient map (D), enhancing slightly after a gadolinium injection (E). The transospinalis muscle on the right showed atrophic change.

FIGURE 2. A cervical CT scan revealed cervical spondylosis and vertebral canal stenosis at right C4–C5 (A, B).

FIGURE 3. Histological findings revealed a proliferation of bundles of axons involving Schwann cells. (hematoxylin and eosin, high-power field)
To Serve Man: AI at RSNA

C. Douglas Phillips, MD, FACR

“Don’t get on that ship! The rest of the book, To Serve Man, it’s... it’s a cookbook!”


Radiology was last spotted in the back seat of a black SUV moving south at a high rate of speed from Chicago. Witnesses at the scene described Radiology arriving at McCormick Place for the annual RSNA meeting and subsequently being forced into the back seat of the car by four to six individuals wearing black suits and black wraparound Ray-Ban sunglasses. The vehicle left with a stylish squeal of tires and then roared out of town, never to be seen again.

Seriously, did you get to the RSNA? WTF? Now, I’m not saying artificial intelligence (AI) hijacked the show, but AI hijacked the show. Holy ****, they somehow found a massive part of McCormick that I swear I’ve never been in before and made it AI-centric. It was like the AI Temple of Anubis. Ribbons with AI were all the rage (see previous column on ribbons, sometime in the last year or two. Maybe more.).

AI was everywhere. It permeated every session and stuck to you. I was getting a burger at McDonald’s and the server asked if I’d like a side of AI with that. This isn’t the tail wagging the dog; this is a tail wagging the WORLD. I learned a few things during my time at RSNA and I’d like to share them with you. I’d also like to make my standard, cursory, and pithy observations. Please forgive me.

First, AI is not out to take over radiology. AI is here to help us. I cannot help but be reminded of that “Twilight Zone” episode, “To Serve Man.” Those aliens, like AI, seemed so nice (though their foreheads were a little too big for my taste) and also were here to “serve” us. Didn’t turn out so well. If AI did a few things for me and made it easier to read studies, cool. If AI is here to “serve” me, we have an issue. Someone told me that AI was so great because it is essentially free. Free? Come on. If that’s true, how can I find a price point competing with it?

The other thing was ML, and I don’t mean major league, or medial lemniscus, or even Merrill Lynch. ML = machine learning. ML seems to be a fellow traveler with AI. So, if AI doesn’t eat our lunch in the near term, ML clearly will. So, as I’ve been schooled, ML means that the computers start to learn tasks without being programmed explicitly to do so. I think about this exactly like teaching the resident staff: The computer is presented a stack of the same lesion you want to diagnose and also, hopefully, some normals, and supposedly learns from this repetition how to diagnose the lesion. Then, you can show it unknowns. “The Terminator” parallels here are too easy, and I will not go there, except to say that when the ML system reading your scan decides that you aren’t worth the bother, or your disease is too bad, you could conceivably be “terminated.” My advice? Bring a close friend (or two) with you to the imaging center.

My take on this from the RSNA 2019 is that we somehow got lost in the weeds. AI/ML took over learning how to diagnose disease on a cross-sectional imaging study UNLESS you choose to use them – they have to be invited. I guess AI/ML is popular; I saw a few of the rooms where AI/ML was being presented, and a greater-than-I-expected number of people were not sleeping. The residents and fellows have taken to AI/ML in a big way, cranking out research and papers galore on AI.

So, here’s the deal. Since the youngsters like it so much, when that spaceship lands and AI wants us to come aboard and be “served,” we let them go first.

Keep doing that good work. Mahalo.
A 28-year-old female gravida 5 with 2 living children delivered at term, was admitted at 39 weeks and 2 days of gestation for an elective cesarean section (C-section) because of her history of two previous C-sections. The patient underwent a standard C-section with a Pfannenstiel incision. A Foley catheter was routinely placed intraoperatively and left in place following the surgery. The patient remained in the hospital for typical continued postoperative evaluation. Immediately following her surgery, the patient continued to have gross hematuria and passed a small blood clot into the tubing of the Foley catheter. Her postoperative laboratory workup was also positive for a mild anemia with a hemoglobin level of 9.6 g/dL (decreased from 11.0 g/dL) and a hematocrit level of 29.9% (decreased from 33.0%). The patient was returned to the operating room for a cystoscopy with clot evacuation. No obvious bladder injury was found. The patient remained in the hospital for typical continued postoperative evaluation. Immediately following her surgery, the patient continued to have gross hematuria and passed a small blood clot into the tubing of the Foley catheter. Her postoperative laboratory workup was also positive for a mild anemia with a hemoglobin level of 9.6 g/dL (decreased from 11.0 g/dL) and a hematocrit level of 29.9% (decreased from 33.0%). The patient was returned to the operating room for a cystoscopy with clot evacuation. No obvious bladder injury was found. The patient remained on continuous bladder irrigation for approximately 24 hours, at which time it was discontinued as her urine had been running light pink to clear. At this time, a CT cystogram was performed.

Multiple axial images were obtained through the pelvis in 5 mm slices following instillation of 400cc of Cysto-Conray through the patient’s existing Foley catheter as per our standard CT cystogram protocol. Post-gravid appearance of the uterus and postoperative changes related to a recent cesarean section were demonstrated (Figure 1). A Foley catheter balloon was noted to lie within the lumen of the bladder (Figure 2). Contrast was noted to extend from the lumen of the bladder into the endometrial cavity at the level of the prior incision along the lower uterine segment through a small fistula (Figure 3). A conservative approach to treatment of the fistula with continued decompression of the urinary bladder was undertaken with a Foley catheter for 1 week. Follow-up cystograms were obtained at 1 week and 4 months following surgery. There was no evidence of the previously demonstrated vesicouterine fistula on either follow-up cystogram.

Urogenital fistulas are classified according to their anatomic location; they include vesicovaginal, vesicocolonic, vesicoperitoneal, ureterovaginal, and vesicouterine fistulas. The overall incidence of urogenital fistulas in the United States is reported to be between less than 0.5% and 10% after surgical intervention. Vesicouterine fistulas are the least common form, accounting for 1-4% of reported cases. Most vesicouterine fistulas in the United States occur after cesarean section, but they may also be secondary to intrauterine contraceptive devices, tumors, or traumatic labor. Other far less frequent etiologies include radiation therapy or iatrogenic causes, such as traumatic catheterizations. The reported incidence of urogenital fistulas is thought to be increasing secondary to an increasing rate of cesarean deliveries. From 1996 to 2009, the rate of cesarean deliveries increased from 20.7% to 32.9%. The cesarean delivery rate for 2015 slightly decreased and was estimated to be 32%; however, the data did not take into account the declining...
FIGURE 1. Axial image demonstrates a postgravid appearance of the uterus (arrows). Contrast is demonstrated within the endometrial cavity.

FIGURE 2. Axial image demonstrates a foley catheter (white arrow) within the urinary bladder. Contrast is demonstrated within the urinary bladder secondary to recent retrograde administration (blue arrow).

FIGURE 3. (A) Axial image demonstrates contrast within the lower uterine segment (blue arrows). (B) Sagittal image demonstrates contrast extending from the lumen of the urinary bladder into the endometrial cavity via a small fistulous tract (red arrows) at the level of the prior incision site.

birth rate in the U.S. Overall, the percentage of cesarean deliveries, as well as the total number of births, have since continued to trend upward.5,6

Delays in the diagnosis of urogenital fistulas are not uncommon, due to delays in the onset of symptoms and, at times, a nonspecific clinical presentation. Imaging studies such as cystography, sonography, computed tomography (CT), or magnetic
resonance (MR) can aid in the diagnosis of urogenital fistulas.\(^7\)

The diagnosis can be made following a thorough history and physical examination, which may demonstrate urine pooling within the vaginal vault. Diagnosis can also be made with cystography, cystoscopy, dye testing, intravenous pyelography (IVP), and/or cross-sectional imaging.\(^7\) However, the findings of such studies are commonly inconclusive, depending on the size and characteristics of the fistulous tract. False-negative IVP’s are common, as these studies may not generate adequate intraluminal pressure within the bladder to opacify the fistula.\(^8\) For smaller fistulas, a dye test or cystography is the initial imaging test of choice. If the findings are inconclusive or clinical suspicion of a fistula remains high, additional evaluation with cross-sectional imaging with intraluminal contrast, including coronal and sagittal reformat, is generally warranted.\(^7,9\)

If a vesicouterine fistula is not recognized and repaired at initial surgery, continuous urinary drainage can sometimes be effective. Additional therapeutic options also include fibrin-based surgical sealants or resection of the fistulous tract utilizing a laparoscopic/robotic/vaginal approach. Of note, the rate of spontaneous healing of the vesicouterine fistula in patients solely undergoing continuous bladder decompression has been reported at 5%.\(^10-16\)

**CONCLUSION**

The clinical presentation of our patient was atypical in the sense that it was such a short time interval from C-section to symptom presentation, which primarily consisted of frank hematuria. In general, patients with a vesicouterine fistula typically present with urine leakage through the vagina, which tends to become more noticeable a few days post-op following removal of the Foley catheter.

Given the small size of the fistulous tract in this case, the patient elected to undergo conservative therapy, with successful healing of the fistula on subsequent imaging studies.

**REFERENCES**

15. Boateng AA, Eltahawy EA, Mahdy A. Vaginal repair of ureterovaginal fistula may be suitable for selected cases. *Int Urogynecol J.* 2013; 24:921.

Prepared by Dr. Evans, Dr. Gazaille III, Dr. Keppke; Dr. Pagur; Dr. Paranjipe; Dr. Tharp; and Dr. Broomhall while with the Department of Diagnostic Radiology, Grandview Medical Center – Kettering Health Network, Dayton, OH; and Dr. Mohla while an OMS IV at the College of Osteopathic Medicine, Kansas City University of Medicine and Biosciences, Kansas City, MO.
Inflammatory Myofibroblastic Tumor

Mark Greenhill; David Aria, MD; Carrie Schaefer, MD; Robin Kaye, MD; Scott A. Jorgensen, MD; Todd Abruzzo, MD; Alexander Towbin, MD; and Richard Towbin, MD

CASE SUMMARY
A 2-year-old female presented to the emergency department with parental concerns regarding persistent, painless left upper-extremity weakness. The patient refused to lift her left arm above her head or to extend it in front of her body to pick up objects. Labs obtained included CBC with differential, CMP, ESR/CRP, uric acid, and LDH. All were unremarkable with the exception of moderate neutropenia (ANC 300) and mild elevation in LDH (255). Urine HVA and VMA were within normal limits.

IMAGING FINDINGS
Radiographs of the left clavicle showed lytic lesions of the left C5 and C6 transverse processes (Figure 1). Subsequent cervical MRI and CT studies were performed, helping to further characterize the lesion as a soft-tissue cervical spinal mass. Coronal and axial CT images of the cervical spine without contrast showed bone destruction of the left C5 and C6 transverse process and lamina with widening of the left C5/C6 neural foramen extending into the left transverse foramen (Figure 2). Axial T1 postcontrast MRI of the cervical spine established the presence of abnormal soft-tissue contrast enhancement centered within the left C5/C6 neural foramen with extension into the extra-medullary space within the spinal canal and approximately 270 degrees of encasement around the left vertebral artery (Figure 3). Transverse PET/CT imaging (Figure 4) showed abnormal FDG uptake within the mass with an SUV of 4.3. Color Doppler ultrasound was performed to locate the left vertebral artery and plan the biopsy route (Figure 5) with subsequent needle biopsy of the mass using ultrasound guidance via an anterolateral approach (Figure 5).

DIAGNOSIS
Inflammatoty myofibroblastic tumor (IMT).

Differential diagnosis of the cervical lesion includes nodular fasciitis, myofibroma, fibrodysplasia ossificans, inflammatory liposarcoma, spindle cell carcinoma, osteomyelitis, and neuroblastoma.

DISCUSSION
Inflammatory myofibroblastic tumor (IMT) is a rare neoplasm of mesenchymal origin most commonly affecting children and young adults. Histologically, IMT is made up of smooth muscle spindle cells embedded in a myxoid or fibrous stroma. Histologically there are inflammatory cells such as plasma cells, lymphocytes, or eosinophils; the neoplasm was initially categorized under a broad classification termed “inflammatory pseudotumors,” which includes...
many different reactive or infectious entities. The gross appearance of IMT is described as soft and rubbery with a white or gray cut-surface.

This tumor is uncommon, with 150-200 reported pediatric cases in the United States. IMT is most commonly found in the lungs or abdomen, but it has been reported in other locations, including two recent reports of occurrence in the head and neck region. A review of 84 cases by Coffin et al (1995) demonstrated that extra-pulmonary involvement presents at a younger age than does pulmonary involvement. In approximately 30% of patients, diagnosis is preceded by a syndrome of intermittent fever, malaise, weight loss, and night sweats, along with laboratory findings of hypo- or normochromic anemia and elevated ESR. These symptoms are thought to be caused by an elevation of the cytokine IL-6, leading to a systemic inflammatory response.

Immunohistochemical characteristics of IMT are variable and nonspecific, but can include positivity for smooth muscle actin (SMA) (80-90% of cases) and cytokeratins AE1, AE3, and CAM 5.2 (33% of cases). About one-half of all IMTs contain an anaplastic lymphoma kinase (ALK) gene rearrangement on chromosome 2 at band 2p23, associated with numerous gene partners. Other gene mutations infrequently seen in IMT include p53 and MDM2. A small portion of ALK-negative IMTs show rearrangement in the ROS1 gene (up to 10%).

Traditionally, subclassification of myofibroblastic tumors has been notoriously difficult due to a lack of specific immunohistochemical markers. The most common immunohistochemical findings are a strong positivity for smooth muscle actin and desmin, and negativity for h-caldesmon. Differential diagnosis includes nodular fasciitis, myofibroma, fibrodysplasia ossificans, fibrous histiocytoma, and spindle cell carcinoma. Given the variable and unpredictable histologic characterization of IMTs, the correct diagnosis is made on the basis of molecular and cytogenetic analysis using techniques such as FISH and PCR.

On CT imaging, IMT can present as a soft-tissue mass slightly hypodense to surrounding muscle, although variations in attenuation are often seen. The presence of adjacent fat stranding is common and likely due to an associated inflammatory process. Calcifications and/or central necrosis are rare of this type of tumor, suggesting a more benign course.

MR imaging tends to reveal intermediate-to-low signal intensity on both T1- and T2-weighted images as a result of the associated fibrosis. Depending on the specific anatomical location, lesions can be either well-circumscribed or ill-defined and infiltrating. Lesions in the head and neck region can appear aggressive, resulting in ill-defined bony erosions. Imaging can reveal expansile osteolytic lesions with an adjacent soft-tissue component. Contrast enhancement patterns are usually nonspecific and variable.
IMT is classified by the World Health Organization as having ‘intermediate biological potential’ mostly due to a tendency for local recurrence.\(^9\) Multiple sources have reported a recurrence rate of 25% for extra-pulmonary lesions.\(^1,2\) The mainstay of treatment is surgical resection; however, this can prove difficult depending on location and extension of the lesion. For unresectable lesions, the use of targeted molecular therapy (ie, crizotinib, tyrosine kinase inhibitor) has been utilized and proven efficacious.\(^8\) Narayanappa et al (2018) reported 2 patients free of disease at 3 years’ follow-up after complete resection.

**CONCLUSION**

Inflammatory myofibroblastic tumors are rare neoplasms of mesenchymal origin primarily seen in children and young adults. Diagnosis can be challenging due to nonspecific clinical presentation and variable anatomic locations of tumors. Diagnosis is primarily one of exclusion and confirmed by biopsy; however, \(ALK\) gene rearrangements are seen in up to 50% of cases. Imaging findings are nonspecific as well, and include variable attenuation values on CT and intermediate-to-low signal intensity on MRI. Lesions in the head and neck can appear malignant, with erosion into bone and infiltration into adjacent soft tissue. Treatment is based on complete surgical excision and the use of specific molecular targets for unresectable lesions. This case illustrates the importance of evaluating all of the images within a study. The lytic lesions revealed on X-ray of the clavicle was initially missed.

**REFERENCES**


Prepared by Mr. Greenhill while a student at Arizona College of Osteopathic Medicine, Glendale, AZ; and Dr. Aria, Dr. Schaefer, Dr. Kaye, Dr. Jorgensen, Dr. Abruzzo, and Dr. Richard Tovbin while on the faculty of Phoenix Children’s Hospital, Phoenix, AZ; and Dr. Alexander Tovbin while on the faculty of Children’s Hospital Medical Center, Cincinnati, OH..
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