



Staging of Pancreatic Cancer with MRI: A Pictorial Review

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Disclosures

- No financial relationships to disclose



Learning Objectives

- Review choice of imaging
- Review MR features of pancreas adenocarcinoma
- Review pancreas cancer staging
- Illustrate MR findings of pancreas adenocarcinoma after neo-adjuvant therapy and surgical resection

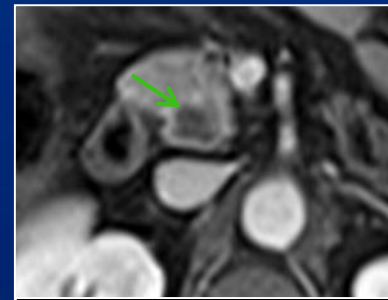
Background

- Highly aggressive tumor with high mortality rate
- Only 15-20% of patients have potentially resectable disease at time of diagnosis
- Early detection when tumor is surgically resectable is best hope for improved survival
- Imaging plays a crucial role in diagnosis and staging
 - Accurate staging has major implications for treatment
 - R2 resection (residual macroscopic disease) does not offer a surgical benefit

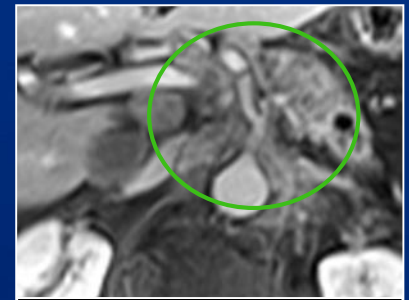
Al-Hawary, Mahmoud M., et al. *Radiology* 270.1 (2014): 248-260.

Imaging Goals

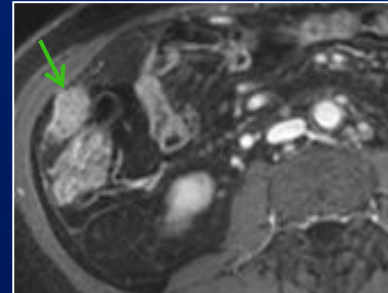
- Diagnosis
- Stage disease
- Restage after neoadjuvant therapy
- Postoperative surveillance



Hypoenhancing mass



Celiac encasement



Omental Implant

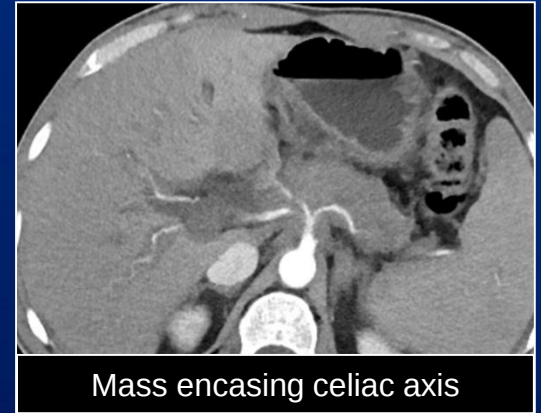


Liver Metastasis

Ultimately, accurate staging carries substantial implications for treatment recommendations, with the *goal of maximizing survival benefit* for patients in whom complete resection can be achieved *and minimizing morbidity* from unnecessary surgery in patients with high risk of residual disease following resection

Choice of Imaging: CT

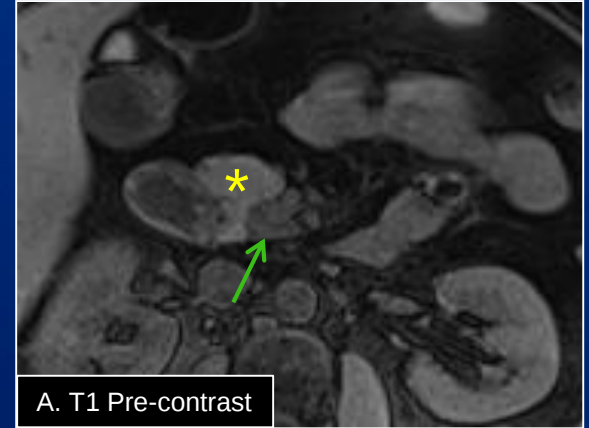
- Multidetector CT angiography
 - Accepted modality
 - Reproducible pancreatic protocol parameters
 - Dual Phase study
 - Negative oral contrast
 - Helical scan with thin sections
 - Pancreatic parenchymal phase at 40-50 sec
 - Portal venous phase at 65-70 sec
 - Smallest available section thickness should be used to allow for high quality reformats and volumetric images



Choice of Imaging: MR

- MR has been shown to be as sensitive and specific as CT in staging pancreatic cancer
- Not as widely used due to cost and availability
- Requires meticulous technique to achieve high quality images for staging purposes
- MR offers superior contrast resolution
- May be superior to CT in detecting liver and peritoneal metastases

(A) T1WI pre-contrast imaging demonstrates excellent soft tissue contrast between **tumor (arrow)** and **pancreatic head (asterisk)**. (B) Post contrast T1WI shows hypoenhancing **tumor (arrow)**



Al-Hawary, Mahmoud M., et al. *Radiology* 270.1 (2014): 248-260.
Holzapfel K et al. *Abdom Imaging* 2011;36(2):179-84

Miller F et al. *AJR* 2006; 187: W365-W374
Toft J et al. *EJR*; 2017; 92: 17-23



Background

Modality

Diagnosis

Staging

Restaging

Surveillance

Advantages of MR

- Superior soft tissue contrast
 - Useful for evaluating subtle non-contour deforming masses
- More sensitive for small liver metastases
- More sensitive for peritoneal and omental metastases
- May better define appropriate surgical candidates
- Can help diagnose mimics
 - Indeterminate pancreatic enlargement on CT
 - Focal fat infiltration
- Better depiction of the pancreatic and bile ducts

Miller FH *AJR* 2006; 187:W365-374.

Motosugi U et al. *Radiology* 2011;260(2):446-53

Soloff, E *Abdominal Radiology* (2017): 1-13.



Background

Modality

Diagnosis

Staging

Restaging

Surveillance

Mayo Clinic Florida MR Protocol

3 Tesla Magnet

IV Contrast:
Weight based dosing of Gadavist

Antiperistaltic:
Glucagon 0.5 mg IV

Pancreas Protocol

Cor / Sag SSFSE

Ax FS SSFSE

Axial In / Opp

Axial DWI

Ax / Cor / Sag Precontrast T1 FS

Axial small FOV arterial T1 FS

Ax / Cor / Sag postcontrast T1 FS

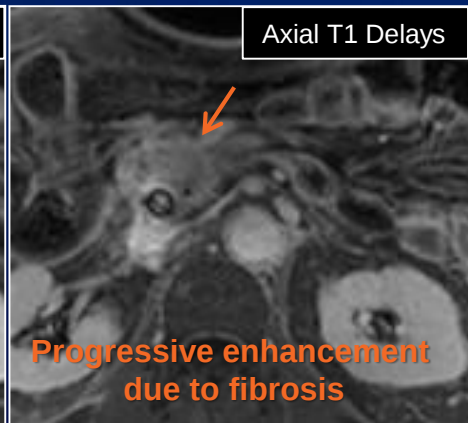
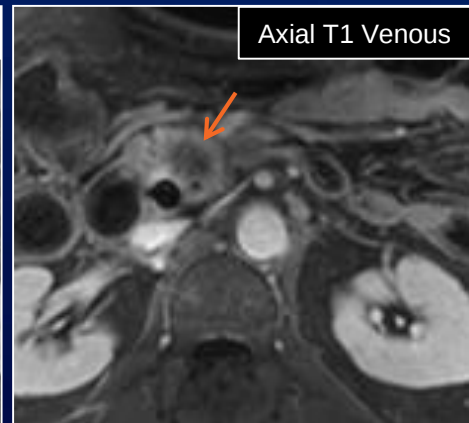
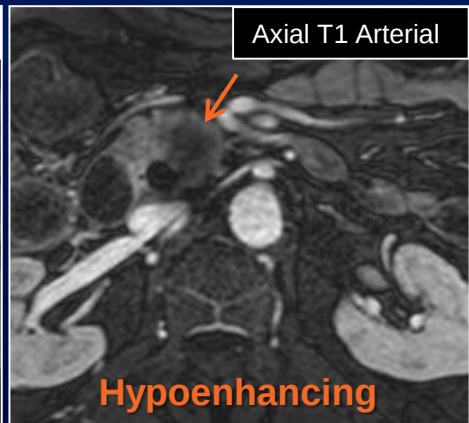
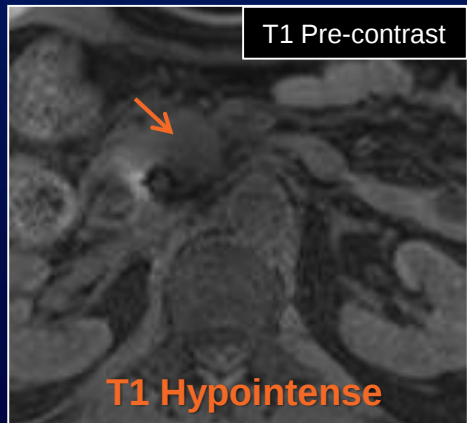
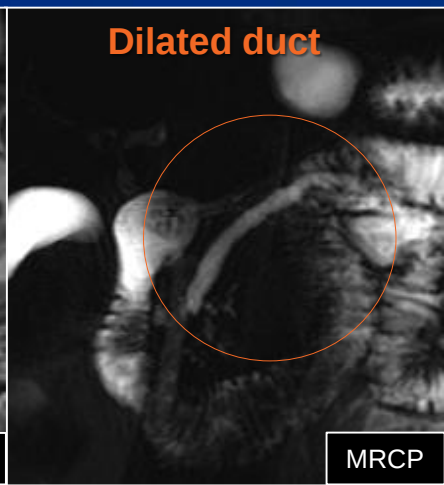
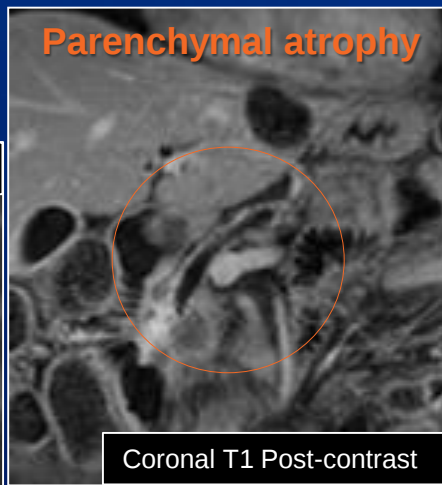
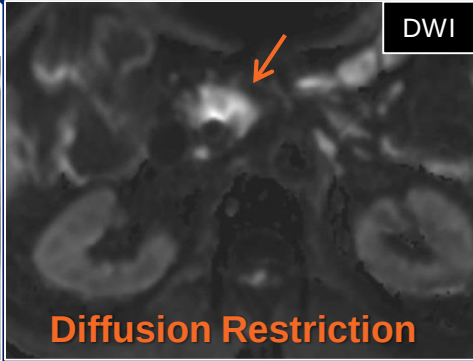
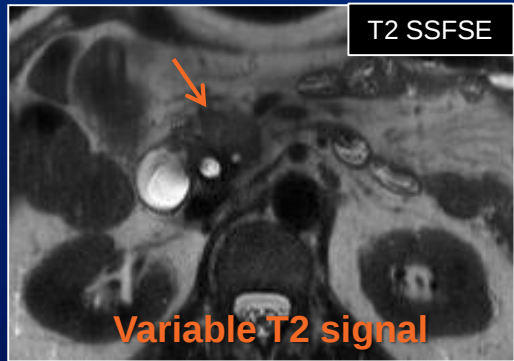
Ax / Cor Thin slice SSFSE

3D MRCP

Axial delayed post contrast T1 FS

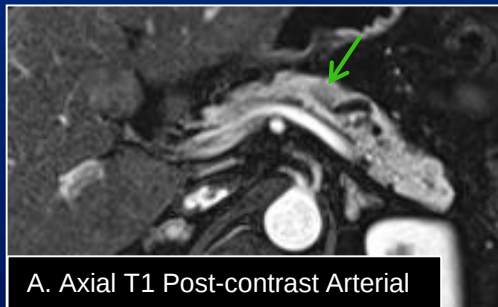
Motion-corrected subtractions

Imaging Findings of Pancreas Adenocarcinoma on MR

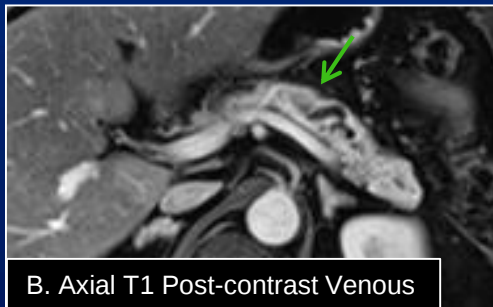


Imaging Findings of Pancreas Adenocarcinoma on MR

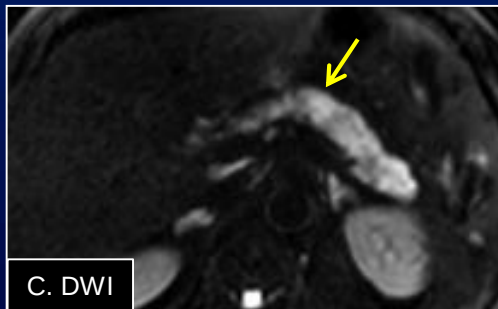
Axial T1WI post contrast images (A and B) shows a small T1 hypointense **mass (arrows)**. On DWI (C), the **mass (arrow)** restricts diffusion. T2WI (D) demonstrates obstruction of the duct (arrow). MRCP images (E and F) show **disruption of the duct (circle)** and **duct dilatation in the tail (arrow)**



A. Axial T1 Post-contrast Arterial



B. Axial T1 Post-contrast Venous



C. DWI



D. T2WI



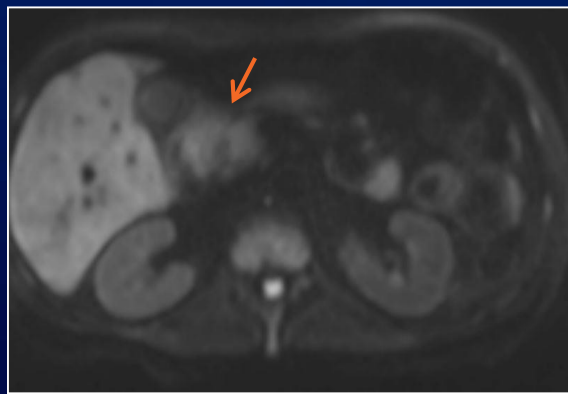
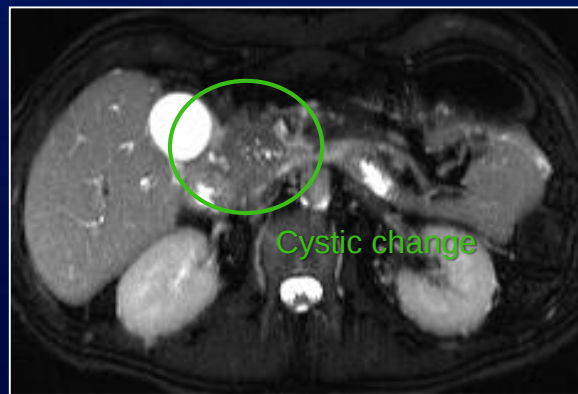
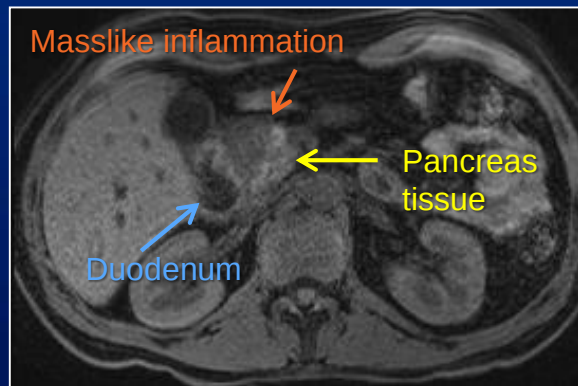
E. MRCP



F. MRCP

Use the secondary findings and superior contrast resolution of MR to identify difficult masses

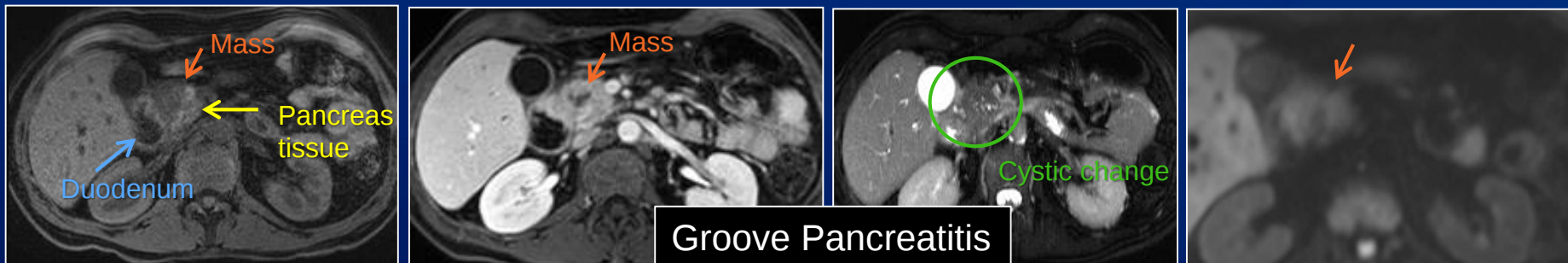
Pancreas Adenocarcinoma Mimics – Groove Pancreatitis



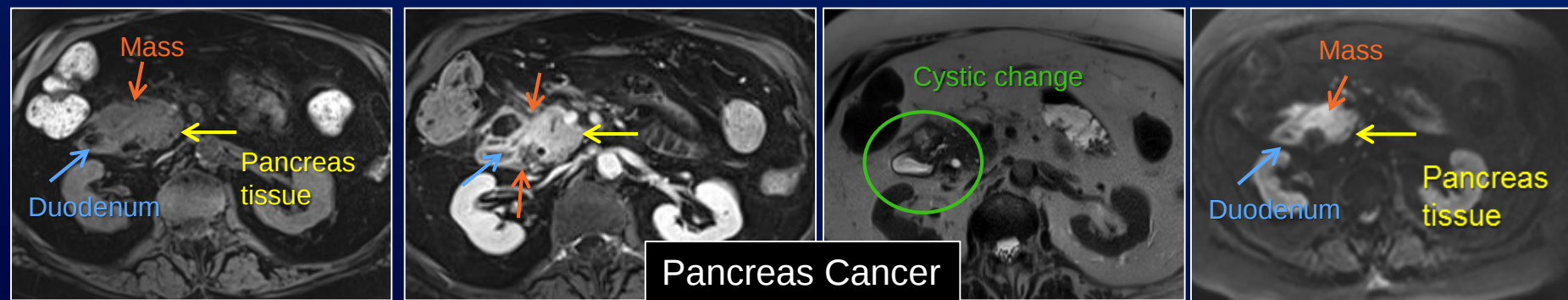
Groove Pancreatitis

- ✓ Prospective dx difficult
 - ✓ Difficult to exclude mass with imaging
- ✓ Curvilinear ST mass b/w panc head and duodenum
- ✓ T1 hypointense
- ✓ Variable T2 signal
 - ✓ Look for cystic change in duodenal wall or groove
- ✓ May show delayed enhancement
- ✓ Whipple may be required for intractable pain or to exclude malignancy

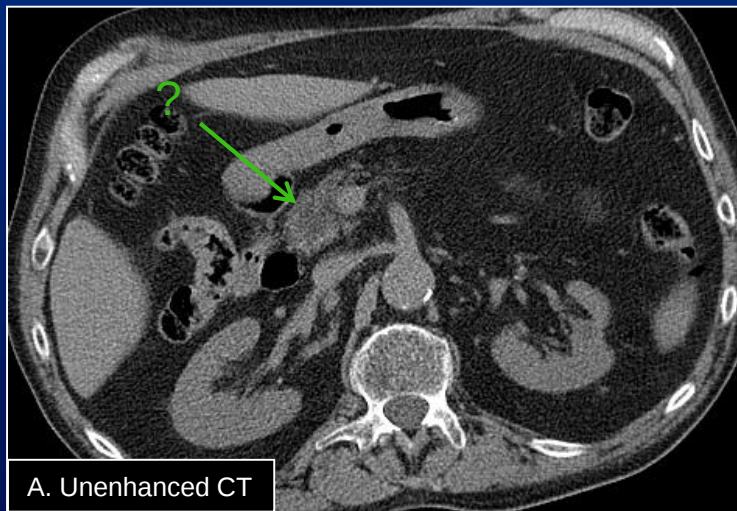
Pancreas Adenocarcinoma Mimics – Groove pancreatitis vs cancer



Groove pancreatitis can be indistinguishable from pancreatic cancer and tissue diagnosis may be required



Pancreas Adenocarcinoma Mimics



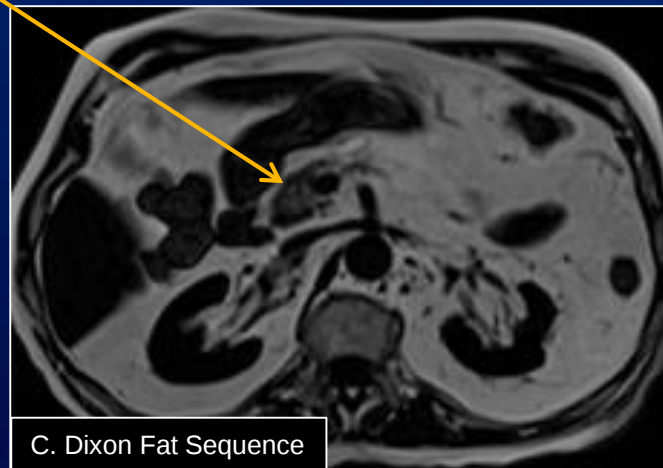
Unenhanced CT (A) shows a **hypodense mass like area (arrow)** in the pancreatic head. MRI is able to diagnose this as a region of focal fat. Out of phase image (B) shows areas of india ink artifact around the **fat (arrow)** and fat sequence (C) shows **fat signal (arrow)** in this region.

Focal Fat

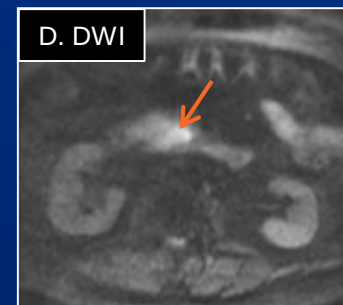
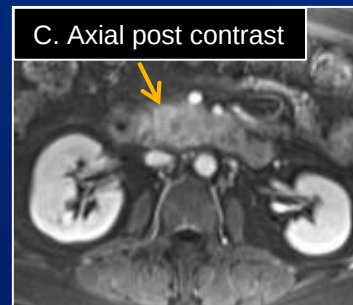
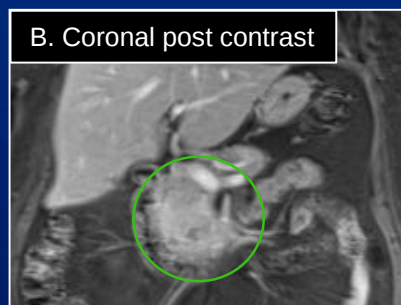
B. Out of phase



C. Dixon Fat Sequence



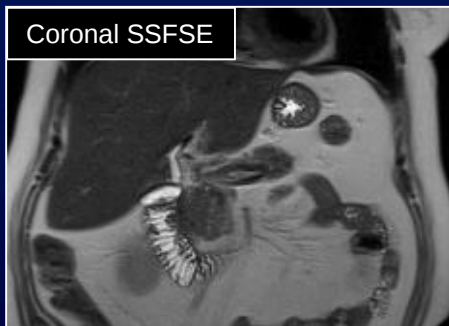
Pancreas Adenocarcinoma Mimics – Focal Pancreatitis



MRI shows **masslike enlargement (circle)** of the uncinate process (A and B) with surrounding inflammatory change. Axial post contrast MR (C) shows **enhancement and adjacent inflammatory change (arrow)**. There is **increased signal on DWI (arrow)** (D).



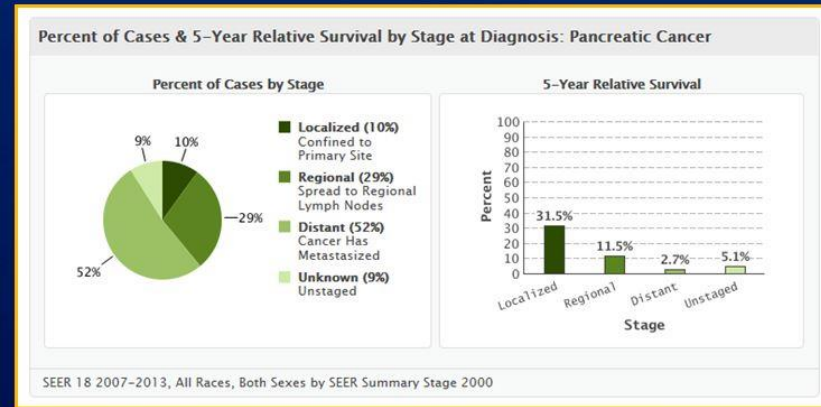
Follow up MR



Follow up MR shows resolution of inflammatory change and no mass. This was a case of focal pancreatitis in the uncinate process mimicking a mass.

Staging

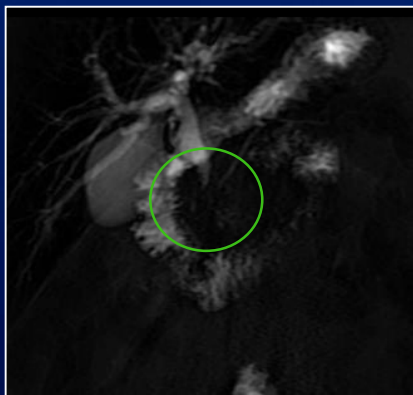
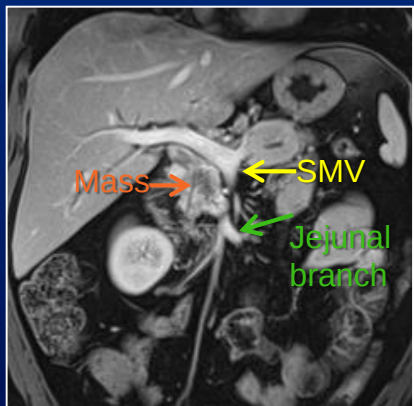
- Based on:
 - Tumor **size**
 - Location** in pancreas
 - Local **extent**, which may involve surrounding vessels
 - Abutment** is < 180 contact with vessel circumference
 - Encasement** is > 180 contact
 - Locoregional disease may enhance more than primary tumor
 - Presence or absence of **metastatic** disease
 - Liver and peritoneum common



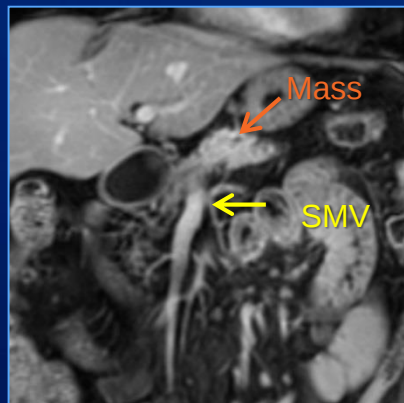
Miller FH AJR 2006; 187:W365-374.

Resectability	Arterial	Venous
Resectable	No contact (CA, SMA, CHA)	No contact or < 180 (SMV , PV)
Borderline	- GDA encasement up to the hepatic artery with either short segment encasement or direct abutment of the hepatic artery without extension to the CA - Tumor abutment of the SMA or CA (<180)	Involvement of the SMV or portal vein (distortion, narrowing, or occlusion) with suitable vessel proximal and distal, allowing for safe resection and replacement
Locally advanced/ Unresectable	- Aortic or IVC invasion or encasement - > 180° SMA or CA encasement - Involvement of first jejunal SMA branch	- Unreconstructable SMV/portal vein - Involvement of draining jejunal branch into SMV

Staging – Location determines type of resection



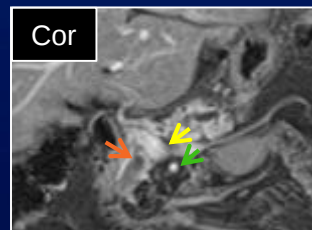
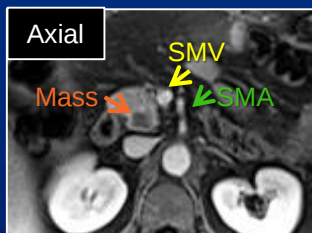
Tumors located in the head / uncinate process
of the pancreas (**right of SMV**)
Possible **pancreaticoduodenectomy**



Tumors located in the body / tail (**left of SMV**)
Possible **distal pancreatectomy**

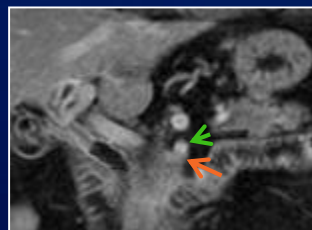
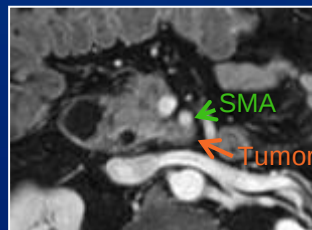
Tumor description:

- ✓ Size
- ✓ Location
 - ✓ Head/Uncinate
Pancreaticoduodenectomy
 - ✓ Neck
Total Pancreatectomy
 - ✓ Body/Tail
Distal Pancreatectomy
- ✓ Pancreatic duct
- ✓ Biliary duct



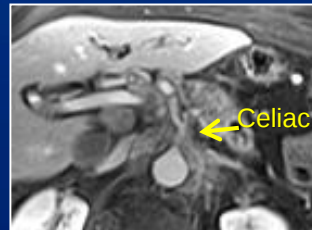
No involvement

Clear fat planes
around vessels



SMA Abutment

Tumor (arrows)
contacts the SMA
(arrow) <180



Encasement

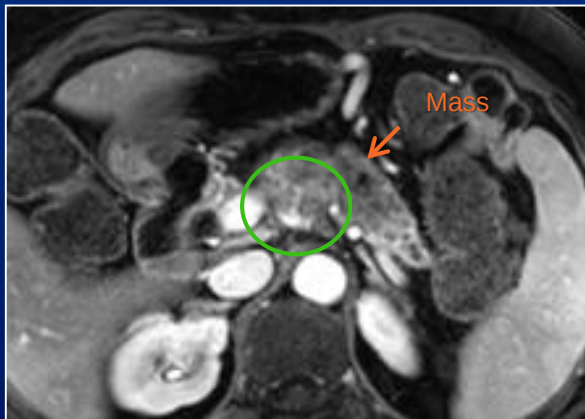
Celiac (arrow) and SMA
(arrow) are encased
(>180) by tumor

Vascular involvement:

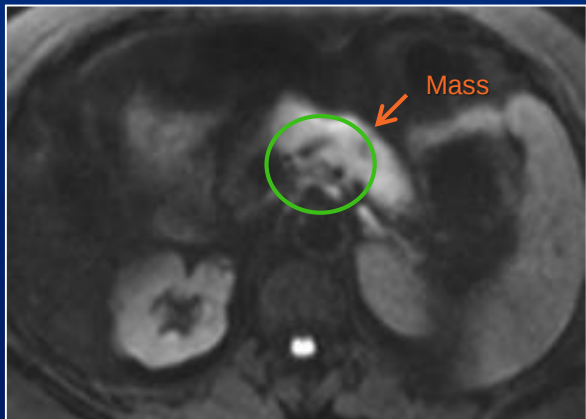
- ✓ <180 (abutment)
- ✓ >180 (encasement)
- ✓ Narrow or irregular contour
- ✓ Thrombus / occlusion
- ✓ Extension to
 - *SMA/SMV branch
 - *GDA > CHA
 - *CHA > Celiac
 - *CHA > bifurcation
- ✓ Variants
- ✓ Collaterals

Staging – Vasculature

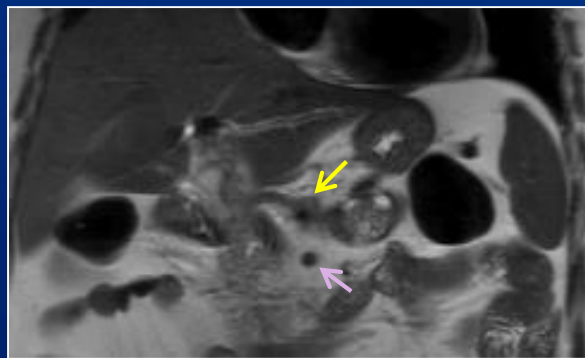
Lu, D. S. AJR. 168.6 (1997): 1439-1443.



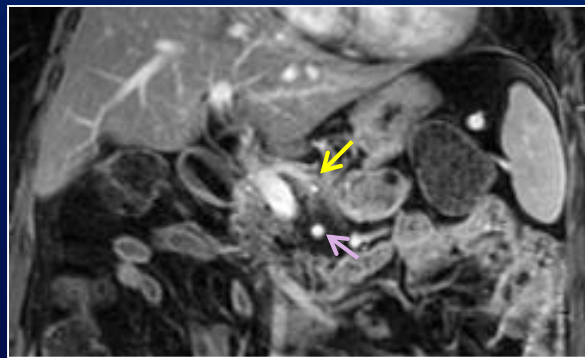
Celiac trifurcation encasement
($>180^\circ$)



Signal voids of the celiac and
splenic arteries (circle) encased
by mass (arrow)



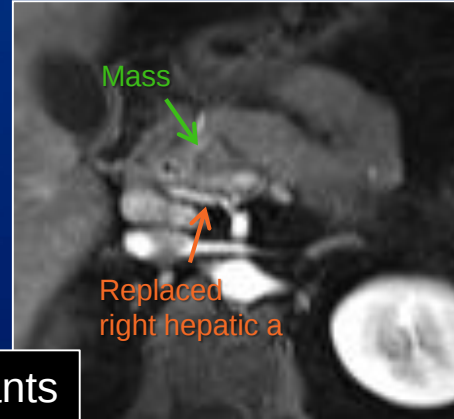
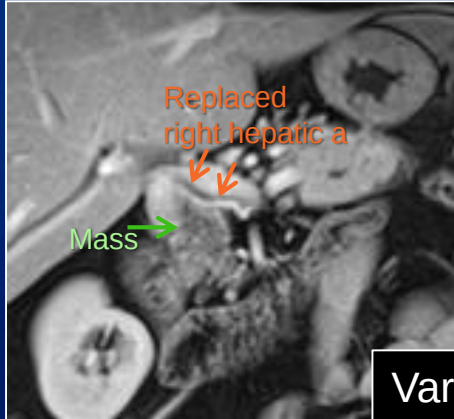
Circumferential encasement of the
celiac (arrow), in comparison to clean
fat planes around the SMA (arrow)



Staging – Vasculature

Viewing in multiple planes and with
multiple sequences helps prove or
disprove vascular involvement

LOCALLY ADVANCED



Variants

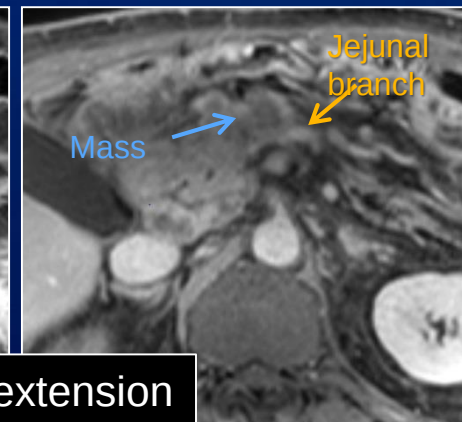
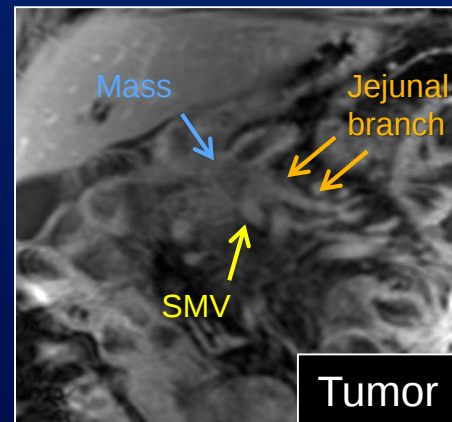
Variant vascular anatomy should be reported

- Avoid injury at surgery
- Avoid overlooking tumor extension

Extension of tumor along vascular branches may render them unresectable

Vascular involvement:

- ✓ <180 (abutment)
- ✓ >180 (encasement)
- ✓ Narrow or irregular contour
- ✓ Thrombus / occlusion
- ✓ Extension to
 - *SMA/SMV branch
 - *GDA ➤ CHA
 - *CHA ➤ Celiac
 - *CHA ➤ bifurcation
- ✓ Variants
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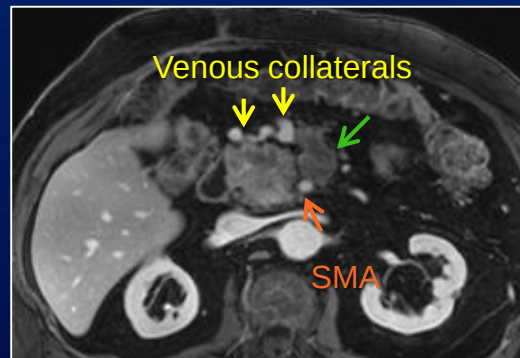
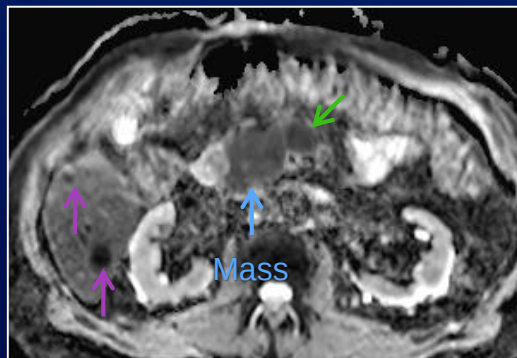
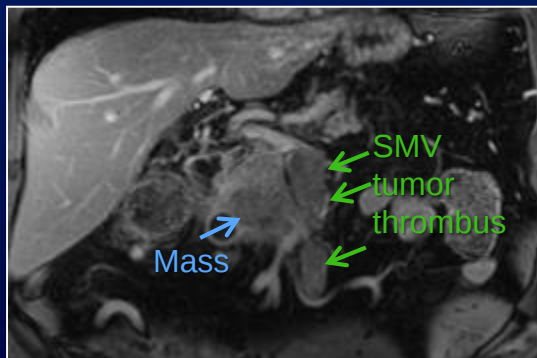
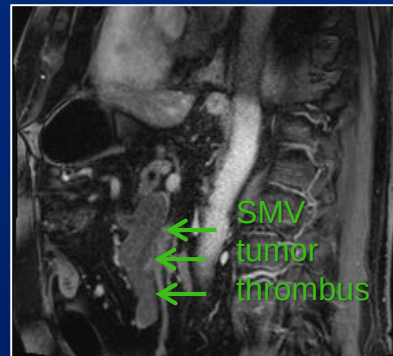
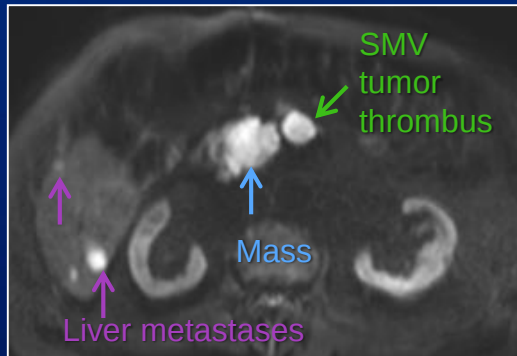
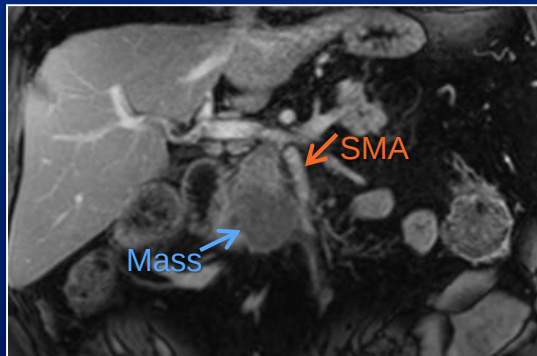


Tumor extension

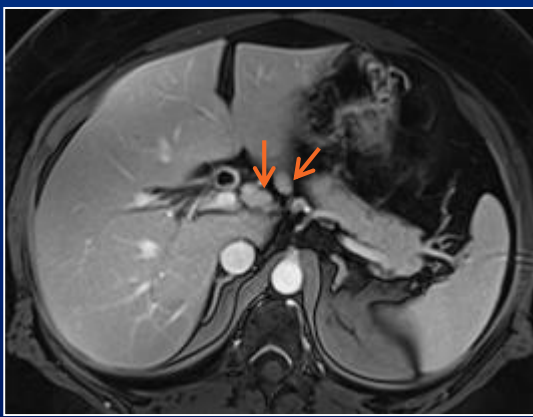
Tumor involvement of the first jejunal branch renders this patient unresectable

Staging – Vasculature

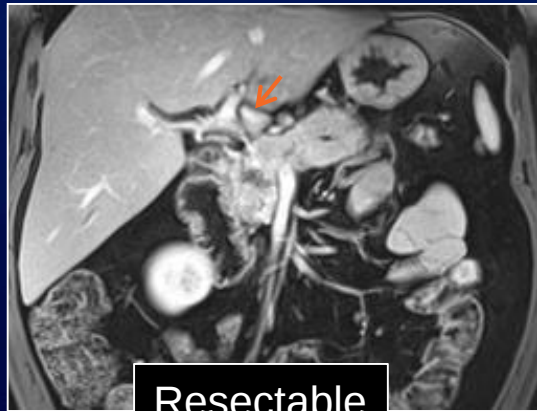
Tumor thrombus and venous collaterals



Unresectable



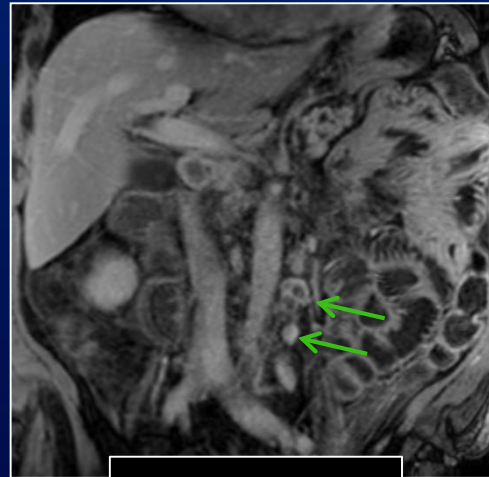
Hepatic arterial lymph nodes (arrows) are in the surgical field and are resectable



Resectable

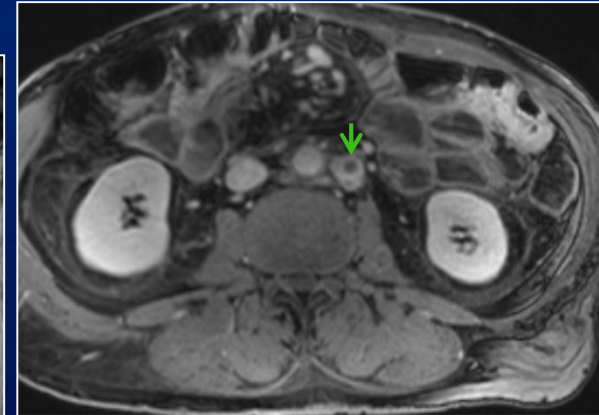
Extrapancreatic:

- ✓ Liver metastases
- ✓ Peritoneal nodules
- ✓ Ascites
- ✓ Lymph Nodes
- ✓ Invasion of organs



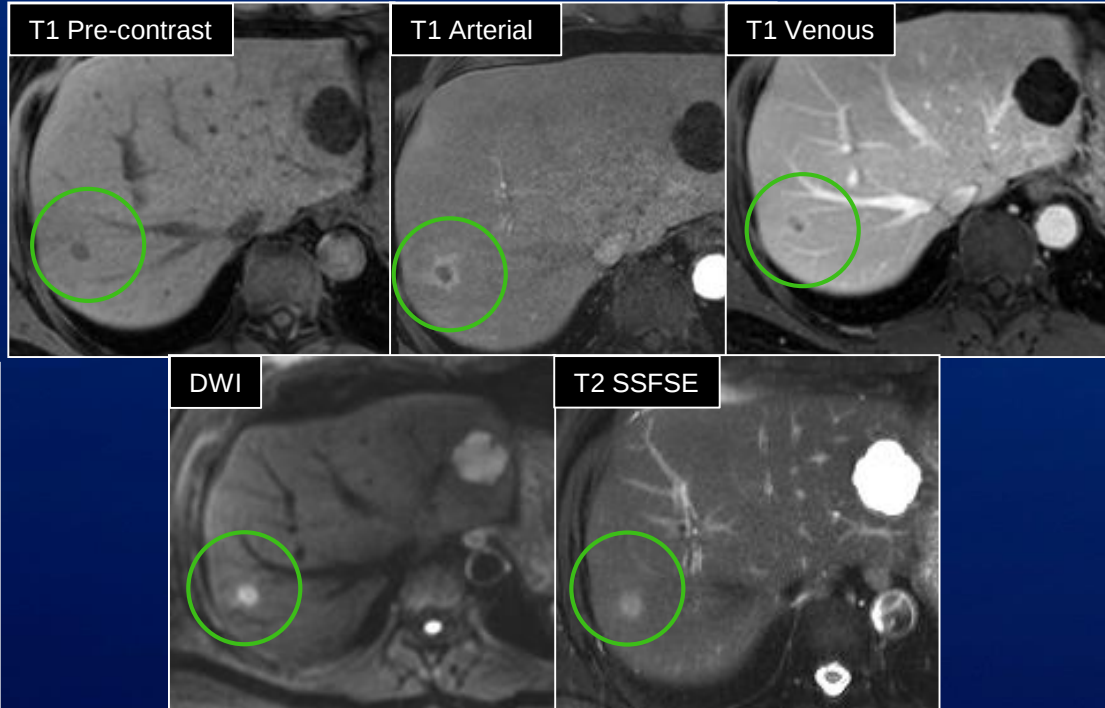
Unresectable

Staging – Lymph Nodes



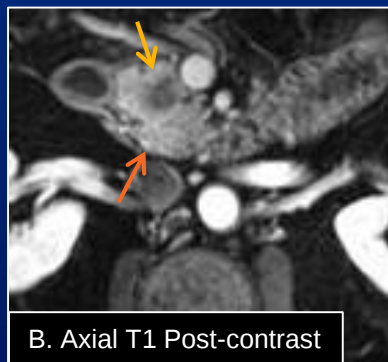
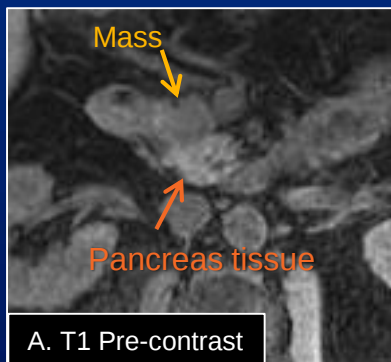
Non-regional retroperitoneal lymph nodes (arrows) equate to metastatic disease

Staging – Metastases

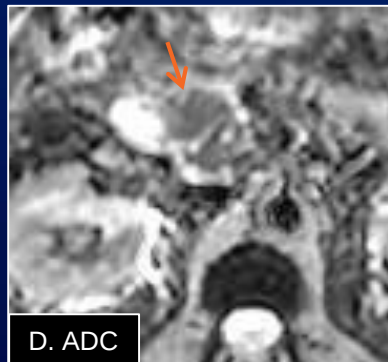
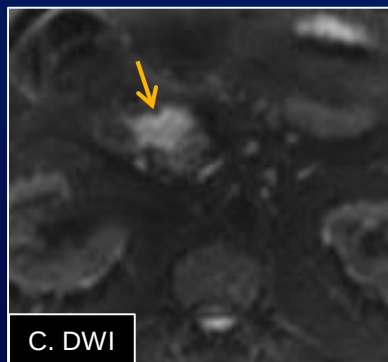


CT and MR performed 2 days apart – MRI better characterizes an indeterminate lesion on CT as a metastasis (circle)

Staging – Putting it all together



(A and B) Small T1 hypointense and hypoenhancing mass (arrow) in the pancreatic head with adjacent T1 hyperintense normal pancreas tissue (arrow)



(C) DWI demonstrates high signal (arrow) in the tumor. (D) ADC map shows associated restricted diffusion of the tumor (arrow)

Tumor description:

- ✓ Size
- ✓ Location
- ✓ Pancreatic duct
- ✓ Biliary duct

Vascular involvement:

- ✓ <180 (abutment)
- ✓ >180 (encasement)
- ✓ Narrow or irregular contour
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- ✓ Extension to
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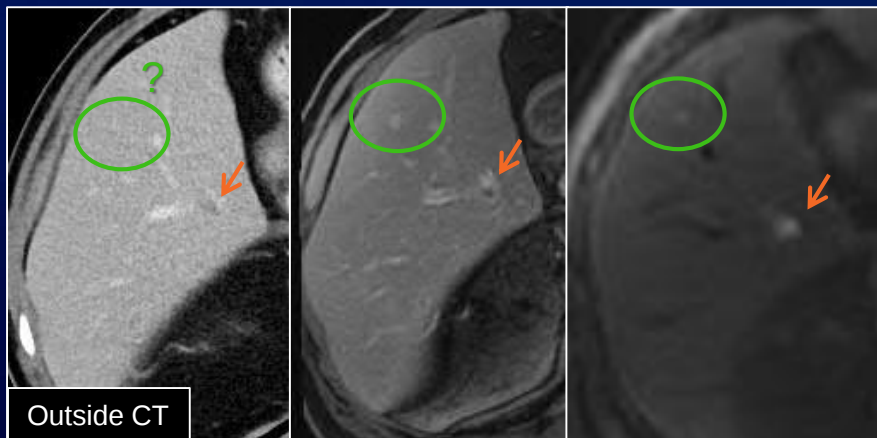
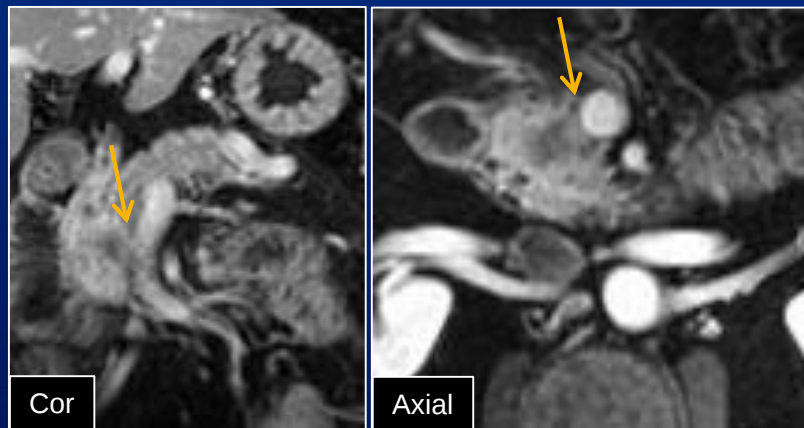
Extrapancreatic:

- ✓ Liver metastases
- ✓ Peritoneal nodules
- ✓ Ascites
- ✓ Lymph Nodes
- ✓ Invasion of organs

Staging – Putting it all together

Abutment of the SMV (<180°)

- If this was the only involvement, then the patient would be considered resectable



Liver metastases

- Small liver mets render the patient unresectable
- CT shows a **hypodense lesion** which is shown to be a metastasis on MR
- MR showed **additional metastasis** not seen on CT

Tumor description:

- ✓ Size
- ✓ Location
- ✓ Pancreatic duct
- ✓ Biliary duct

Vascular involvement:

- ✓ <180 (abutment)
- ✓ >180 (encasement)
- ✓ Narrow or irregular contour
- ✓ Thrombus / occlusion
- ✓ Extension to
 - *SMA/SMV branch
 - *GDA > CHA
 - *CHA > Celiac
 - *CHA > bifurcation
- ✓ Variants
- ✓ Collaterals

Extrapancreatic:

- ✓ Liver metastases
- ✓ Peritoneal nodules
- ✓ Ascites
- ✓ Lymph Nodes
- ✓ Invasion of organs

Neoadjuvant follow up

- A limited number of patients with locally advanced pancreatic cancer can be down staged after neoadjuvant therapy
 - Up to 30% of patients
- Restaging after neoadjuvant therapy can be a challenge

Challenge:

- ✓ Post treatment changes around pancreas and vessels
 - ✓ Solid tumor contact around vessels replaced by fat stranding or perivascular “haziness”
 - ✓ Tumor vs fibrosis?
- ✓ Peripancreatic inflammation

Morgan et al

Morgan DE *AJR* 2010; 194:615-622

- Lower sensitivity of CT for prediction of resectability b/w neoadjuvant therapy and controls without preoperative therapy
 - Not statistically significant
- Sensitivities were 86%, 71%, and 14% for the neoadjuvant group and 90%, 90%, and 60% for the control group ($p > 0.05$).
- Majority of error in neoadjuvant group due to *overestimation of vascular involvement*, particularly venous

Cassinotto et al

Cassinotto C *EJR* 2013; 82: 589-593

- Neoadjuvant reduces CT accuracy of tumor staging
 - Neoadjuvant (58%)
 - Control group w/o neoadjuvant tx (88%)
- CT specificity also lower
 - Neoadjuvant (52%)
 - Control (88%)
- *Overestimation of vascular involvement in neoadjuvant*
- Tendency to understage in control group

Kim et al

Kim YE *Radiology* 2009; 250: 758-765

- 38 Pts (12 neoadjuvant)
- *Neoadjuvant reduces CT accuracy of tumor staging*
 - 58% neoadjuvant
 - 95% control
- Prediction for resectability was comparable b/w neoadjuvant and control
 - 83% neoadjuvant
 - 81% control
- Small number of pts in neoadjuvant group

Background

Modality

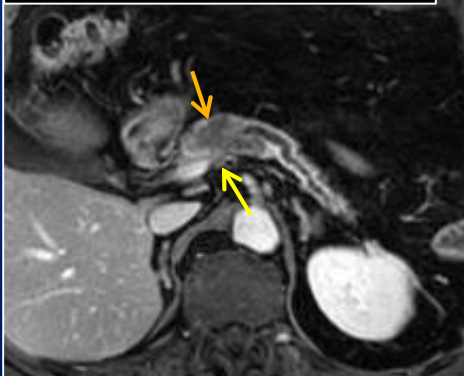
Diagnosis

Staging

Restaging

Surveillance

A. Axial T1 Post-contrast Venous



B. Sagittal T1 Post-contrast



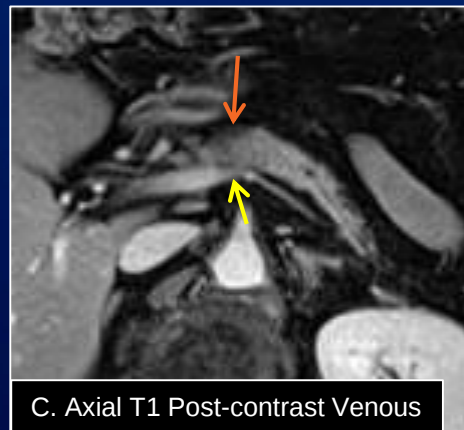
Restaging – Case 1

Significant decrease in size of **mass** seen on (C) axial post contrast image. Retraction from the **veins** is well demonstrated on sagittal T1WI post contrast imaging (D) with fat plane between tumor and SMV (**arrow**)

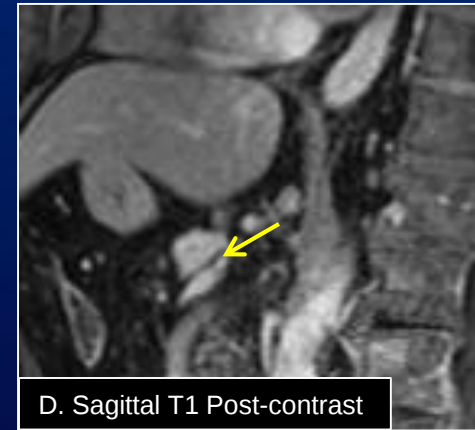
(A and B) Hypoenhancing pancreatic neck **mass** (arrow) abutting the portal confluence (arrow)

Neoadjuvant chemotherapy

Pylorus preserving total
pancreatectomy with
R0 resection

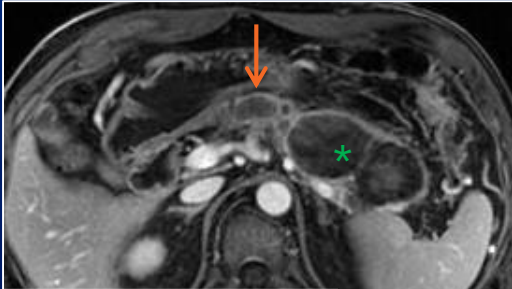


C. Axial T1 Post-contrast Venous



D. Sagittal T1 Post-contrast

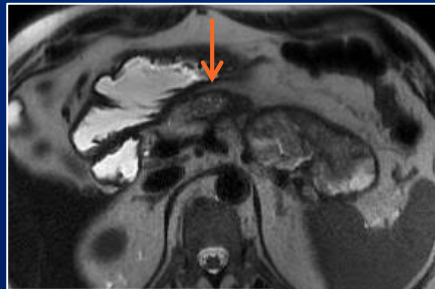
Restaging – Case 2



A. Axial T1 Post-contrast



B. Coronal T1 Post-contrast



C. Axial T2 SSFSE

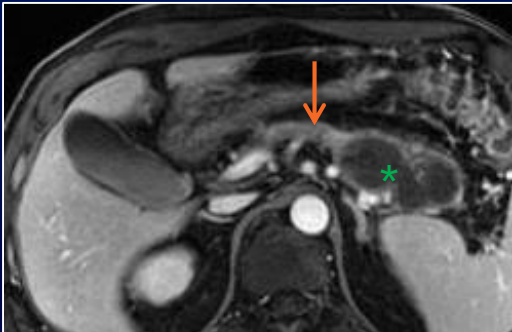
(A) Axial post contrast imaging shows a large **hypoenhancing mass** in the body of the pancreas (*) with **tumor in duct** (arrow). (B) Coronal post contrast image shows **gastric invasion** (circle). (C) Axial SSFSE shows dilated duct with **tumor** (arrow)



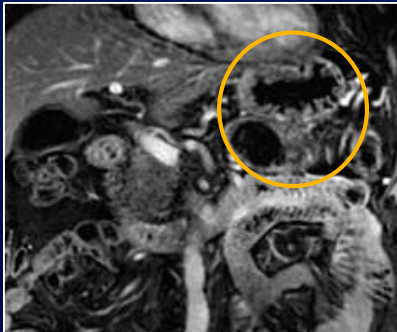
Neoadjuvant



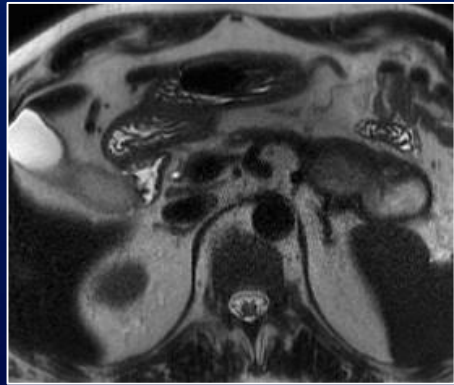
Therapy



Decrease in size of **mass** and **tumor in duct**



Minimal gastric wall attachment

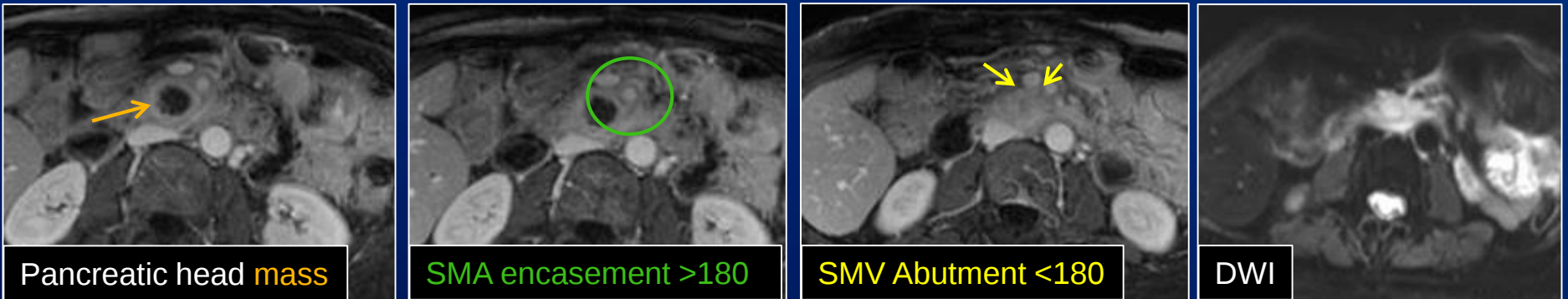


Subtotal
pancreatectomy,
splenectomy,
and partial gastrectomy
with R0 resection



Restaging – Case 3

Pt w/locally advanced pancreatic adenocarcinoma at initial staging



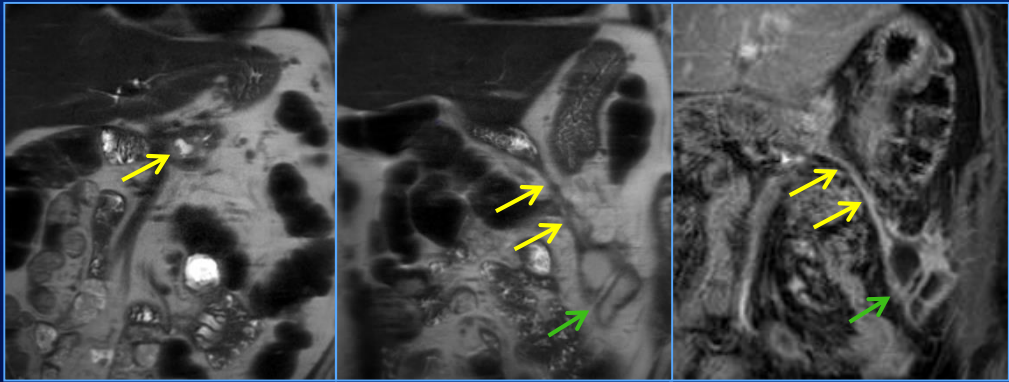
Neoadjuvant Therapy



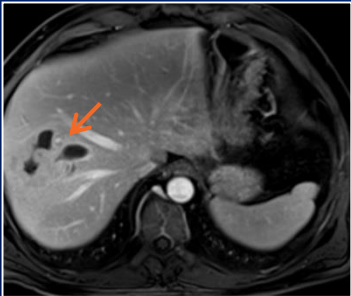
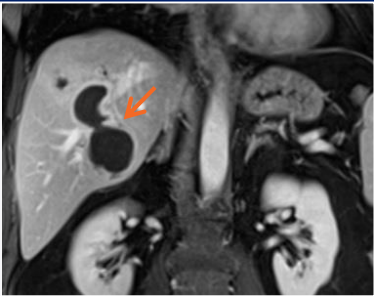
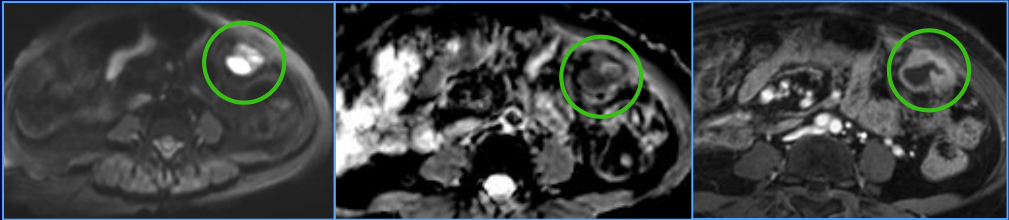
Patient went on to Whipple with R0 resection

Surveillance – Postoperative complications

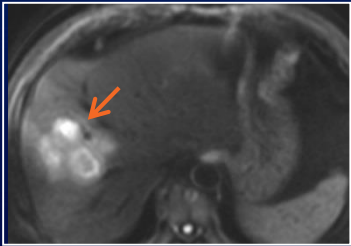
- What to look for:
- ✓ Postop complications
 - ✓ Surgical bed recurrence
 - ✓ Vascular encasement
 - ✓ Liver metastases
 - ✓ Peritoneal nodules
 - ✓ Ascites
 - ✓ Lymph Nodes



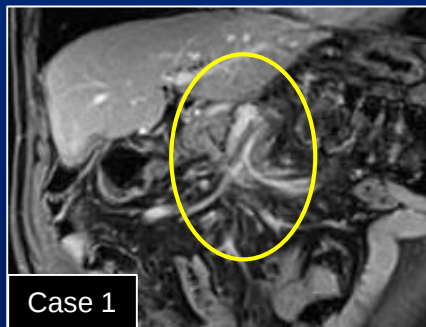
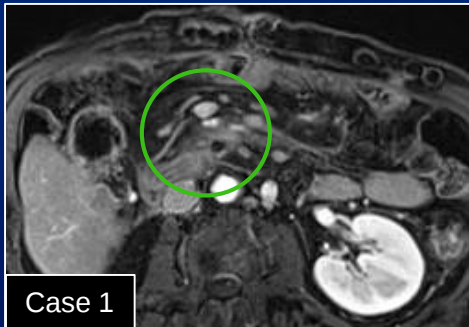
Pancreatic leak with pseudocyst



Hepatic abscesses



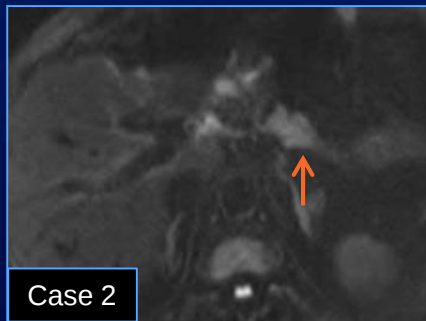
Surveillance - Recurrence



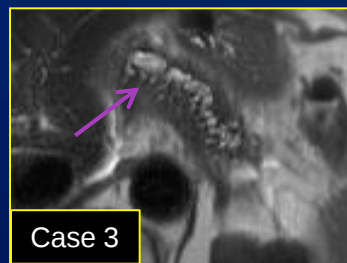
What to look for:

- ✓ Postop complications
- ✓ Surgical bed recurrence
- ✓ Vascular encasement
- ✓ Liver metastases
- ✓ Peritoneal nodules
- ✓ Ascites
- ✓ Lymph Nodes

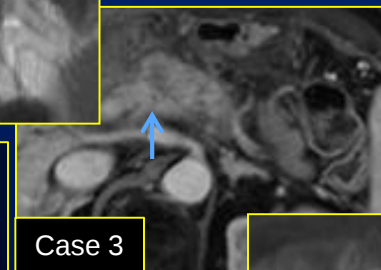
First surveillance scan post total pancreatectomy shows **infiltrative tissue in surgical bed** and **new soft tissue encasing SMA** and branches



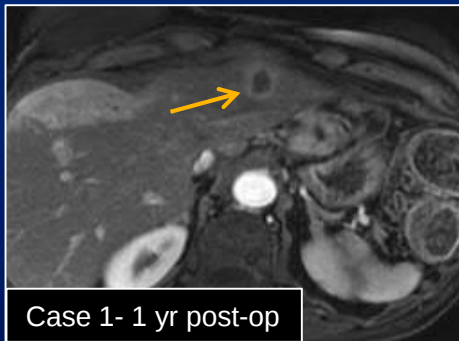
Recurrent **tumor** in pancreatic remnant with **restricted diffusion**



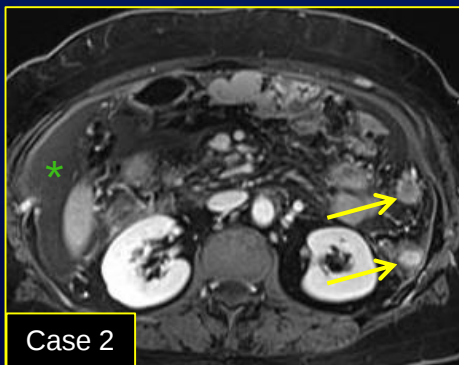
New **pancreatic duct dilatation** with **hypoenhancing mass** in pancreatic remnant and associated **restricted diffusion**



Surveillance - Metastases



Surveillance scan 1 year postop shows new **liver metastasis**



Ascites and multiple **peritoneal implants**

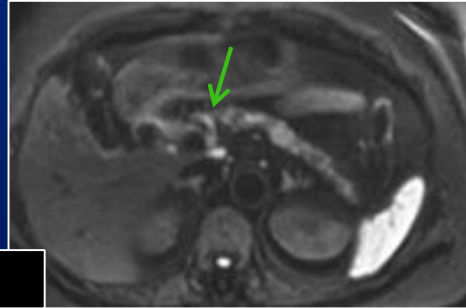
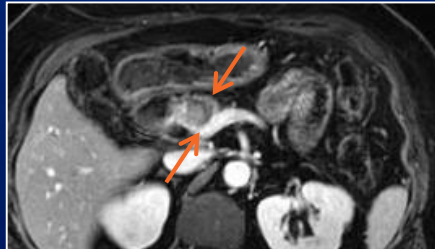
What to look for:

- ✓ Postop complications
- ✓ Surgical bed recurrence
- ✓ Vascular encasement
- ✓ **Metastases**
 - ✓ **Liver**
 - ✓ **Peritoneal nodules**
 - ✓ **Distant**
- ✓ **Ascites**
- ✓ **Lymph Nodes**

Surveillance 1 year postop shows new **muscle metastases** and **R femoral neck metastasis**



Putting it all together – Restaging and Surveillance



Initial Staging MRI

Initial Staging: Borderline Resectable

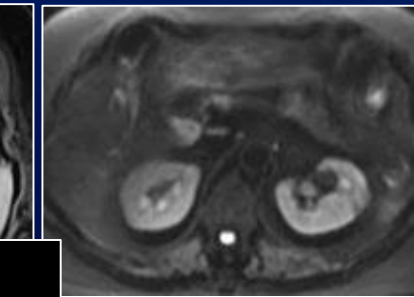
- ✓ GDA encasement w/short segment CHA encasement
- ✓ Pancreatic head mass with abutment (<180) of PV and SMV
- ✓ No liver or peritoneal mets



Neoadjuvant



Therapy



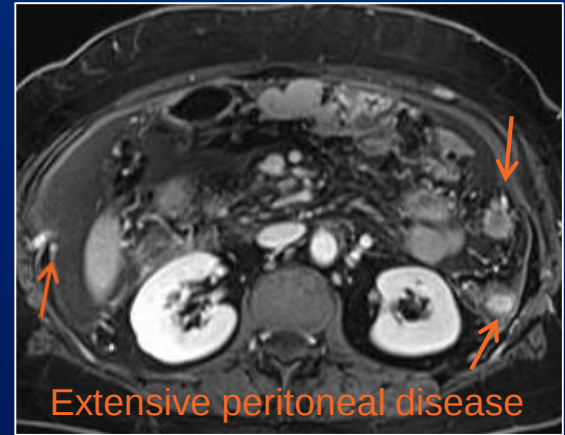
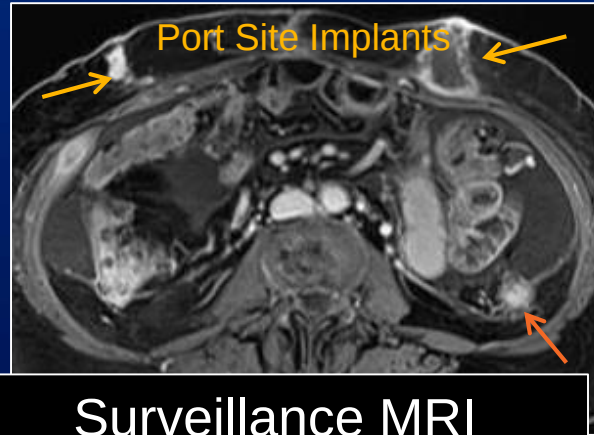
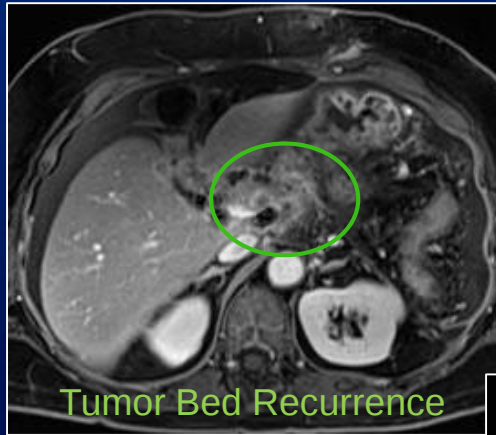
Restaging MRI

Restaging: + Tx response, no mets

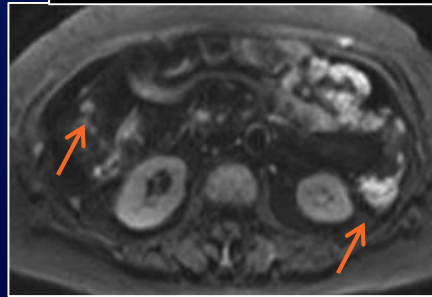
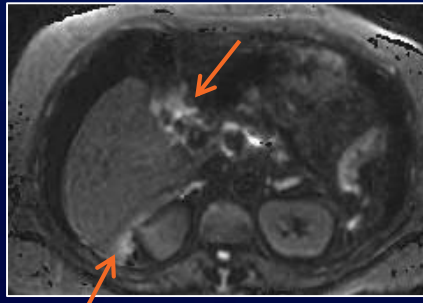
- ✓ GDA encased (not shown), improved soft tissue around CHA with only minimal tissue (arrow)
- ✓ Primary tumor much smaller
- ✓ Minimal abutment of PV and SMV
- ✓ No liver or peritoneal mets

Putting it all together – Restaging and Surveillance

Patient was initially planned for Whipple procedure but underwent total pancreatectomy due to high grade dysplasia in the ducts from IPMN at the time of surgery, R0 resection



Surveillance MRI



Surveillance scan:

- ✓ Recurrence in surgical bed
- ✓ Extensive metastatic disease

Conclusions

- MRI has been shown to be equivalent to CT in staging pancreatic cancer
- MRI can be an excellent modality in diagnosis, staging, and surveillance of pancreatic cancer
- MRI may be superior to CT in diagnosing hepatic and peritoneal metastases
- MRI may better define appropriate surgical candidates

