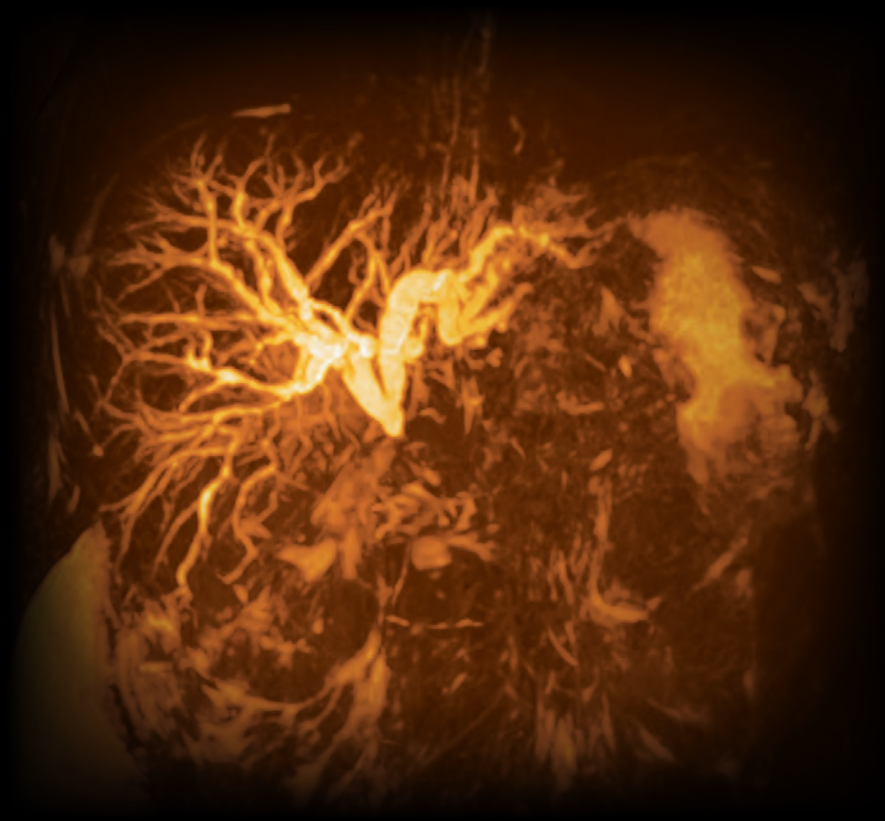
February 2025
Volume 54, Number 1

AppliedRadiology®

The Journal of Practical Medical Imaging and Management



CME Untangling the Postoperative Upper GI Tract: Imaging Appearance of Altered Anatomy and Its Complications

Klippel-Feil Syndrome Essentials, Part 2: Advanced Imaging Techniques and Diagnostic Strategies

AI and Radiology: Bridging the Gap Between Peer Review, Education, and Value-Based Care

MRI Safety Gets an Overhaul

Intraductal Papilloma in a Male Patient

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The Journal of Practical Medical Imaging and Management

Anderson Publishing, Ltd
180 Glenside Avenue,
Scotch Plains, NJ 07076
Tel: 908-301-1995
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Applied Radiology®

The Journal of Practical Medical Imaging and Management

February 2025
Vol 54 No 1

Applied Radiology (ISSN 0160-9963, USPS 943180) is published in print 6 times a year, January, March, May, July, September, and November, by Anderson Publishing Ltd at 180 Glenside Ave., Scotch Plains NJ 07076. Periodicals postage paid at Scotch Plains, NJ and additional mailing offices. Free subscriptions for US-based qualified radiology professionals. Subscriptions for the US and its territories and possessions: $115 per year, $225 for two years. Foreign and Canadian subscriptions $215 for one year payable in US funds, international money orders, or by credit card only. Postmaster: Please send address changes to Applied Radiology, PO Box 317, Lincolnshire, IL 60069-0317 (847-564-5942) or email AppliedRadiology@Omeda.com.

Celebrating Leaders on the Horizon

Erin Simon Schwartz, MD

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

One of my favorite parts of attending the annual RSNA meeting as part of the *Applied Radiology* team is the celebration of the Leaders on the Horizon program winners. Through the submission of original research papers or clinical review articles, 6 radiology residents win a trip to the meeting and a scholarship to support their educational efforts. This program highlights our tremendous partnership with Bracco Diagnostics, Inc, which provides a generous, unrestricted educational grant to support this program. Their investment in these future radiologists—future leaders in our field—is demonstrative of their commitment to radiology.

Here are the 2024 winners:

Clinical Research

1. Abhijan Maity, MD (first year), Indira Gandhi Government Medical College, Nagpur, India, for "Diagnostic Accuracy of Cerebroplacental Ratio in Anticipating Adverse Perinatal Outcome in Uncomplicated, Appropriate-for-Gestational-Age Pregnancies at Term."
2. Kamyar Ghabili, MD (second year), Penn State Health Milton S. Hershey Medical Center, Hershey, Pennsylvania, for "Comparing Diagnostic Efficacy of Contrast-enhanced Ultrasound and CT Angiography for Detecting Type 2 Endoleaks: A Comparison with Conventional Angiography and Assessment of Periprocedural Factors."
3. Luis Lorenzo Chan, MD (fourth year), St. Luke's Medical Center, Quezon City, the Philippines, for "Pleural Fluid Volume Estimates and the Actual Volume: A Cross-Sectional Analysis."

Clinical Review

1. Hira Qureshi, MD (second year), Henry Ford Hospital, Detroit, Michigan, for "Ankle Impingement Syndromes: What the Radiologist Needs to Know."
2. Yesim Yekta Yuruk, MD (fourth year), Health Sciences University Izmir Tepecik Education and Research Hospital, Izmir, Turkey, for "Computed Tomography-like Images from Magnetic Resonance Imaging: A Comprehensive Review of the Zero-Echo-Time Sequence."
3. Jacob Schick, MD (first year), Johns Hopkins, Baltimore, Maryland, for "Contrast Enhanced Ultrasound for Characterization and Biopsy of Hepatic Metastasis."

Could you be one of our 2025 winners? All radiology residents are welcome to submit a clinical research paper or a clinical review for this year's program. Winners will be considered for publication in a special supplement to *Applied Radiology*.

Go to https://appliedradiology.com/leaders or *click here to learn more about the program and apply!*

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0067

Untangling the Postoperative Upper GI Tract: Imaging Appearance of Altered Anatomy and Its Complications

Description

The authors discuss how an understanding of typical postsurgical anatomy of the upper gastrointestinal tract is fundamental for identifying and classifying postoperative complications on imaging. This review illustrates the expected imaging appearance of various bariatric, anti-reflux, gastric, and hepatopancreatobiliary surgeries, and discuss associated complications along with their multi-modality evaluation where appropriate.

Learning Objectives

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

1. Understand the surgical elements of several upper gastrointestinal tract procedures.
2. Formulate strategies for the assessment of postoperative complications.
3. Integrate multi-modality evaluation of suspected postoperative complications to guide patient management.

Target Audience

- Radiologists
- Related Imaging Professionals

Authors

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Commercial Support

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CE: March 5, 2025

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Disclosures

Planner: Erin Simon Schwartz, MD, discloses no relevant financial relationships with any ineligible companies.

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CME DETAILS ON PAGE 5

Untangling the Postoperative Upper GI Tract: Imaging Appearance of Altered Anatomy and Its Complications

Thomas Seykora, MD; Charles M. Vollmer, MD; Melkamu Adeb, MD

Introduction

There are many surgical procedures involving the upper gastrointestinal (UGI) tract that result in altered anatomy, such as new alimentary conduits and/or enteric, biliary, or pancreatic anastomoses. These are performed for a variety of indications, which include bariatric and metabolic surgery, malignancy resection, biliary disease, chronic pancreatitis, and reconstruction following injury.

As radiologists play a critical role in assessing postoperative complications, their understanding of postsurgical anatomy is essential for appropriate image interpretation and subsequent patient management. This article reviews common UGI operations, demonstrates their expected postoperative imaging appearance, and highlights pertinent complications.

UGI Procedures That Alter Anatomy

Bariatric Surgery

Roux-en-Y Gastric Bypass

The Roux-en-Y gastric bypass (RYGB) is performed for the treatment of obesity and its associated disorders.[1] As its applications have grown, the number of surgeries performed has increased.[2]

Technically, the RYGB involves stapling the stomach into a gastric pouch and remnant stomach; creating a biliopancreatic limb in continuity with the remnant stomach and duodenum; anastomosis of the biliopancreatic limb to the jejunum (jejunojejunostomy); and restoring the UGI tract by anastomosing the gastric pouch to the jejunum (gastrojejunostomy).[3]

When identifying an alimentary limb on CT, it helps to work proximally from the gastroesophageal junction and administer oral contrast (Figure 1). Searching for the luminal staple line on multiple planes can help identify the jejunojejunostomy, which can vary in location.

Complications associated with RYGB surgery can occur immediately or later in the postoperative period (Table 1).[4] Perforation, a notable late-stage complication, is typically the complication of an ulcer (Figure 1).[4] Internal hernias are infrequent and result from migration of bowel loops into mesenteric defects (e.g., Petersen space) created during surgery (Figure 1). Common findings include small bowel obstruction with focal transition points, crowding and abnormal location of small bowel loops, and mesenteric abnormalities such as swirling, engorgement, and stretching of mesenteric vessels.[5] Gastro-gastric fistula, which can have early or late onset, should be considered when patients have postoperative weight gain (Figure 1).[6]

Less common complications include the Roux-en-O error in which the biliopancreatic limb is connected to the gastric pouch, creating a continuous, obstructive circuit.[7] Afferent loop syndrome, an infrequent condition that results from an isolated obstruction of the biliopancreatic limb,[8] should be differentiated from typical obstruction, as it may warrant a

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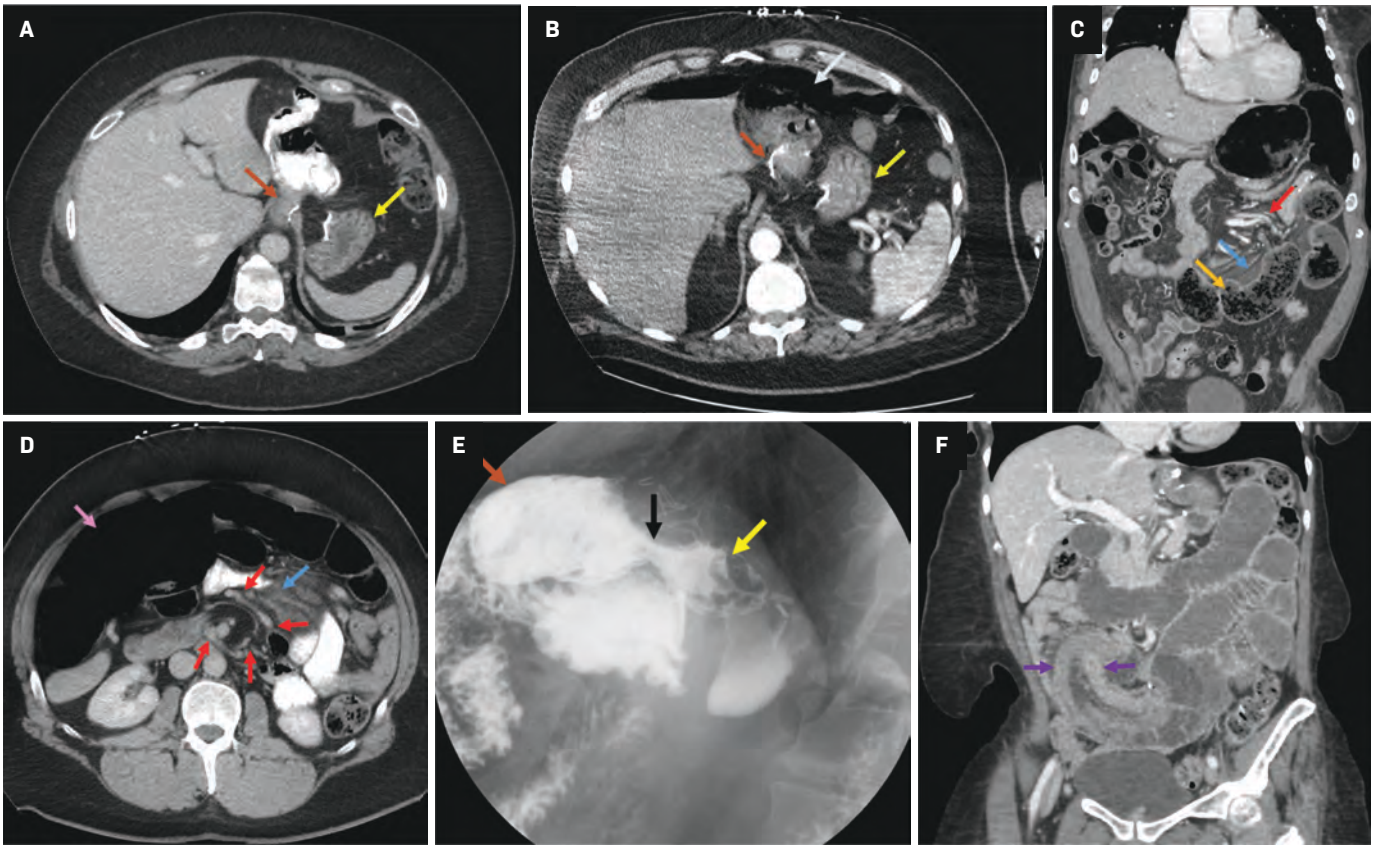
Disclosure: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0058

Figure 1. Contrast-enhanced axial CT with oral contrast demonstrates normal postsurgical anatomy of Roux-en-Y gastric bypass (RYGB) (A) with the formation of the gastric pouch and alimentary limb (brown arrow) and excluded remnant stomach and afferent limb (yellow arrow). Contrast-enhanced axial CT (B) demonstrates pneumoperitoneum (white arrow) in a patient with a remote history of RYGB (brown and yellow arrows). The patient underwent laparotomy and Graham patch repair of a perforation at the gastrojejunal anastomosis. Contrast-enhanced coronal CT reformation of a patient with prior RYGB (C) demonstrates small bowel obstruction with dilated and fecalized small bowel (orange arrow), mesenteric swirling (red arrow), and edema (blue arrow). The patient underwent diagnostic laparotomy, which confirmed a perforated Petersen space internal hernia. Contrast-enhanced axial CT with oral contrast of a patient with prior RYGB (D) demonstrates mesenteric swirling (red arrows) and edema (blue arrow); small bowel obstruction was present (not shown). Ascending and transverse colon dilation was also noted (pink arrow). The patient underwent diagnostic laparoscopy, which confirmed an internal hernia through the jejunojejunostomy mesenteric defect. Upper gastrointestinal fluoroscopy in a patient with a prior RYGB (E) demonstrates an abnormal connection (black arrow) between the gastric pouch (brown arrow) and excluded stomach (yellow arrow). Endoscopy confirmed the presence of a 1.5 cm gastro-gastric fistula. Contrast-enhanced coronal CT reformation in a patient with prior RYGB (F) demonstrates small bowel obstruction secondary to jejunojejunal intussusception (purple arrows). Diagnostic laparoscopy demonstrated large segment common channel intussusception, which was successfully reduced and treated with enteroplication of the biliopancreatic limb to the common channel.



follow-up endoscopic evaluation of the jejunojejunostomy.[9] Retrograde intussusception, while rare, usually presents with symptoms of bowel obstruction (Figure 1).[10]

Duodenal Switch

The duodenal switch (DS), also known as biliopancreatic diversion with duodenal switch (BPD-DS), is less common than RYGB but it has seen a recent renaissance.[2] This approach combines a sleeve gastrectomy (SG) with diversion of bile and pancreatic enzymes, which leads to fat malabsorption and weight loss.[11] This can be performed as a primary operation or for patients who have experienced weight gain after SG alone as it is sometimes safer than a repeat SG or RYGB revision.[12]

The procedure consists of SG; transection of the duodenum and ileum to create the biliopancreatic limb; duodenoileostomy to restore continuity of the UGI tract and create the alimentary limb; and ileoileostomy to anastomose the biliopancreatic limb to the alimentary limb.[12]

Strategies to identify the alimentary limb are similar to those used for RYGB. The duodenal stump of the biliopancreatic limb can usually be identified by a surgical staple line near the porta hepatis. As with RYGB, the intra-abdominal location of the ileoileostomy can vary (Figure 2).

Complications associated with BPD-DS are analogous to those for

Table 1. Upper Gastrointestinal Tract Surgeries, Anastomoses, and Complications

SURGERY	ANASTOMOSES	COMPLICATIONS
Roux-en-Y gastric bypass	Gastrojejunostomy Jejunojejunostomy	*Early* Anastomotic leak Gastro-gastric fistula Hemorrhage Intra-abdominal infection Roux-en-O error Stenosis *Late* Afferent loop syndrome Gastro-gastric fistula Internal hernia Intussusception Marginal ulcer Obstruction Perforation
Duodenal switch	Duodenoileostomy Ileoileostomy	Afferent loop syndrome Anastomotic leak Bowel obstruction Duodenal stump leak Hemorrhage Internal hernia Stenosis
Nissen, Toupet, or Dor fundoplication	N/A	Gastric/esophageal leak Stomach slippage Tight wrap Wrap disruption Wrap migration
Billroth I	Gastroduodenostomy	Anastomotic leak Bowel obstruction Hemorrhage Intra-abdominal infection Marginal ulcer Reflux
Billroth II	Gastrojejunostomy ± BEE	Afferent loop syndrome Anastomotic leak Anastomotic stricture Bowel obstruction Duodenal stump leak Efferent loop syndrome Gastric adenocarcinoma

RYGB (Table 1).[13,14] In particular, the duodenal stump can leak. Clues to this diagnosis include fluid or free air adjacent to the staple line. Diagnosing duodenal stump leak using CT with oral contrast or fluoroscopic studies can be challenging as the peristaltic wave of the biliopancreatic limb toward the ileoileostomy hinders retrograde flow of contrast along the long luminal channel. Additionally, afferent loop syndrome is possible, although rare.[15]

Anti-Reflux Surgery

Fundoplication

Gastroesophageal reflux disease is common, affecting an estimated 20% of North Americans.[16] Nissen fundoplication is a popular, antireflux surgery used with patients who have refractory symptoms despite medical therapy.[17] The technical elements include mobilization of the distal esophagus into the abdomen and suturing the proximal stomach in a 360° wrap around the esophagus, which contains a bougie dilator to maintain patency.[18] A partial 270° posterior wrap (Toupet) or anterior 180° wrap (Dor) are performed in some instances, such as when there is underlying esophageal dysmotility.[16]

On CT, the fundoplication wrap normally appears as a swirling, focal bulge below the esophageal diaphragmatic hiatus and can contain oral contrast (Figure 3).[18] Fluoroscopy will demonstrate narrowing of the distal esophagus and a smooth filling defect.[18]

Complications are predominantly related to wrap formation and integrity (Table 1).[18] Patients can present with symptoms of recurrent reflux, obstruction, or both, which are typically evaluated with fluoroscopy (Figure 3).[18] Intraoperative gastric or esophageal

Table 1. continued

SURGERY	ANASTOMOSES	COMPLICATIONS
		Hemorrhage Internal hernia Intra-abdominal infection Marginal ulcer
Total gastrectomy	Esophagojejunostomy Jejunojejunostomy	Afferent loop syndrome Anastomotic leak Bowel obstruction Hemorrhage Internal hernia Intra-abdominal infection
Whipple	Duodeno- or gastrojejunostomy Hepaticojejunostomy Pancreaticojejunostomy or pancreaticogastrostomy ± BEE	Afferent loop syndrome Anastomotic leak Bile leak Pancreatic fistula Anastomotic stricture Delayed gastric emptying Hemorrhage GDA pseudoaneurysm Intra-abdominal infection Marginal ulcer Pancreatitis
Total pancreatectomy	Gastrojejunostomy Hepaticojejunostomy	Anastomotic leak Bile leak Anastomotic stricture Hemorrhage Intra-abdominal infection Marginal ulcer
Puestow procedure	Jejunojejunostomy Pancreaticojejunostomy	Anastomotic leak Bowel obstruction Hemorrhage Intra-abdominal infection
Roux-en-Y hepaticojejunostomy or choledochojejunostomy	Hepaticojejunostomy and jejunojejunostomy Choledochojejunostomy	Anastomotic leak Bile leak Anastomotic stricture Cholangitis Intra-abdominal infection Sump syndrome

Abbreviations: BEE, Braun enteroenterostomy; GDA, gastroduodenal artery.

perforations, while rare, have been reported.[19]

Gastrectomy

Billroth I and Billroth II

The Billroth I (BI) reconstruction is used to resect a malignancy or an ulcer following a distal gastrectomy. It is an end-to-end reconstruction of the alimentary tract, involving a gastroduodenostomy between the remnant stomach and duodenum.

The Billroth II (BII) reconstruction, an alternative procedure, is applied more frequently. Rather than directly re-anastomosing the duodenum and remnant stomach, the BII entails stapling the proximal duodenum to create a duodenal stump near the Ampulla of Vater.[20] A gastrojejunostomy is then performed to restore continuity of the GI tract.[20] The afferent limb may be formed in either an iso- or anti-peristaltic configuration. A variation using a Roux limb for the gastrojejunostomy, which involves the creation of a jejunojejunostomy distal to the gastrojejunostomy, has grown in popularity.[21] Furthermore, a Braun enteroenterostomy (BEE), an "omega loop" forming a side-to-side jejunojejunostomy that diverts retrograde reflux, is sometimes added to the procedure.[22]

On CT, following the esophagus distally to the remnant stomach will help identify the gastrojejunostomy (Figure 4). The duodenal stump staple line is similarly identified adjacent to the liver (Figure 4).

The complication profiles of BI and BII are similar (Table 1).[23-25] Internal hernia is only possible following BII, especially with Roux limb variants.[26] As in BPD-DS, the BII duodenal stump can, rarely, be the source of an anastomotic leak (Figure 4)[27] and

Figure 2. Contrast-enhanced coronal CT reformation with oral contrast demonstrates the normal appearance of a duodenal switch, with sleeve gastrectomy (brown arrow), biliopancreatic limb (green arrows), and ileoileal anastomosis (yellow arrow).

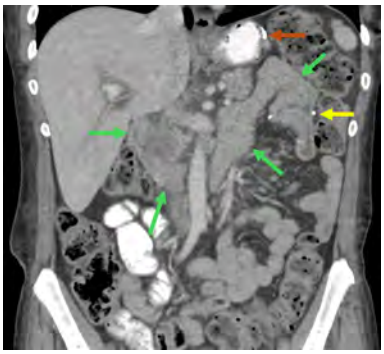
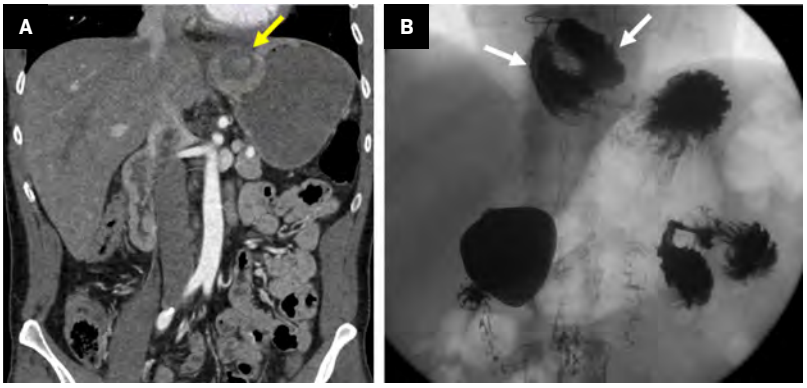


Figure 3. Contrast-enhanced coronal CT reformation (A) demonstrates the normal appearance of a Nissen fundoplication, with a swirling bulge located just below the esophageal diaphragmatic hiatus (yellow arrow). Upper gastrointestinal fluoroscopy (B) demonstrates partial unwrapping of a Nissen fundoplication, which contains oral contrast within the wrap (white arrows) and is located above the diaphragm.



afferent loop syndrome is possible (Figure 4).[28] Even more rare is efferent loop syndrome, which is obstruction at the gastrojejunostomy from edema or limb kinking in the early postoperative period, which presents with symptoms of bowel obstruction.[29]

Total Gastrectomy

Total gastrectomy is performed when gastric malignancy affects the proximal stomach, and a Roux-en-Y esophagojejunostomy is the preferred method for reconstruction.[20] The process involves transection of the distal esophagus and duodenum, creating the duodenal stump and biliopancreatic limb; transection of the jejunum and re-anastomosis with esophagojejunostomy, creating the alimentary limb; and jejunojejunostomy to anastomose the biliopancreatic and alimentary limbs. Strategies for identifying these limbs on imaging are similar to those previously discussed.

Postoperative complications are similar to those for BII (Table 1). One feared complication is leakage of the esophagojejunal anastomosis (Figure 5).[30] The presence of fluid or free air adjacent to the anastomosis or new pleural/mediastinal effusion should raise suspicion of a leak.

Hepatopancreatobiliary Surgery

Whipple

The Whipple procedure, also called pancreaticoduodenectomy, is performed for malignant and benign diseases of the pancreatic head.[31] The technique comprises resection of the pancreatic head, duodenum, and proximal jejunum; cholecystectomy; pancreaticojejunostomy, or less commonly pancreaticogastrostomy; duodenojejunostomy (in pylorus-preserving Whipple) or gastrojejunostomy; and hepaticojejunostomy. Optional BEE has also demonstrated lower rates of delayed gastric emptying and afferent loop syndrome (Figure 6).[32]

Identifying the anastomosis following a pancreaticojejunostomy is aided by identifying the remnant pancreas in the native bed and then searching distally. Alternatively, searching backward a few centimeters from the jejunal end, often delineated with a staple line, will lead to the pancreaticojejunostomy site. A pancreaticogastrostomy will be visible following the stomach distally from the gastroesophageal junction. Determining the location of the common hepatic duct and proximal common bile duct (CBD) is useful before moving distally to the hepaticojejunostomy, and the presence of pneumobilia can aid in detection.[33] Lastly, following the stomach distally from the gastroesophageal junction will help identify the duodenojejunostomy/gastrojejunostomy, most often now in a left upper-quadrant, antecolic position.

The postoperative complications from the Whipple procedure are summarized in Table 1.[31] Postoperative pancreatic fistula (POPF), or leakage of pancreatic enzyme-containing fluid from the pancreaticojejunostomy (Figure 7), is a hazardous complication that has received great attention in surgical literature.[34] One challenge in diagnosing POPF on imaging is differentiating between benign, reactive peripancreatic postsurgical fluid and fluid stemming directly from pancreatic leak. Helpful clues for diagnosis are the presence of extraluminal air or surrounding inflammatory changes, clinical exam findings, and surgical drain output parameters.[31,35] Furthermore, the presence of fluid adjacent to the hepaticojejunostomy can be indicative of a bile leak; however, distinguishing this from a POPF can be challenging on CT.[31] If suspected, a nuclear medicine hepatobiliary

Figure 4. Coronal CT reformation (A) demonstrates normal appearance of a Billroth II gastrojejunostomy (brown arrow) and duodenal stump (green arrow). Contrast-enhanced coronal CT reformation with oral contrast of a patient with leukocytosis (B) on postoperative day 3 following gastrectomy with Billroth II reconstruction. There is a right upper-quadrant fluid collection (blue arrows) abutting the duodenal stump (green arrow). Percutaneous drainage was performed, which removed 375 mL of bilious fluid, suspicious for a duodenal stump leak. Contrast-enhanced coronal CT reformation of a patient with prior Billroth II reconstruction (C) presenting with nausea and vomiting. There is dilation of the biliopancreatic limb (yellow arrows) with normal caliber of the efferent limb (brown arrow) consistent with afferent limb syndrome. The patient's symptoms and imaging findings resolved with nasogastric tube decompression. Follow-up endoscopy was unremarkable.

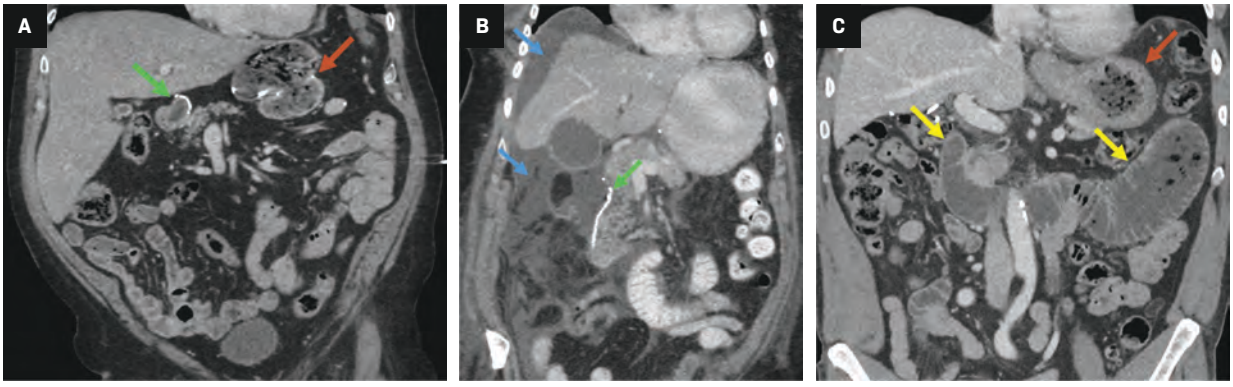


Figure 5. Contrast-enhanced coronal CT reformation of a patient with recent total gastrectomy demonstrates air (white arrows) and fluid (blue arrow) adjacent to the esophagojejunal anastomosis along with a left pleural effusion (purple arrow) concerning for leak. Anastomotic leak was confirmed at laparotomy and treated with esophageal stent placement.

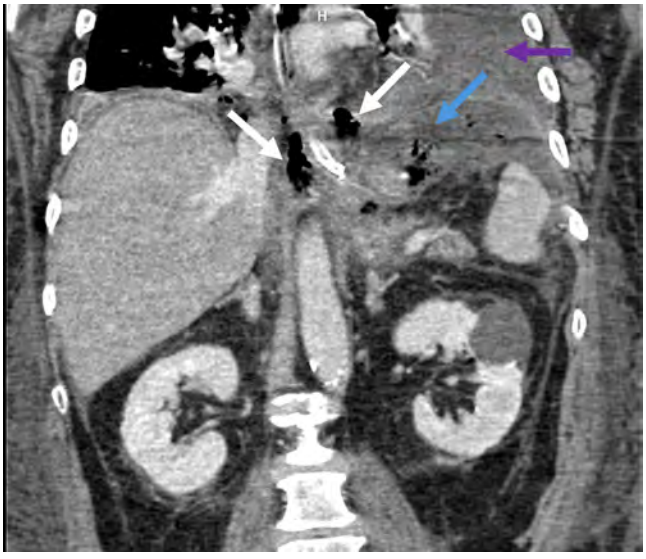
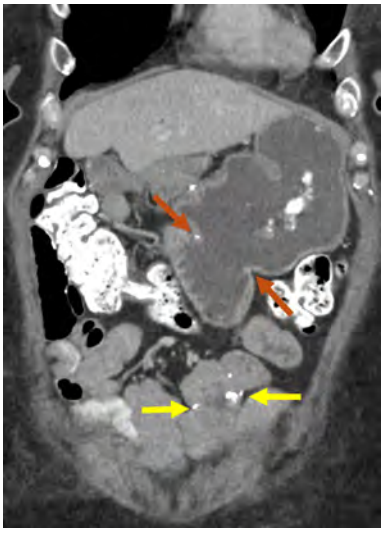


Figure 6. Contrast-enhanced coronal CT reformation with oral contrast demonstrates the normal appearance of a Whipple with gastrojejunostomy (brown arrows) and additional side-to-side Braun enteroenterostomy (yellow arrows).



iminodiacetic acid (HIDA) scan can be a helpful adjunct. In the long term, stricture may develop at the hepaticojejunostomy, resulting in jaundice or cholangitis, and this can be assessed with magnetic resonance cholangiopancreatography (MRCP, Figure 7).[31]

Total Pancreatectomy

Removal of the entire pancreas is performed for malignancies, multifocal tumors, cystic neoplasms (intraductal papillary mucinous neoplasm), refractory chronic pancreatitis, or in a "staged" or "completion" fashion following an initial partial pancreatectomy. In addition to the pancreas, the spleen, duodenum, gallbladder, and CBD are removed.[31] Reconstruction involves hepaticojejunostomy and gastrojejunostomy. Methods for identifying pancreatectomy (Figure 8), and its postsurgical complications, are similar to those described for Whipple, but without the risk of a pancreatic leak. Development of a bile leak or marginal ulcer can require reintervention (Table 1).[36]

Puestow

The Puestow procedure, or lateral pancreaticojejunostomy, is performed as a pancreatic duct

Figure 7. Contrast-enhanced coronal CT reformation (A) on postoperative day 3 following a Whipple. There is a biliary stent and a fluid collection extending into the left upper-quadrant (blue arrows), which abuts the pancreaticojejunostomy (orange arrow). Percutaneous drainage removed 100 mL of gray fluid with amylase of 7915 and lipase > 300,000, consistent with pancreatic fistula. Coronal maximum intensity projection (MIP) image from 3D magnetic resonance cholangiopancreatography in a patient with prior Whipple (B) and symptoms of biliary obstruction demonstrates an abrupt cutoff and signal loss at the hepaticojejunostomy suspicious for stricture (green arrow). Subsequent percutaneous transhepatic cholangiogram showed a high-grade anastomotic stricture that was treated with an internal/external biliary drain.

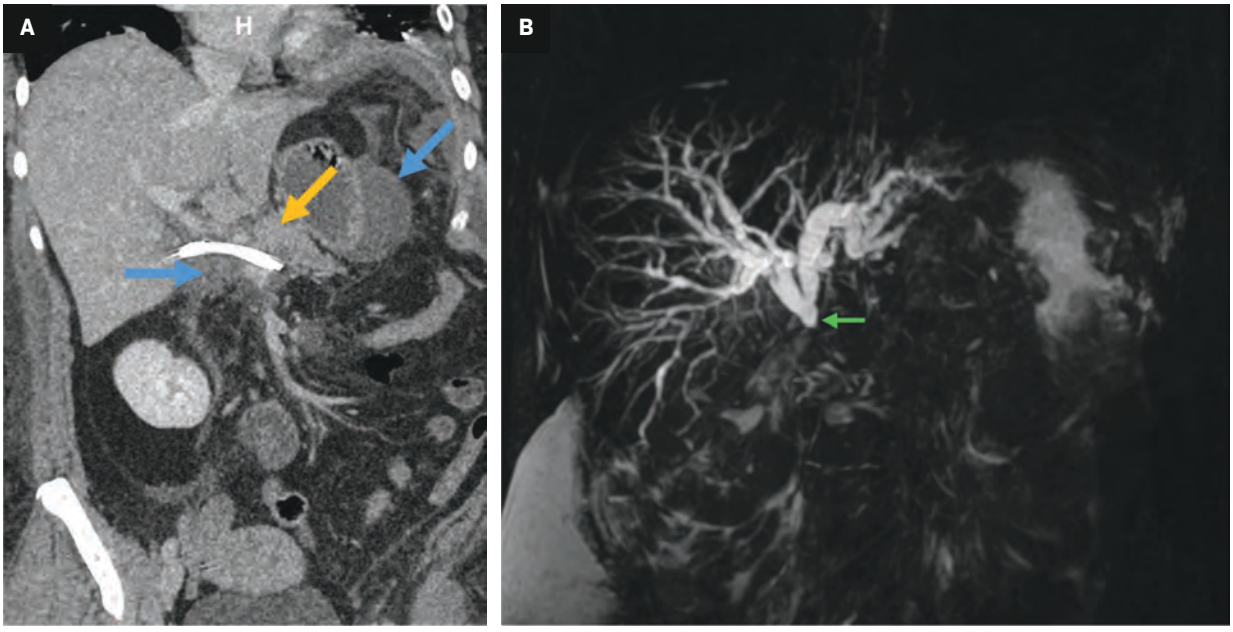


Figure 8. Normal contrast-enhanced coronal CT reformation with oral contrast of a patient with prior total pancreatectomy. The hepaticojejunostomy is sometimes identified by the presence of pneumobilia (white arrow).

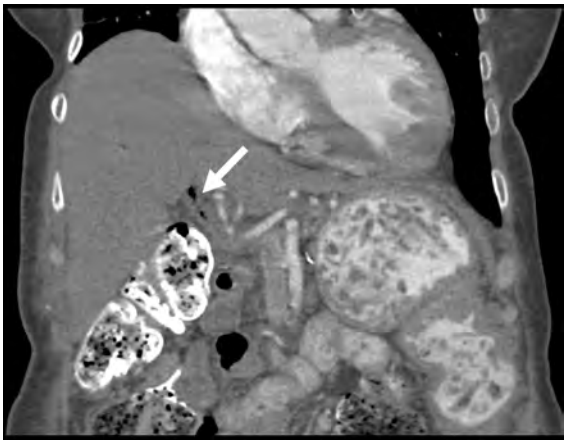
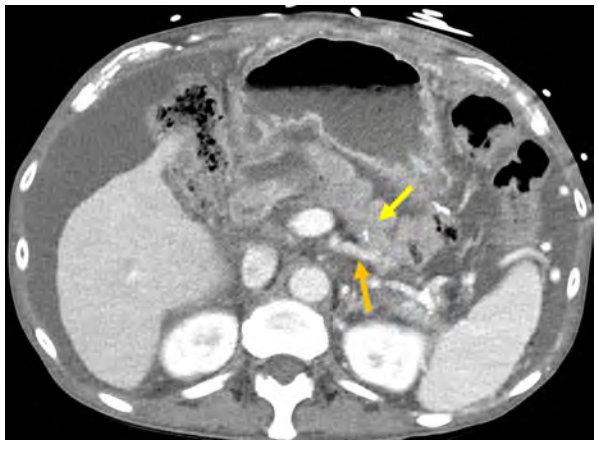


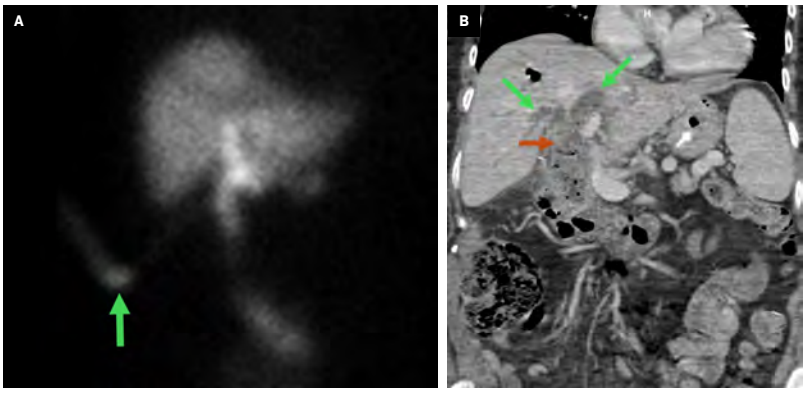
Figure 9. Contrast-enhanced axial CT demonstrates normal appearance of a Puestow procedure, with the jejunal limb (yellow arrow) and atrophic remnant pancreas (orange arrow).



drainage procedure for chronic pancreatitis. This consists of creating a longitudinal incision along the main pancreatic duct; creation of a jejunal Roux limb and pancreaticojejunostomy along the pancreatic duct incision; and jejunojejunostomy to restore GI tract continuity (Figure 9). There are also variations of this procedure, which involve additional uncovering the pancreatic head (Frey procedure) or removal of the pancreatic head (Beger procedure), both of which rely on Roux limb drainage.[37]

Associated complications include intra-abdominal infection, hemorrhage, obstruction, and rarely

Figure 10. Nuclear medicine hepatobiliary iminodiacetic acid scan (A) on postoperative day 3 following a choledochojejunostomy revision for choledocholithiasis demonstrates radiotracer activity within a surgical drain terminating in the gallbladder fossa (green arrow), consistent with postoperative bile leak. Contrast-enhanced coronal CT (B) reformation of a patient with prior choledochojejunostomy demonstrates intrahepatic biliary duct dilatation (green arrows) and debris in the distal common bile duct (brown arrow), suspicious for sump syndrome. The patient subsequently developed recurrent episodes of cholangitis and required treatment with multiple endoscopic retrograde cholangiopancreatographies.



anastomotic leak, with infection among the more common (Table 1).[38]

Roux-en-Y Hepaticojejunostomy

Roux-en-Y hepaticojejunostomy (RYHJ) is a reconstruction technique applied following biliary bypass for benign or post-transplant stricture, resection of malignancy involving the biliary tree, choledochal cyst resection, or repair of iatrogenic or traumatic injury.[39] The technique involves the creation of a jejunal Roux limb, hepaticojejunostomy, and jejunojejunostomy to restore GI tract continuity. A variant is the choledochoduodenostomy, which is a technically simpler procedure where the bile duct is directly re-anastomosed to duodenum, avoiding transection and re-anastomosis of jejunum. When feasible, RYHJ, which has fewer long-term complications, is favored.[40]

Tips to identify the hepaticojejunostomy are like those previously described. Complications associated with RYHJ are predominantly related to the biliary anastomosis (Table 1).[41,42] Nuclear medicine HIDA scan and MRCP can be useful additional studies for the evaluation of bile leak and stricture (Figure 10). The rare complication of sump syndrome is more prevalent in choledochoduodenostomy and typically occurs in a side-to-side anastomosis where debris accumulating in the bile duct distal to the anastomosis causes obstruction (Figure 10).[43] As a result, these patients are prone to developing cholangitis.[44]

Conclusion

There are many UGI tract surgeries that result in altered anatomy and the creation of new limbs/conduits. An understanding of the expected postsurgical appearance is fundamental to identify postoperative complications, many of which stem from the creation of new anastomoses. Multimodality evaluation with CT, fluoroscopy, MRI with MRCP, and HIDA scan can aid in further evaluation of suspicious findings and guide patient management.

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Klippel-Feil Syndrome Essentials, Part 2: Advanced Imaging Techniques and Diagnostic Strategies

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Introduction

In part 1 of our review, we explored the embryological development and genetic foundations of Klippel-Feil syndrome (KFS), providing a critical understanding of its origins. Part 2 focuses on the more clinical aspects of KFS, including its diagnosis, associated conditions, and imaging techniques. We aim to address the challenges posed by the syndrome's phenotypic variability and highlight the importance of imaging in confirming diagnoses and guiding treatment.

Imaging

Imaging is vital to confirm a suspected case of KFS as the patterns of fusion may aid in future follow-up and potentially screen for those at highest risk for developing spinal cord injury. Though less sophisticated than current KFS classification systems, one could broadly diagnose KFS in anyone with any degree of congenital cervical vertebrae fusion.[1-3] Congenital fusions are demonstrated by osseous bridging between 2 or more vertebrae.[4,5] This fusion typically goes undetected until later in life when mechanical or neurological signs and symptoms may begin.[6,7] Diagnosis may be complicated owing to the natural ossification progression of the pediatric cervical spine. Ongoing ossification may make cervical synostosis difficult to appreciate on radiographic imaging.[6] Pseudosubluxation, which can be normal in children less than 8 years old, particularly involving C2-C4, should not be mistaken for instability.[8,9]

The original and most commonly used classification of KFS is based on the extent of the fusion. Type I involves massive fusion of cervical and upper thoracic vertebrae (Figure 1). Type II is characterized by fusion at only 1 or 2 interspaces, often accompanied by other cervical spine anomalies such as hemivertebrae or atlantooccipital fusion (Figure 2). Type III includes cervical fusions associated with lower thoracic or lumbar fusion (Figure 3). Other classification systems were discussed in Part 1.

A 2006 study by Samartzis et al[5] examined the congenital fusion patterns of 28 predominantly pediatric patients with KFS. They classified type I as a single, congenitally fused cervical segment (25% of patients), type II as multiple, noncontinuous fused segments (50% of patients), and type III as multiple contiguous fused segments (25% of patients), with axial neck symptoms common in type I and radiculopathy and myelopathy more common with types II and III. Employing this same classification system, Gruber et al[10] found that all 17 patients with KFS in their large retrospective CT review were Samartzis type I. They noted that vertebral levels C2-C3 and C5-C6 were the most commonly fused but that congenital

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Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0056

Figure 1. Type I Klippel-Feil syndrome (KFS). (A) Sagittal CT in bone window and (B) fat-saturated sagittal T2-weighted MRI show type I KFS with anterior and posterior fusion of C4-C6 and wedge-shaped C3. MRI also demonstrates the platybasia, cerebellar tonsillar ectopia, and basilar invagination with mass effect on the brainstem and the cervicomedullary junction.

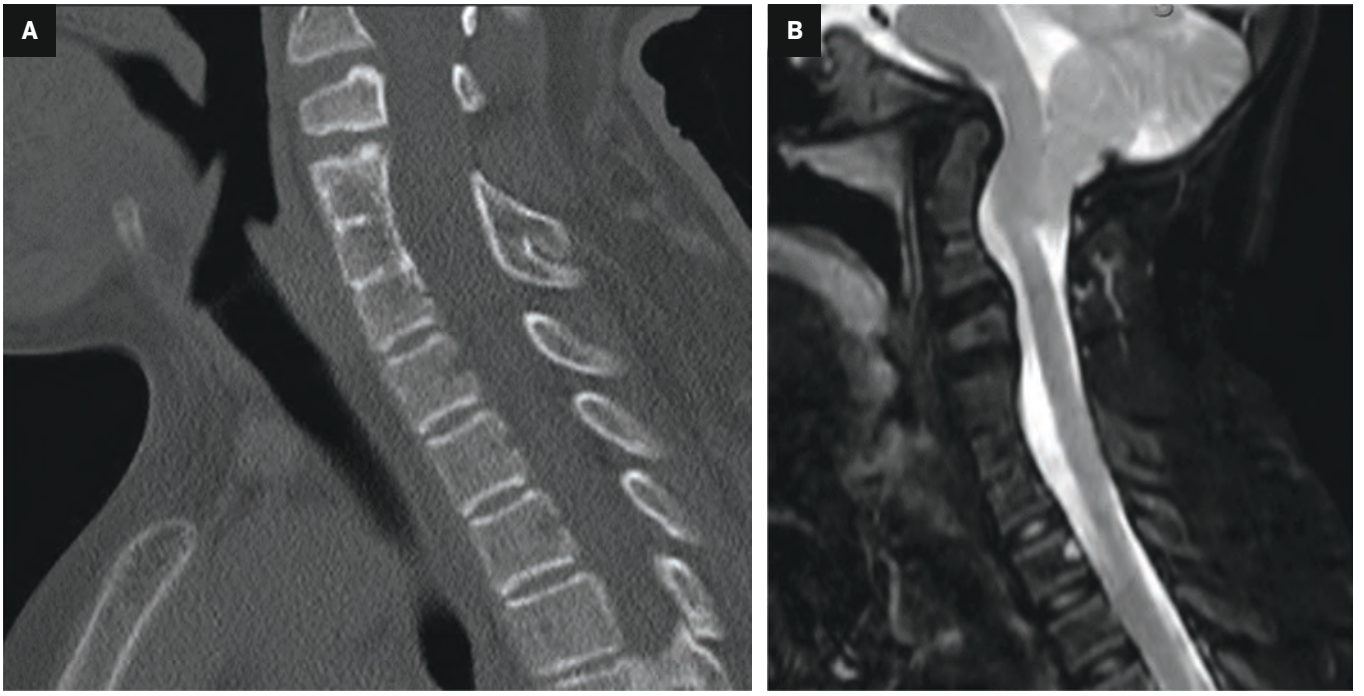


Figure 2. Type II Klippel-Feil syndrome (KFS). (A) Lateral radiograph in neutral position and (B) sagittal T2-weighted MRI show type II KFS with multilevel anterior and posterior cervical vertebral fusion and atlantooccipital fusion. MRI also demonstrates significant upper cervical spinal canal narrowing.

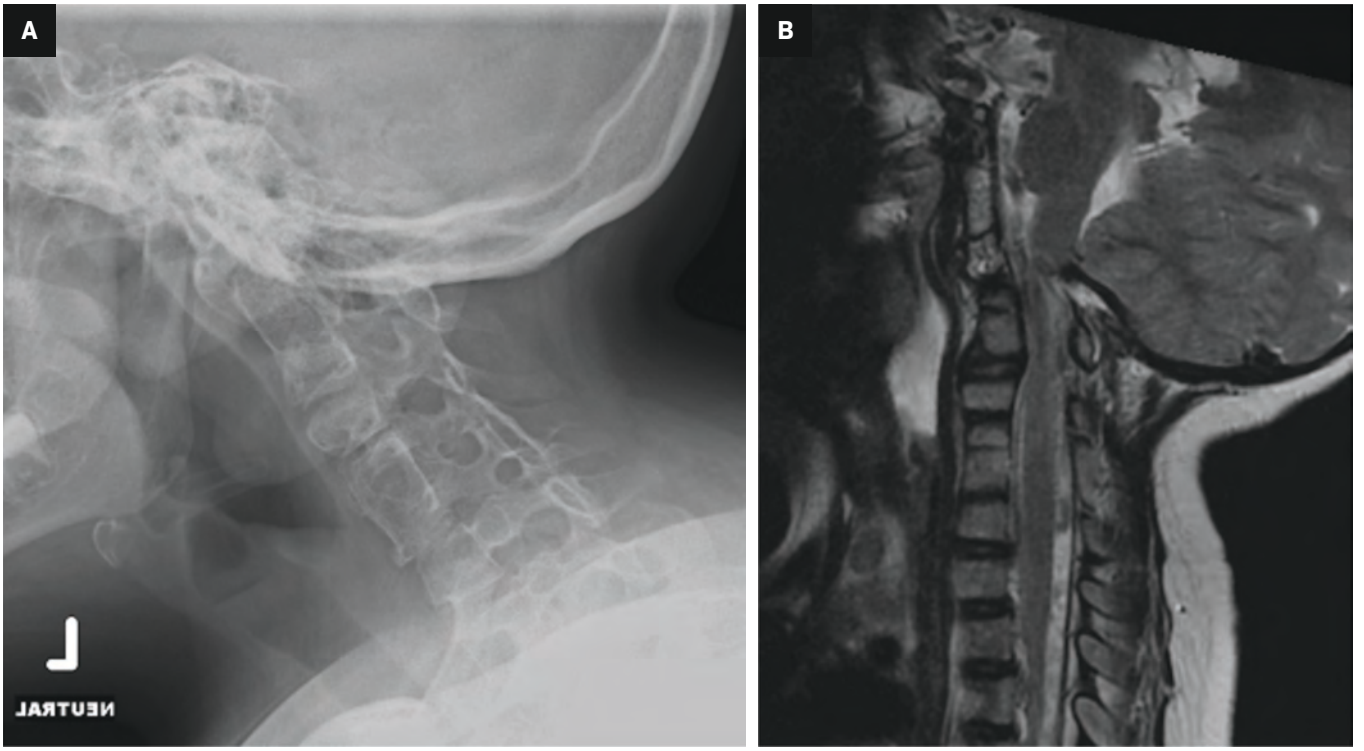
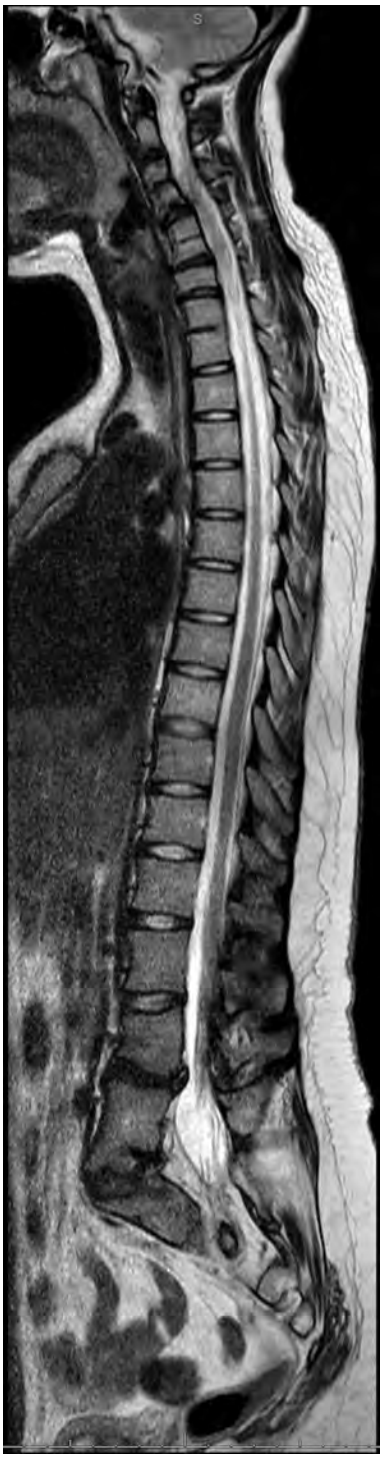


Figure 3. Type III Klippel-Feil syndrome (KFS). Complete spine T2-weighted sagittal MRI showing type III KFS with fusion at C3-C4, C5-C6, T1-T2, L2-L3, and L4-L5 vertebra. Disc degeneration is observed in the superior C4-C5 junctional level.



scoliosis, a reportedly common finding in KFS,[11,12] was absent in their patients. Further research is needed to determine the prevalence of individual fusion patterns, but a region-specific classification system can provide insight into the risk of future symptom development.

Another classification described in 2008 by Samartzis et al[4] categorizes fusion patterns in KFS as anterior, posterior, and complete fusion based on lateral radiographs. Anterior fusion involves interbody bridging, posterior fusion involves the facet joints, posterior arches, and spinous processes, and complete fusion includes both anterior and posterior fusion. Complete fusion may be seen radiographically as the "wasp-waist sign" (Figure 4),[13] an anterior indentation occurring at the interbody space of the fused segments.[14]

With this classification system in place, Samartzis et al[4] then retrospectively looked at patients with KFS stratified by age and found that the prevalence of complete fusion increased with age, while incomplete fusion was more prevalent in younger age groups. The incompletely fused segments were most commonly posterior. Familiarity with the categories of fusion and their more commonly associated ages can aid in distinguishing KFS from changes related to juvenile rheumatoid arthritis,[15,16] fibrodysplasia ossificans progressiva,[17-19] ossification of the posterior longitudinal ligament,[20] and ankylosing spondylitis.

Atlantoaxial instability is a common risk factor in patients with KFS that could potentially lead to cervical spinal cord injury (Figure 2). It is important to diagnose this instability because patients with hypermobility in the upper cervical region have been shown to be at the greatest risk for spinal cord injury.[21] However, some suggest that hypermobility of the atlantoaxial junction does not definitely increase the risk for neurological signs.[22]

Spinal stenosis, another risk factor for cervical spinal cord injury in KFS,[23,24] is measured as the space available for the cord (SAC) and examined on lateral neutral radiographs.[25] A SAC of <13 mm suggests an inadequate amount of space for the spinal cord; however, SAC typically *increases* at levels of congenital fusion.[25] This suggests cervical injuries are more likely the result of hypermobility between fused and nonfused segments rather than stenosis.

The vertebral body width (VBW) may be a more reliable anatomical marker for assessing the risk of spinal cord injury. The VBW is measured at the midpoint of each body, including the fused segments, on anteroposterior radiographs. Patients with KFS show an average decrease in VBW of the fused segments compared with the nonfused segments, and this lower VBW has been associated with an increased prevalence of cervical spinal cord injury.[25] This further supports the hypothesis that cervical spinal cord injuries are due to hypermobility because of the unequal articulating surface areas leading to facet joint instability. The difference of articulating surface areas may also explain the high prevalence of degenerative vertebral changes in KFS[9,26] (Figure 5).

The cervical spinal cord has a smaller cross-sectional area in patients with KFS from the C2-C7 segments.[27] This suggests a loss of axons, but it is not known whether the loss is secondary to mechanical stress on the spinal cord or developmental.[27]

Although cervical fusion is the hallmark of KFS, other spinal and appendicular skeletal abnormalities, including hemivertebrae, butterfly vertebrae, scoliosis, kyphosis,

Figure 4. Segmentation anomaly in type I Klippel-Feil syndrome (KFS). Sagittal CT in bone window showing hemivertebrae at C4, a vertebral body segmentation anomaly commonly seen in KFS, with a "wasp-waist" sign at the level of fusion.

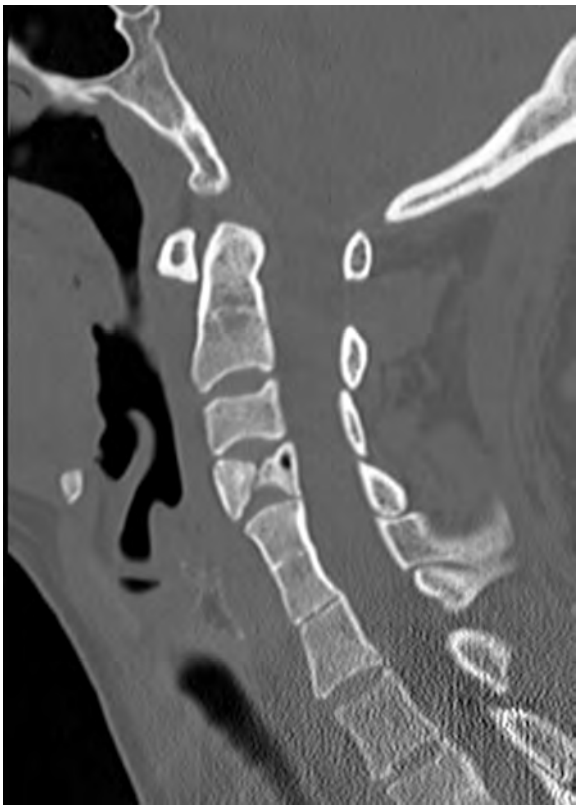
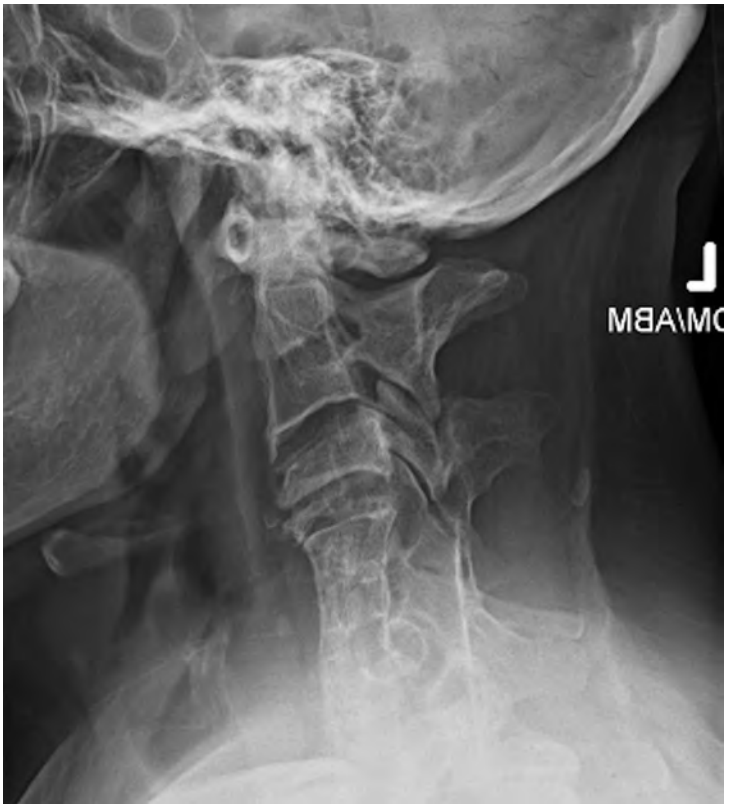


Figure 5. Degenerative changes in type I Klippel-Feil syndrome (KFS). Lateral radiograph in neutral position demonstrating type I KFS with fusion of C4-C7 and superior junctional degeneration changes in the C3-C4 vertebral bodies.



thoracic and/or lumbar fusion, cervical ribs, and bifid ribs, may be present (Figure 4),[28-31] highlighting the importance of imaging a KFS patient's entire spine. Moreover, because of the array of visceral and sensory deformities associated with KFS, additional imaging is needed. At a minimum, patients should undergo imaging of their entire spine, renal ultrasound, neurological assessment, and auditory testing. Follow-up often includes annual cervical flexion and extension radiographs for higher-risk patients based on their fusion pattern. Lower-risk patients may undergo less frequent follow-up.[32]

Spine MRI is the preferred modality for assessing neuropathic symptoms such as myelopathy and radiculopathy as it can readily diagnose spinal cord abnormalities such as syringomyelia.[33]

Diagnosis and Clinical Associations

Clinicians forming treatment plans for patients with KFS must consider the association between KFS and other anomalies. Considerable phenotypic heterogeneity among patients with KFS has led to several cohort studies describing various presentations of the syndrome.[22,34,35] These variations in phenotype may contribute to diagnostic challenges.[36] Traditionally, patients with KFS have been identified by a triad of symptoms—a low-set hairline on the posterior head, a short neck, and limited neck movement—but fewer than 50% patients with KFS exhibit these characteristics.[37,38] Fusion patterns, the extent of fusion, and the location of the rostral-most fusion could serve as more accurate diagnostic criteria for KFS.

Klippel-Feil syndrome is often diagnosed after a patient presents to the clinician with related neurological symptoms, commonly nuchal rigidity and sensory motor disorders in the distal upper extremities.[39,40] Approximately 78% of patients with KFS have scoliosis.[36] Neurological symptoms are present in about 25% of patients with KFS, which Rovreau et al[41] have attributed to cervical hypermobility. A host of other craniofacial abnormalities have been associated with KFS, such as cleft palate, micrognathia, and dental anomalies.[36] The literature

Figure 6. Genitourinary abnormalities in Klippel-Feil syndrome. Axial T2-weighted MRI image showing an absent left kidney.

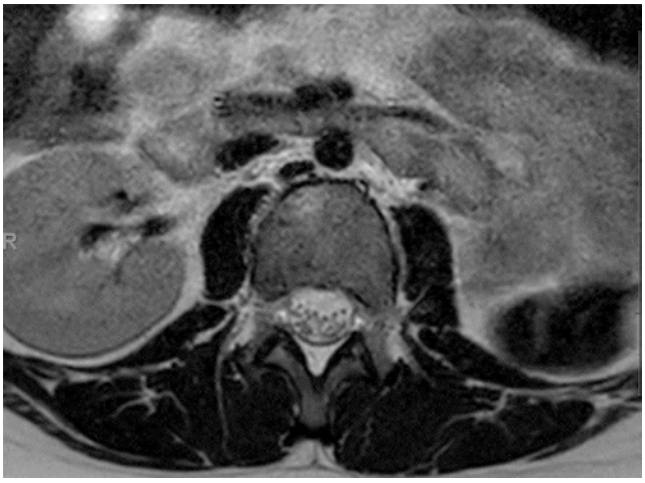


Figure 7. Sprengel deformity in Klippel-Feil syndrome (KFS). 3D reconstructed CT image demonstrates Sprengel deformity with scapular elevation in a patient with KFS.

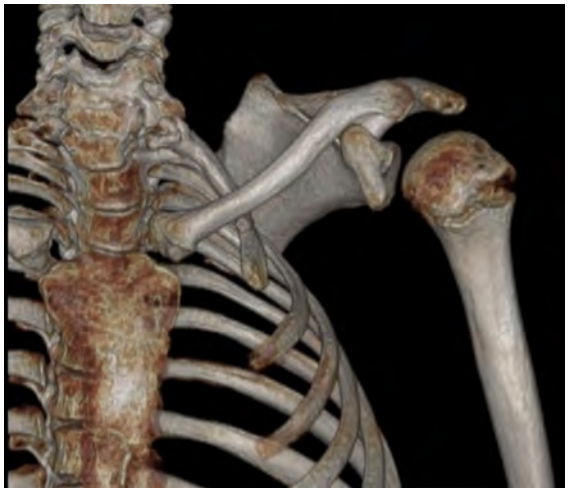
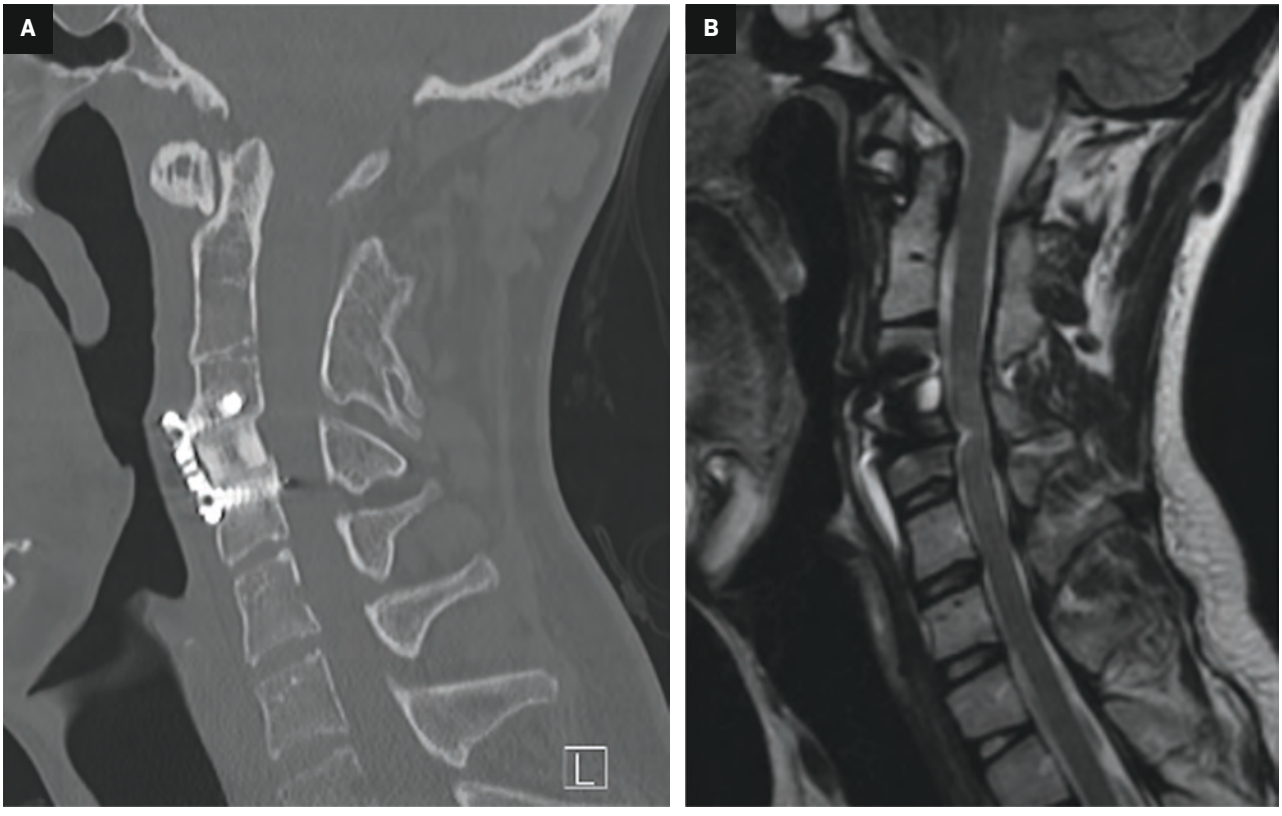


Figure 8. Postsurgical changes in Klippel-Feil syndrome (KFS). (A) Sagittal CT in bone window and (B) sagittal T2-weighted MRI (B) showing changes following anterior cervical discectomy, graft placement, and instrumented fusion of C4-C6 in a patient with KFS with congenital fusion of C2-C3.



reports additional, associated neurological pathologies, including Chiari type III malformation,[42] Brown-Sequard syndrome,[43] neurenteric cyst,[44] meningocele,[45] tetraplegia,[46] split cord malformation,[47] and multiple aneurysms.[48]

Non-neurological conditions, including genitourinary abnormalities (Figure 6) and Sprengel deformity of the scapula (Figure 7), are commonly found in patients with KFS,[35,49] with associated incidences of 65% and 35%, respectively.[50] Chandra et al[51] attribute the association between renal abnormalities and KFS to the simultaneous differentiation of the cervical vertebrae and genitourinary tract and proximity during embryonic development. A thorough examination for Sprengel deformity is warranted in patients with KFS regardless of the severity of their symptoms. KFS has also been associated with osteoarthritis of the temporomandibular joints,[52] tricuspid valve regurgitation,[53] complete lung agenesis,[54] and congenital megacolon.[55]

Treatment

Klippel-Feil syndrome presents two challenges for planning treatment. The first is the need to correct the congenital fusion and prevent secondary complications. Fusion of the cervical vertebrae increases susceptibility to cervical disc degeneration, spondylosis, and eventual spinal canal stenosis.[37,56] A combined approach of skull traction, cervical bracing, and advising the patient to refrain from activities with the potential to cause cervical injury can be employed to defer surgery, alleviate symptoms, and minimize the potential of neurological complications from traumatic injury.[57]

The second challenge is that KFS introduces additional complications that must be accounted for when treating other primary congenital abnormalities. In patients with basilar impression and KFS, surgical treatments usually involve an anterior approach, with the goal of spinal decompression. These can often be accompanied by surgical fusion to stabilize the spine (Figure 8).

Conclusion

Physicians and researchers can more accurately diagnose KFS and associated anomalies by conducting a thorough examination of embryology and molecular genetics. Understanding the classification systems allows for more accurate risk stratification and planning for initial and follow-up imaging.

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AI and Radiology: Bridging the Gap Between Peer Review, Education, and Value-Based Care

M. Aamir Hussain, MD; Matthew Wrenn, BS

In radiology, peer review is a cornerstone of maintaining diagnostic accuracy and ensuring high standards of patient care. By identifying discrepancies in image interpretations and offering valuable learning opportunities, peer review helps radiologists continuously improve their practice. However, traditional methods of peer review face significant challenges, including time constraints, limited access to specialized expertise, and the potential for bias. According to a survey conducted by the American College of Radiology, 43% of radiologists identified time constraints as a major barrier to effective peer review, underscoring the need for more efficient and effective solutions.[1]

As health care shifts toward value-based care, the importance of timely and accurate peer review becomes even more critical. Value-based care links patient outcomes to reimbursement, placing diagnostic quality at the forefront of radiology practices. Artificial intelligence (AI) and machine learning offer promising solutions to transform peer review processes, enabling better outcomes through enhanced diagnostic accuracy and workflow efficiency.[2,3]

The Role of AI in Enhancing Peer Review

Traditional peer review methods, while essential, often struggle with inefficiencies. Radiologists, already burdened with heavy workloads, may not have the time to conduct thorough reviews. The process itself can be subjective, with variations in expertise and interpretation contributing to inconsistencies. AI-driven peer review addresses these challenges by providing objective and standardized assessments.[3]

AI has the potential to significantly enhance peer review by providing more objective assessments of diagnostic images, highlighting discrepancies, and improving consistency in evaluations. For example, AI algorithms can be trained to detect specific types of anomalies in reporting behavior, such as repetitive patterns of typos at certain times of the day.[4] This not only reduces the likelihood of missed diagnoses but also allows for a more focused and efficient review process.

AI also facilitates case selection for peer review, prioritizing high-risk or educationally significant cases. This targeted approach ensures that radiologists can focus their efforts on the most impactful reviews, addressing time constraints and improving diagnostic consistency.[1]

AI-Powered Education and Training in Radiology

Continuous education is crucial in radiology, given the rapid advancements in imaging technology and the growing complexity of diagnostic procedures. Traditional educational methods, however, often struggle to keep pace with these developments, and radiologists may find it challenging to stay current with the latest best practices. AI can fill this gap by analyzing individual radiologists' diagnostic patterns and identifying knowledge gaps, providing tailored educational content.[5]

AI-driven educational platforms can simulate rare cases, offering radiologists the opportunity to diagnose conditions they may not encounter in their routine work. These platforms can also provide instant feedback on diagnostic decisions, helping radiologists identify and correct mistakes in real time.[6]

Furthermore, AI integrated into the picture archiving and communication system (PACS) environment can analyze a radiologist's diagnostic history to identify knowledge gaps and

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Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0029

recommend targeted learning resources by using advanced machine algorithms, ensuring that education is relevant and effective.

By integrating AI into radiology education, health care systems can ensure that radiologists are not only proficient in using the latest imaging technologies, but also are adept at applying best practices in their diagnostic work. This, in turn, can lead to more accurate diagnoses, fewer errors, and, ultimately, better patient outcomes.

AI in Value-Based Care and Patient Outcomes

A shift toward value-based care in health care emphasizes the importance of patient outcomes and cost-effectiveness. In that environment, accuracy and efficiency of radiology services are paramount. AI-driven peer review and education offer significant advantages in aligning radiology practices with the goals of value-based care.[2]

The transition to value-based care emphasizes diagnostic accuracy and efficiency as these directly influence patient outcomes and costs. Poor-quality radiology reports can lead to delayed or incorrect treatments, driving up health care costs and compromising patient safety. By reducing errors and improving diagnostic precision, AI can align radiology practices with the goals of value-based care.[2]

AI not only supports diagnostic accuracy but also fosters continuous learning and improvement. Radiologists using AI-driven peer review systems report increased confidence in their diagnostic abilities, as well as enhanced clarity and quality in their reports.[1]

As health care systems increasingly adopt value-based care frameworks, integrating AI into radiology practices will become essential. AI not only supports the clinical goals of improving patient outcomes but also helps health care providers meet the financial and operational demands of value-based care, making it a valuable tool in the future of radiology.[1]

In Closing

The integration of AI into peer review and education in radiology holds tremendous potential to transform the field, particularly in the context of value-based care. By enhancing diagnostic accuracy, streamlining workflows, and fostering continuous learning, AI can help radiologists meet the increasing demands of their profession while improving patient outcomes. As the health care industry continues to evolve, the adoption of AI-driven solutions will be crucial in ensuring that radiology remains at the forefront of medical innovation, delivering the highest standards of care in a value-based environment.

New innovations coming to market are at the forefront of this

transformation, showcasing how AI can be specifically tailored to meet the needs of radiology departments and help improve patient care through enhanced diagnostic accuracy and education.

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MRI Safety Gets an Overhaul

Kerri Reeves

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

Last June, the American College of Radiology Committee on MR Safety released its anticipated *ACR Manual on MR Safety,* the sixth and most significant update to safety guidelines first published in 2002 as an *American Journal of Radiology* white paper. At 146 pages, the current manual is almost 3 times larger than its previous 55-page edition published in 2020.

The 2024 manual consists of 16 chapters, 5 appendices, and multiple supporting materials such as checklists, visuals, and "key points" summaries. It also incorporates changes gleaned from among 770 comments received during the public comment period that followed an initial draft released in the spring of 2023.

Indeed, the revised manual represents a "vast improvement over previous iterations," says William Faulkner, BS, RT(R)(MR)(CT), MRSO, (MRSC), CEO of William Faulkner Associates.

Robert E. Watson Jr, MD, PhD, MRMD (MRSC), outgoing chair of the ACR Committee on MR Safety, agrees.

"We're encouraging people to use [the manual] as an educational training resource however they feel it's necessary to establish their [own MRI safety] policies and procedures," says Dr Watson, who is also a professor of radiology in the division of neuroradiology at The Mayo Clinic in Rochester, Minnesota. "[A]ccidents happen, and breakdowns and gaps in policies and procedures can let a tragic outcome get through. It's our job in MR safety to be proactive to try to plug those holes."

Radiologist Responsibility Reigns

Publication of the ACR's safety manual coincides with the release of the results of *Applied Radiology*'s annual MRI Safety Survey. According to the AR survey of 288 respondents, nearly equal numbers said responsibility for the safety of MRI patients falls on their facility's supervising radiologist (46.5%), while 44.1% said it falls on the radiological technologist. Another 8% said responsibility falls on the shoulders of the MRI safety officer, while less than 2% identified the department administrator as the primary safety overseer. Further, the survey found that only 58.1% of facilities have a specified MR Medical Director for MR Safety (MRMD).

While the ACR's revised manual recommends that each facility appoint an MR safety officer and an MR safety expert, it states that an MRMD should oversee MRI operational safety.

"Before a patient undergoes a medical procedure, if there is a safety question, the MR radiologist [must make] a risk-benefit decision," says Faulkner. "As a technologist, we don't practice medicine [or] determine safety, we implement it; a radiologist will make that safety determination. Radiologists may delegate a function, but they don't delegate responsibility in the end."

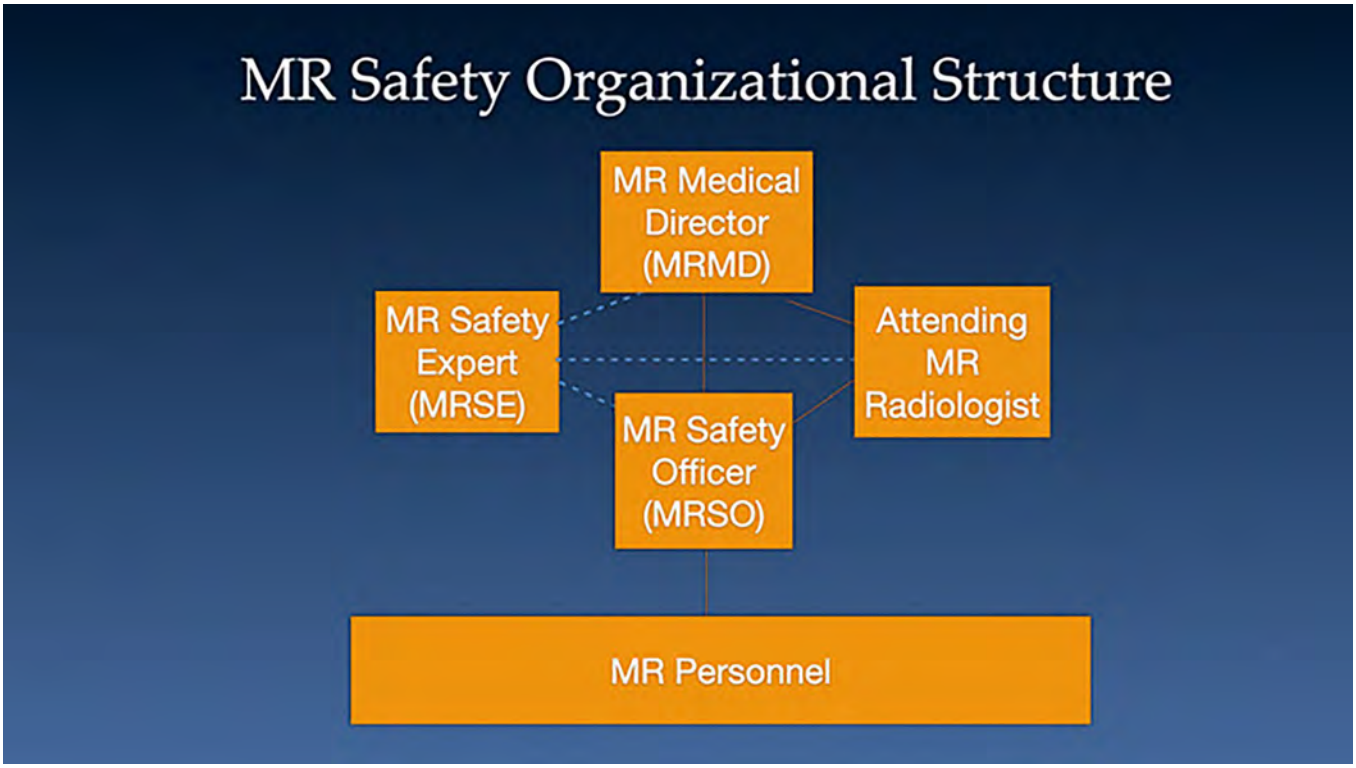
Noting that many radiologists rely on the expertise of their institution's MR safety team (Figure 1), Faulkner argues training should be mandatory for these physicians. To this end, future radiologists completing their residency will be required to undergo core MR safety education, according to Dr Watson. He says the American Board of Radiology Boards Part 1 now includes a "Non-Interpretive Skills" section, including a dedicated MRI safety section in the study syllabus.

"The MRMD is … at the top of the pyramid in terms of ensuring that the policies are in place, that the training is up to speed," he adds, recommending "a well-defined organizational structure around management of MR safety."

Asked if their facility's MR-trained radiologists undergo annual safety training, about one-third of survey respondents each answered in the affirmative or the negative (36.5% versus 33.3%, respectively), and just over 28% said they weren't sure. Nearly three-quarters of respondents (71.2%),

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0051

Figure 1. Facilities should maintain an organizational structure around management of MR safety. Image courtesy William Faulkner, BS, RT(R)(MR)(CT), MRSO (MRSC).



meanwhile, said all their MRI technologists undergo annual training.

Major Manual Updates

Rather than setting out an explicit set of directives, the manual is intended to serve as a guide for developing safety policies and procedures, as well as offer a structure for execution, Dr Watson explains. As a result, the manual includes checklists, tables, and key points summaries to help explain complex topics such as staffing scenarios, "full stop and final check" processes, heating safety risks, photos of signage, access areas, and implants or device labeling.

Among its new content, the manual highlights skills in which MR Level 1 and Level 2 personnel should be expected to demonstrate mastery. For example, while both Level 1 and 2 personnel need to know general magnetic field safety and emergency procedures, only Level 2 staff are required to understand thermal burn prevention and cryogen and quench safety processes. For the first time, the manual addresses the possibility that sites may consider additional MR safety-level stratification, says Dr Watson.

"With complex MR environments like hybrid procedural suites, it can become 'artificial' to be shoving everyone into just Level 1 and Level 2," he says, explaining that further stratification can enable facilities to better tailor safety education to the various personnel and their roles working in PET/MR or hybrid procedural interventional suites.

The ACR also recommends minimum requirements for staffing under various scenarios. For example, Dr Watson says, "No technologist should be working alone, including in emergency, off-hours situations."

Ensuring that only non-ferromagnetic objects and devices are permitted inside Zone IV (the scanner room) is arguably the most important safety consideration in MRI, which the manual covers thoroughly. In detailing the risks posed by portable objects like wheelchairs, oximetry monitors, and stretchers, the manual recommends tethering equipment to wall anchors using tether strap or cable systems, and

Figure 2. Tether MR unsafe items in Zone 3 for short-term, temporary securing. Image courtesy Robert E. Watson Jr, MD, PhD, MRMD (MRSC).

pocketless attire for staff to prevent magnetic items from being inadvertently brought into Zone IV (Figure 2).

Considering these and other potential dangers, the manual also offers new emergency response guidance. It also recommends that personnel be prepared for emergencies not related to the equipment itself, such as a patient medical emergency.

"You can't run a code in the scan room if a patient has a medical emergency. You have to quickly and safely remove them from the MRI environment and secure it," says Faulkner. According to the AR safety survey, however, about half of the respondents said their facility does not practice annual "mock code" drills.

Responding to a growing trend in medical imaging, remote MR scanning, the new manual calls for institutional policies governing all remote operations. This includes staffing.

"We currently recommend there be a Level 2 technologist who is onsite to oversee [the exam]," says Dr Watson. Acknowledging that remote scanning is still evolving, he notes that the safety manual, now available online, can be updated as new data and information on clinical experience emerge.

There is an updated section on managing patients with implants, which includes plain X-ray, CT, and MR images illustrating possible MRI safety risks. In addition, there is a new appendix to help guide radiologists when there are unclear MR safety conditions associated with implanted devices.

"This is in an effort to get very challenging exams done, with the recognition that being overly cautious and simply denying a patient an MRI due to their devices can lead to failure to make an important, and potentially lifesaving, diagnosis. It can be crucial to the patient to be 'intelligently aggressive' in these situations, and take full advantage of the expertise of the MR safety team in an effort to get crucial clinically indicated MRIs done," says Dr Watson.

Developing a Culture of Safety

The *ACR Manual on MR Safety* recommends that all MRI facilities create, maintain, and review their safety policies—as well as require their Level 1 and 2 personnel to undergo annual training—at least once a year. About 46% of survey respondents to the AR survey said their practices are reviewed annually, while just under 40% said they are reviewed "as required."

"The manual has plenty of material, but you've got to do your own work," Faulkner says, even if that means going beyond the minimum standards to address the unique characteristics of a given facility. "This is not a one-size-fits-all thing."

Ultimately, the optimal safety plan requires sufficient resources and should be developed by a committee of radiologists, technologists, nurses, and clinical assistants to cover as many eventualities and scenarios as possible, Dr Watson adds.

"A working safety committee is where you can build a true culture around MRI safety, doing your best to identify … the 'predictable surprises,'" he says. "You have a culture that says, 'We have work to do on this, and it's our job to be proactive.'"

Intraductal Papilloma in a Man

Stephanie D. Schwartz, DO; Moumita S.R. Choudhury, MD; Suzanne M. Jacques, MD; Evita Singh, MD

Case Summary

An adult man presented with a palpable, painful lump in the retroareolar region of the left breast, at the 3 o'clock position, present for 4 months. The patient denied a history of trauma, fever, nipple discharge, superficial erythema, and bruising. Further questioning revealed no similar symptoms in the past and no family history of breast cancer.

Imaging Findings

Diagnostic mammogram (Figure 1) demonstrated a circumscribed, oval mass within the retroareolar left breast. Targeted breast US (Figure 2) revealed an irregular, circumscribed, complex cystic and solid mass with posterior acoustic enhancement and peripheral Doppler flow. US-guided core needle biopsy was performed. Histopathologic analysis (Figure 3) demonstrates highly fragmented papillae with fibrovascular cores lined by columnar cells with apocrine metaplasia.

Diagnosis

Intraductal papilloma.

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Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

The differential diagnosis for breast lesions in men with similar presentation includes gynecomastia, invasive ductal carcinoma, ductal carcinoma in situ, abscess, lipoma, and epidermal inclusion cyst.

Discussion

The most common cause of bloody discharge from the female breast is intraductal papilloma, which is associated with 40-70% of cases of pathological nipple discharge in women.[1] While intraductal papillomas are not uncommon in women, they are exceedingly rare in men. A literature review identified 15 published cases of histopathologically proven intraductal papilloma in male patients, aged 11-78 years between 1984 and 2020.[1-5] Eleven patients presented with unilateral nipple discharge, which was bloody in a majority (73%) of those cases. Palpable masses were reported in 8 of the cases, and 10 cases without reported pain. A study by Zhong et al[6] identified 117 cases of male-breast papillary lesions at a single medical center between 2000 and 2019. Five of these cases were pathology-proven, benign, intraductal papillomas.

Intraductal papillomas, although benign, are high-risk lesions with the potential for malignant transformation. One case in the literature demonstrated malignant transformation to invasive ductal carcinoma 3 years after diagnosis in a man who did not undergo surgical excision.[4] Another case demonstrated an intraductal papilloma in a man with associated atypical ductal hyperplasia,[7] which is also a high-risk feature. These were the only 2 cases in our review that reported associated pain.

The patient in our case is unique in that he presented with a painful, palpable lump, without nipple discharge. This combination of signs and symptoms was not reported in any of the cases we reviewed.

The histopathological features are diagnostic for this entity. Intraductal papillomas arise within ducts in central (solitary) or peripheral (multiple) locations.[8] They are composed of papillae with fibrovascular cores, usually covered by both epithelial and myoepithelial layers.[8] When the epithelium is apocrine, as in this case, the myoepithelial cells can be markedly diminished or completely lost.[9,10] These benign lesions can be associated with usual ductal hyperplasia, cuboidal to columnar cell changes, and apocrine change.[8] Focal necrosis or hemorrhage may be present in larger lesions.

Conclusion

Given that intraductal papillomas are high-risk lesions, it is important to recognize that, although rare, they can occur in men. Our literature review identified 15-20 published cases of intraductal papilloma in men, the majority of who presented with painless, palpable lumps and nipple discharge. Our case highlights a unique presentation of intraductal papilloma in a man who presented with a painful lump, without associated nipple discharge.

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0053

Figure 1. Craniocaudal view of the left breast demonstrates an oval, circumscribed retroareolar mass without associated calcification or overlying skin thickening.

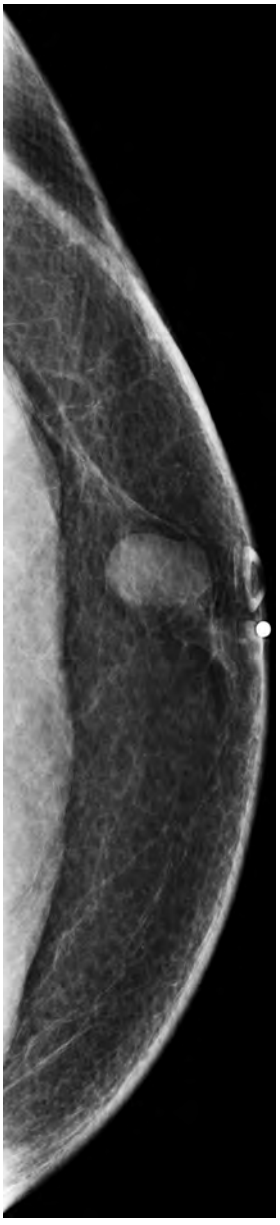


Figure 2. (A) Targeted US of the left breast lesion, 3 o'clock position demonstrated a 1.5 × 1.1 cm irregular, circumscribed complex, predominantly anechoic, cystic lesion with solid components and posterior acoustic enhancement. (B) Peripheral Doppler flow and posterior acoustic enhancement are demonstrated.

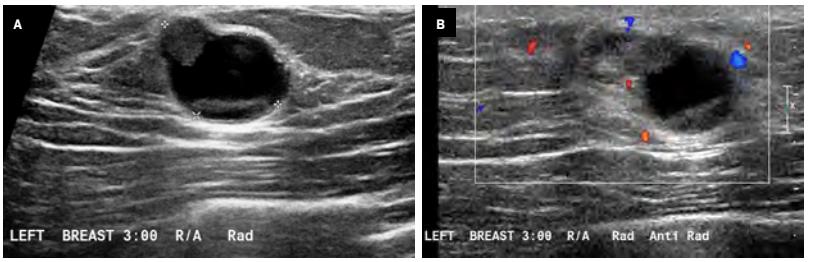
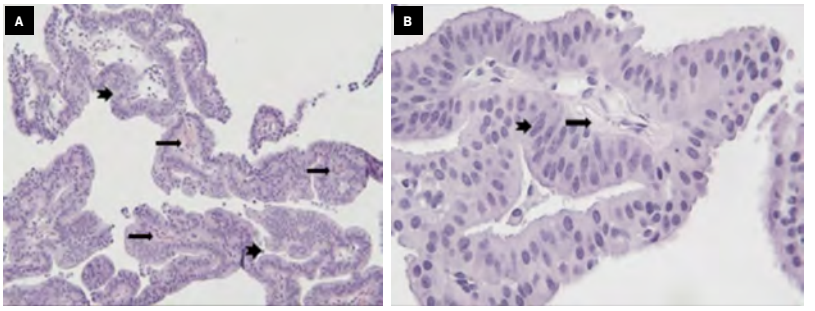


Figure 3. (A) Highly fragmented papillae with fibrovascular cores (arrows) lined by columnar cells with apocrine metaplasia (arrowheads) (H&E ×100). (B) The apocrine epithelium (arrowhead) lining the fibrovascular cores (arrow) shows uniform nuclei and prominent eosinophilic cytoplasm (apocrine metaplasia) (H&E ×400).



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Breast Leiomyoma

Kavya Puchhalapalli, MD; Anubha Wadhwa, MD; Daniel Dykstra, MD; Solomon Cherian, MD

Case Summary

A middle-aged, asymptomatic patient presented for routine screening mammography.

Imaging Findings

Screening mammogram of the left breast (Figure 1) demonstrated an asymmetry in the posterior, upper quadrant on the mediolateral oblique (MLO) view. On subsequent tomosynthesis images, this was localized to the posterior, upper-inner quadrant of the left breast. Diagnostic mammogram (Figure 2) demonstrated a 6 mm round asymmetry in the posterior upper-inner left breast, which appeared more consistent with a circumscribed mass. Diagnostic US (Figure 3) revealed a corresponding 6 × 5 × 5 mm round, hypoechoic mass with some angular margins at the 11 o'clock position in the left breast, 12 cm from the nipple. The mass was assessed as BI-RADS 4, suspicious for malignancy, and US-guided biopsy was recommended. US-guided biopsy (Figure 4) adequately sampled the mass with postprocedure mammography (Figure 5), demonstrating appropriate positioning of the biopsy clip.

Figure 1. Screening mammogram mediolateral oblique view demonstrates an asymmetry (arrow) in the posterior upper-left breast.

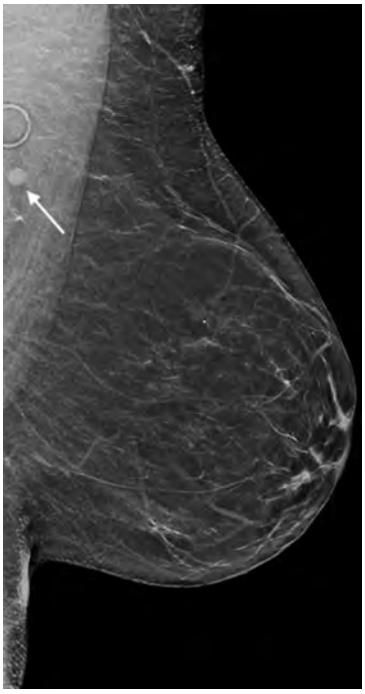
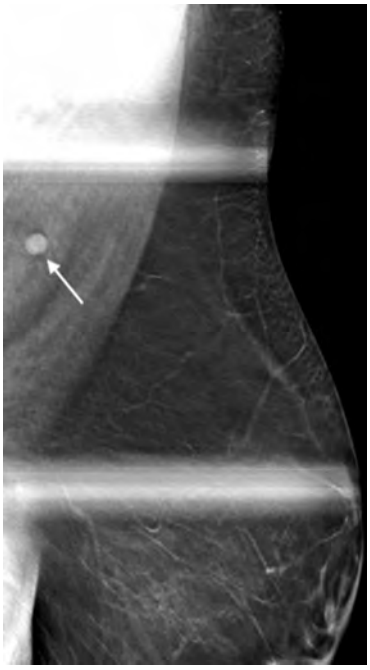


Figure 2. Spot compression mediolateral oblique view with tomosynthesis demonstrates a 6 mm circumscribed round asymmetry (arrow) in the posterior upper-inner left breast.



Diagnosis

Leiomyoma of the breast.

The differential diagnosis for a round, hypoechoic mass in the posterior breast includes fibroadenoma, intramammary lymph node, complicated cyst, papilloma, phyllodes tumor, sarcoma, metastatic malignancy, and schwannoma.

Discussion

Leiomyomas are benign, nonepithelial neoplasms. While most often associated with the uterus and sometimes with the small bowel and esophagus, they rarely occur in other organs.[1] Leiomyomas of the breast are very rare and predominantly seen in female patients aged 40 to 60, with only a few published case reports.[2] Most breast leiomyomas are peri-areolar, with peripheral or deeper parenchymal lesions being extremely rare.[1,2] Their etiology is largely unknown and are theorized to arise from embryological displacement of the areolar, capillary, or subcutaneous

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Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0054

Figure 3. US image shows a 6 × 5 × 5-mm round hypoechoic mass with some angular margins at the 11:00 position, 12 cm from the nipple.

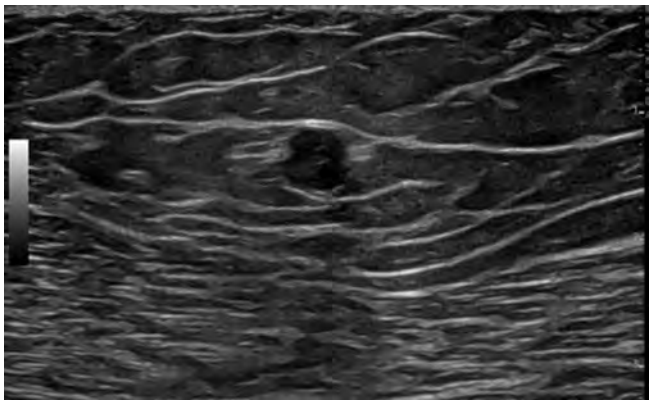


Figure 4. US-guided biopsy image demonstrates sampling of the mass.

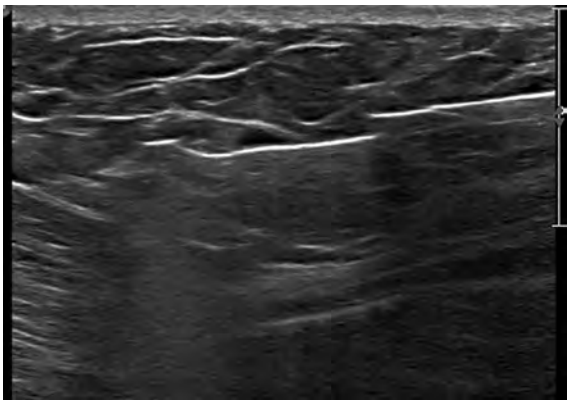
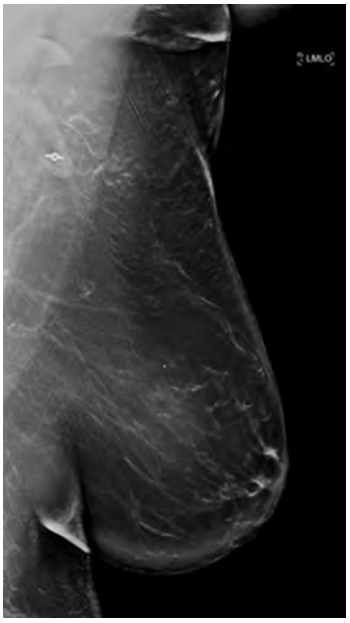


Figure 5. Postprocedure mammogram shows appropriate positioning of the biopsy clip.



smooth muscle cells of the breast, with subsequent overgrowth and transformation.[3]

Case reports and literature reviews describe imaging findings of mammary leiomyomas to be relatively nonspecific, with the most similarity shared with fibroadenomas.[2,3] They usually appear as circumscribed, round or oval homogeneous masses on mammography, and circumscribed homogeneous solid hypoechoic masses on US.[4,5] In this case, based on the imaging features and the posterior upper location on the initial 2D synthesized MLO view, the lesion could have easily been mistaken for an intramammary lymph node, a benign BI-RADS II finding, and the patient would not have been called back for diagnostic imaging.[6] However, subsequent tomosynthesis images localized the mass to be more medial, which was further confirmed on the diagnostic mammogram and US. This demonstrates the importance of using a multimodal approach for precise localization to better characterize and diagnose breast lesions.[7]

Leiomyosarcomas are rare, malignant, mesenchymal tumors showing smooth muscle differentiation. Most often they are found in the abdomen or uterus, and they can be aggressive.[8] Leiomyosarcomas of the breast are extremely rare, and it is worth noting that they have been seen in the peripheral and deep-breast parenchyma, which is uncommon for benign leiomyomas.[3,4] Breast leiomyosarcomas can often be mammographically and sonographically indistinguishable from a leiomyoma as they are typically circumscribed and slow growing.[4,9]

Currently, the definitive diagnostic test for breast leiomyomas/sarcomas is tissue sampling. While uterine leiomyomas are often distinguished from uterine leiomyosarcomas on MRI,[8] little has been published on MR features of breast leiomyomas. They have been described in the limited case reports as circumscribed masses intermediate to high signal on T2-weighted images and persistent enhancement on dynamic postcontrast images.[2,10] MRI may not be helpful to distinguish leiomyomas from leiomyosarcomas or other breast masses as features are nonspecific and most lesions being too small to definitively characterize.[2] Thus, tissue sampling remains the preferred tool for diagnosis of breast leiomyomas/sarcomas.

Owing to their low prevalence, no standard guidelines have been established for the management of leiomyomas. However, it is theorized that they can be treated similarly to leiomyomas of other organs based on their pathological similarity.[1,3] The accepted treatment is local resection

with free margins due to the potential of leiomyomas to continually grow, unlike most other benign lesions.[3] In a literature review of 20 breast leiomyoma case reports by Brandão et al, a majority of the leiomyomas were resected with free margins, with a few patients opting for mastectomies.[2] In well-sampled, asymptomatic cases, surveillance is also considered a reasonable approach.[10]

Conclusion

Leiomyomas of the breast are very rare and typically have nonspecific imaging features that most closely mimic fibroadenomas. Typically breast leiomyomas are found in the peri-areolar breast tissue instead of in the deeper, peripheral breast parenchyma, as in this case. This case also highlights the importance of using a multimodal approach to achieve precise localization, which can better characterize and diagnose breast lesions. Accurate diagnosis of leiomyomas is key, as they are often mammographically and sonographically indistinguishable from leiomyosarcomas.

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Neuropathic Shoulder Joint with Syringomyelia

Katrin Vetter, DO; Tyana Raynor, DO; Tejas Shinde, MD

Case Summary

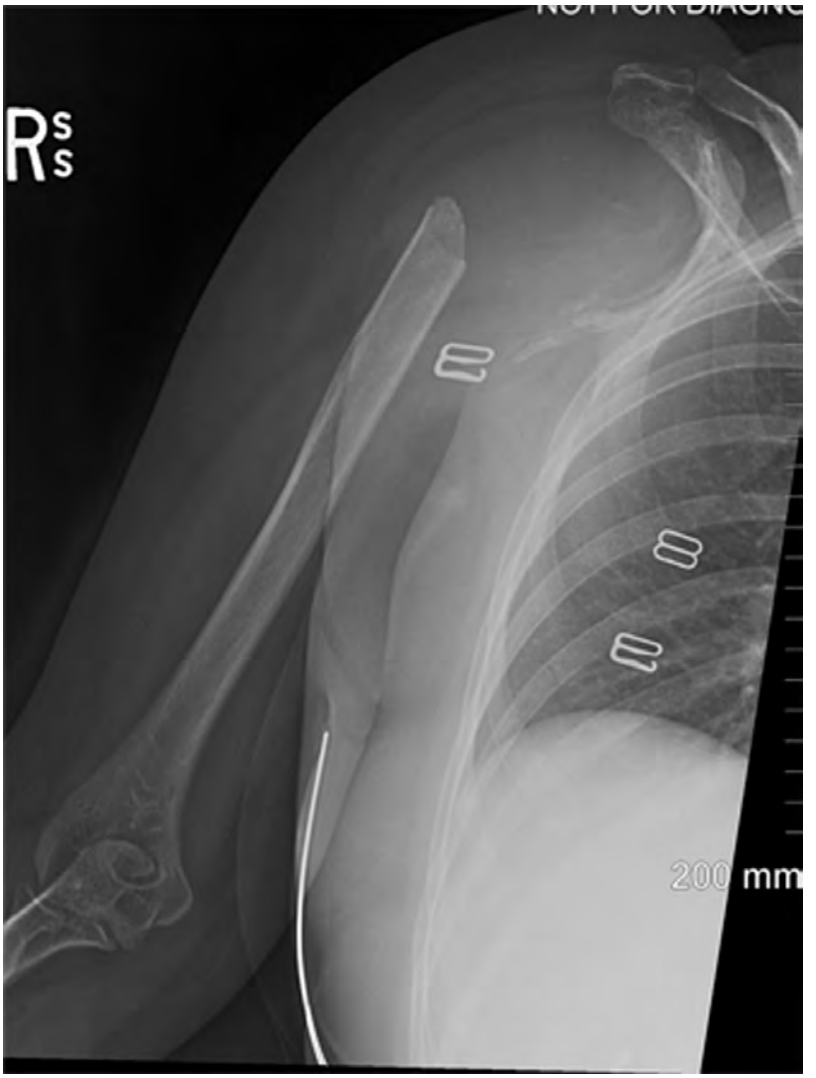
A previously healthy adult presented with a 6- to 12-month history of progressively worsening pain and loss of range of motion in the right shoulder. The patient reported radiation of pain into the right hand and noticed bruising of the right upper arm. There was no reported trauma, prior surgical intervention, recent illness, fever, night sweats, or worsening pain at night. Laboratory values were within normal limits without leukocytosis or other inflammatory markers.

Imaging Findings

Right shoulder radiographs showed massive osteolysis of the humeral head and glenoid, without significant new bone production (Figure 1). A US of the right upper extremity was also performed to evaluate for deep venous thrombosis. Vascular structures were normal, but the US demonstrated a large, complex joint effusion and synovitis in the shoulder.

An MRI of the right shoulder confirmed the extensive osteolysis of the proximal humerus and the glenoid, a large glenohumeral joint effusion, and significant synovial proliferation (Figure 2). Additional MRI of the cervical and thoracic spine was recommended to evaluate for syringomyelia; this revealed syringomyelia extending from the C2 through T8 levels. Low-lying cerebellar tonsils were also noted, consistent with a Chiari I deformity (Figure 3). A follow-up CT of the right shoulder was performed, which again demonstrated massive osteolysis of the right proximal humerus and glenoid with large joint effusion (Figure 4). A skeletal survey showed no other osteolytic lesions.

Figure 1. The initial anteroposterior radiograph of the right humerus in internal rotation demonstrates severe osteolysis of the proximal right humeral head, neck, and glenoid. A few calcified foci are noted in the expected region of the right humeral head.



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Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Published: February 1, 2025. https://doi.org/10.37549/AR-D-24-0055

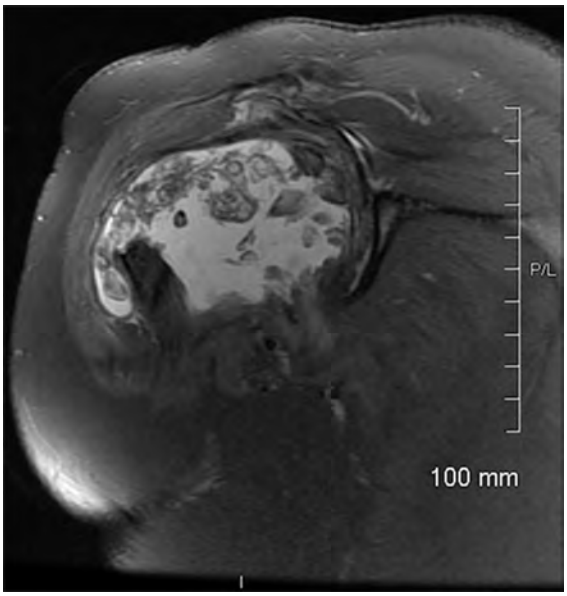


Figure 2. Axial proton density fat-suppressed sequence demonstrates extensive osteolysis of the proximal humerus. Additionally, there is a large shoulder joint effusion with associated severe synovial proliferation.

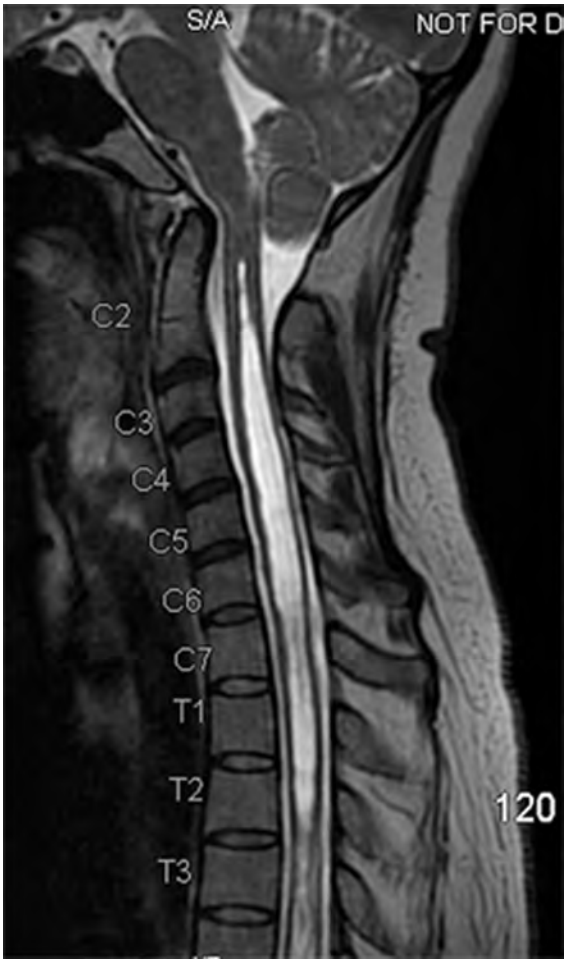


Figure 3. MRI of sagittal T2-weighted imaging of the cervical and upper thoracic spine demonstrates Chiari I deformity with caudal descent of the cerebellar tonsils to the level of the posterior arch of C1. There is an associated syrinx (inferior extent not included).

Diagnosis

Neuropathic joint (Charcot joint) with associated syringomyelia.

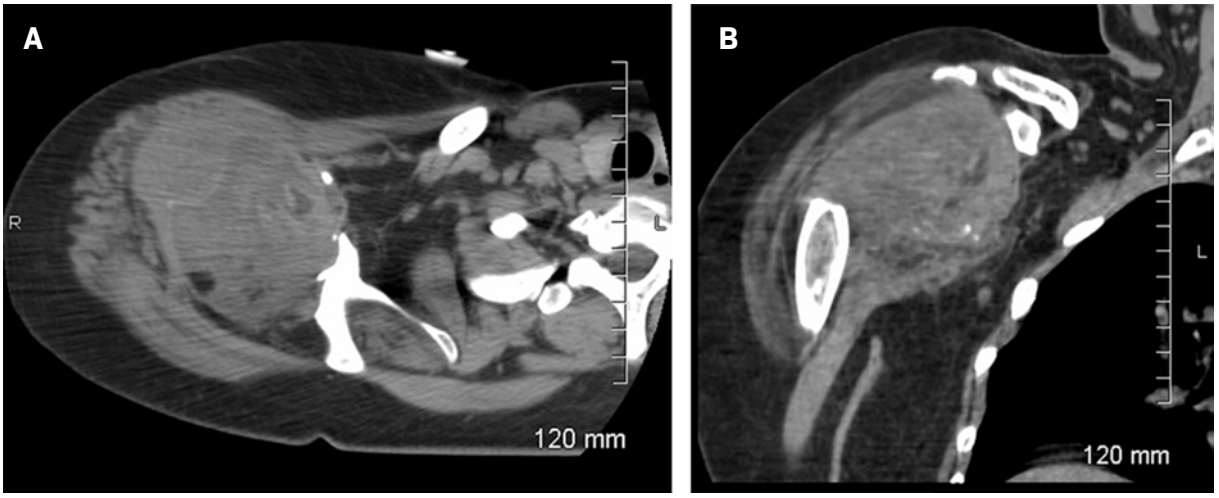
The differential diagnosis of massive osteolysis of the shoulder joint includes Gorham-Stout disease, Milwaukee shoulder, and infectious processes, including septic joint/osteomyelitis. Neuropathic joints can result from various etiologies, including diabetes mellitus, syringomyelia, neurosyphilis/tabes dorsalis, traumatic spinal cord injury, alcoholism, or tumors compressing/involving the spinal cord or peripheral nerves.

Discussion

Shoulder pain and limited range of motion are common general complaints, often related to trauma, arthritis, and subacromial impingement. Patients presenting with similar symptoms secondary to massive osteolysis are much rarer; to our knowledge, only a few have been reported in the literature. The clinical presentation of this case, along with normal inflammatory laboratory values and lack of leukocytosis, was not consistent with an infectious process or other inflammatory causes. The patient did not have diabetes mellitus.

Gorham-Stout disease, commonly known as “vanishing bone disease,” is a rare vascular disorder characterized by progressive osteolysis. It is a multisystem, developmental disorder of lymphangiogenesis that also affects bone, with slow endothelial cell turnover and associated cutaneous lymphatic malformations. Gorham-Stout, which predominately affects males, is typically diagnosed based on imaging findings and biopsy.

Figure 4. Axial (A) and coronal reformation (B) nonenhanced CT imaging demonstrates massive osteolysis of the right proximal humerus and glenoid with scattered intra-articular bony fragments. There is also a large glenohumeral joint effusion with severe mass-like synovial thickening.



The mean age of presentation is 12.8 years. It is polyostotic, typically involving the ribs, cranium, clavicles, and cervical vertebrae.[1] A treatment approach involving oral medications to suppress the immune system, and medications such as interferon alpha-2b, and rapamycin to target lymphatic vessel formation, has been found to inhibit disease progression, symptoms, and complications. Surgical intervention may be necessary to stabilize or remove affected bones as well as treat symptoms of the disease.[1]

In this case, the subsequent diagnosis of a Chiari I deformity and large syrinx clinched the diagnosis of neuropathic joint with massive osteolysis. The presentation of a neuropathic joint may include severe and rapid joint destruction, effusion, limited range of motion, and instability. Typically, the joints are painless and lack significant neurological deficits.

Physical examination may demonstrate abnormalities in proprioception and decreased or blunted deep-pain sensation.[2-4]

Imaging findings include generally normal bone density, large joint effusion, and severe, massive, bony destruction without new bone formation. Cross-sectional imaging supports the diagnosis and assessment of the extent as well as underlying causes. Common etiologies for neuropathic joints include diabetes mellitus, syrinogomyelia, tabes dorsalis, alcoholism, and spinal cord injury.[2]

According to the literature, when the shoulder is involved, it is typically secondary to syringomyelia and Chiari I deformity.[3,5] The exact etiology of osteolysis is unclear but may be related to alteration in blood flow, leading to osseous hyperemia and increased bone resorption.[3] MRI of the entire spinal cord is the preferred modality to assess the size and extent of the syrinx. The craniocervical junction should be evaluated for caudal descent of the cerebellar tonsils greater than 5 mm below the foramen magnum and narrowing of the cerebrospinal fluid spaces to indicate Chiari I deformity. In our case, the diagnosis was supported by the MRI findings (Figure 3).[6]

Treatment of the affected joint can vary from conservative management to steroid injections, proper joint splinting, and physical therapy. Other treatment options include arthrodesis and joint reconstruction.[7] Treatment of the underlying etiology is important.

Conclusion

Massive joint osteolysis is rare. Laboratory studies and imaging can assess for underlying etiologies and define the extent of the abnormalities. Imaging modalities that should be considered include MRI of the brain and cervical spine since spinal cord syringomyelia can present with a neuropathic joint in the upper extremity.

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"When your mind tries to verify a preconceived notion you can miss the obvious."

—James Cook

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The Invisible Gorilla

C. Douglas Phillips, MD, FACR

Truer words have infrequently been spoken. Going into a situation and knowing (in your own little head) what you will see can significantly influence what you really *do* see. The "invisible gorilla" test made that pretty clear. What's the invisible gorilla test, you ask?

Allow me.

Test subjects were asked to watch people in contrasting gym clothing passing a ball and to count how many times players in the white shirts passed the ball. Midway through, a gorilla came into view, pounded its chest, and walked off. More than half of the observers never saw it.

Radiology angle? Oooh, too easy.

Ever look a second time at a study you (or maybe someone you know) read and see the gorilla in the first glance? Pounding its chest and daring you to miss it? You know *exactly* what you will do next; you will look at the report to see if the gorilla has made it there. And, sometimes, it has not.

Were you (or they) asleep? Did you have a TIA? Nope, unlikely. You might have been guided to somewhere else in the study, had a reason to question something else, were distracted, or perhaps there was an IT glitch. Who knows? But you didn't see the gorilla.

I see enough of these to wonder if gremlins may have something to do with it. An evil influence from another dimension. Maybe something to do with the drones over New Jersey. Voodoo.

And don't think this is unique to radiology. The cutaneous lesion, oral cavity lesion, fill-in-the-blank lesion that was overlooked or just did not reach the supra-gorilla level and slips through being seen by 10 or more well-intended clinicians. We've all seen those, too.

Unfortunately, you aren't going to be forgiven for missing the gorilla. You've got to hope that the gorilla was innocuous, because once the gorilla is spotted, the gorilla is as conspicuous as, well, a gorilla parading amongst a few folks in shorts and t-shirts passing a ball. Some people feel it may be evolution hurting us; our eyes and brains were conditioned to things moving at lesser speeds; not hurtling down the interstate at 75 mph, piloting an aircraft flying at 500 mph, or trying to get through 1400 images in the short period of time we have allotted to read a CT. Intuition can mislead you, for sure.

Look out for the gorilla. And keep doing that good work. Mahalo.