Fundamentals of Radiographic Staging of Pancreatic Cancer

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Medical College of Wisconsin
Department of Radiology
Disclosures

• None
Where did you grow up?
Do you agree that Aaron Rodgers is better than Matt Ryan?
Role of Imaging

- Tumor detection & characterization
- Staging
- Predict if R0 resection can be achieved safely
- Detect and describe vascular variants for presurgical planning
Keys to Success

- Great imaging
- Ease of access and reproducibility
- Standardized Interpretation & Reporting
Keys to Success

Great imaging

*MDCT pancreas protocol
*Image before any intervention
Why MDCT?
Why MDCT?

- Good spatial resolution
- Wide field of coverage in one exam
- Good contrast differentiation between tumor and normal parenchyma
- 3-D data sets for multi-planar vascular and pancreatic reconstructions
- Reproducibility
- Ease of access
Keys To Success

Imaging that is easily available and reproducible

*Enterprise access with standardization
Access & Standardization

- 11 Locations for CT Imaging
- 17 CT scanners
- 11 Different CT models
- 3 CT vendors
*Lead CT Technologist(s) are critical working in conjunction with MD champion
MDCT Technique

MDCT
» Scanner with 64-slice or greater preferred

Oral Contrast
» Neutral contrast agent (water)
» No positive contrast

Intravenous contrast
» 100-120cc of IV contrast injected at 3-5cc/sec

Phases
» Pancreatic phase (Late arterial phase)
» Hepatic phase (Portal venous phase)
Dual-phase Technique

Late-arterial (Pancreatic) Phase
- Peak aortic arrival + 15 sec.
- Best phase for detecting tumors
- Best phase to evaluate for arterial anatomy and tumor involvement
CT Protocol

• Dual-phase Technique

  » Portal Venous Phase
    – Peak aortic arrival + 45 sec.
    – Best phase to evaluate for venous anatomy and tumor involvement
    – Best phase to evaluate liver for mets
Late Arterial Phase
- Tumor detection (adenocarcinoma & neuroendocrine tumor)
- Arterial anatomy
- Tumor-artery relationship

Portal-Venous Phase
- Identify metastases
- Venous Anatomy
- Tumor-vein relationship
Where is the tumor in the pancreatic head?
Tumor Detection

Late Arterial Phase

Portal-Venous Phase
Where is the tumor in the pancreatic head?
Reformations

Curved Plane Reconstruction

Courtesy WD Foley, MD
Resectable adenocarcinoma of the pancreatic head/uncinate process (arrow) confined to the pancreas. Note the low attenuation tumor is distinct from the SMA and SMV with persistent fat plane (arrowhead).
Keys to success

Standardized Radiographic Staging

*Standardized interpretation and reporting using an accepted staging system
Clinical Staging

Operable
- Resectable
- Borderline Resectable

Inoperable
- Locally Advanced (Type A vs. B)
- Metastatic

Arterial involvement

Venous involvement

Extrapancreatic disease

Courtesy Naveen Kulkarni, MD
# MD Anderson
Clinical/Imaging Staging

<table>
<thead>
<tr>
<th>Tissue Plane</th>
<th>Abutment (≤ 180°)</th>
<th>Encasement (&gt; 180°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA</td>
<td>Resectable</td>
<td></td>
</tr>
<tr>
<td>CA</td>
<td>Borderline</td>
<td></td>
</tr>
<tr>
<td>CHA</td>
<td></td>
<td>Locally Adv</td>
</tr>
<tr>
<td>SMV/PV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Courtesy WD Foley, MD
## NCCN Guidelines Version 1.2019

### Pancreatic Adenocarcinoma

#### CRITERIA DEFINING RESECTABILITY STATUS

<table>
<thead>
<tr>
<th>Resectability Status</th>
<th>Arterial</th>
<th>Venous</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resectable</strong></td>
<td>No arterial tumor contact (celiac axis [CA], superior mesenteric artery [SMA], or common hepatic artery [CHA]).</td>
<td>No tumor contact with the superior mesenteric vein (SMV) or portal vein (PV) or ≤180° contact without vein contour irregularity.</td>
</tr>
</tbody>
</table>
| **Borderline Resectable**<sup>b</sup> | Pancreatic head/uncinate process:  
- Solid tumor contact with CHA without extension to CA or hepatic artery bifurcation allowing for safe and complete resection and reconstruction.  
- Solid tumor contact with the SMA of ≤180°  
- Solid tumor contact with variant arterial anatomy (e.g., accessory right hepatic artery, replaced right hepatic artery, replaced CHA, and the origin of replaced or accessory artery) and the presence and degree of tumor contact should be noted if present, as it may affect surgical planning.  
Pancreatic body/tail:  
- Solid tumor contact with the CA of ≤180°  
- Solid tumor contact with the CA of >180° without involvement of the aorta and with intact and uninvolved gastroduodenal artery thereby permitting a modified Appleby procedure (some panel members prefer these criteria to be in the unresectable category). |  
| **Unresectable**<sup>b</sup> | Distant metastasis (including non-regional lymph node metastasis)  
Head/uncinate process:  
- Solid tumor contact with SMA >180°  
- Solid tumor contact with the CA >180°  
Body and tail:  
- Solid tumor contact of >180° with the SMA or CA  
- Solid tumor contact with the CA and aortic involvement | Head/uncinate process:  
- Unreconstructible SM/PV due to tumor involvement or occlusion (can be due to tumor or bland thrombus)  
- Contact with most proximal draining jejunal branch into SMV  
Body and tail:  
- Unreconstructible SM/PV due to tumor involvement or occlusion (can be due to tumor or bland thrombus) |


<sup>b</sup>Solid tumor contact may be replaced with increased hazy density/stranding of the fat surrounding the peri-pancreatic vessels (typically seen following neoadjuvant therapy); this finding should be reported on the staging and follow-up scans. Decision on resectability status should be made in these patients, in consensus at multidisciplinary meetings/discussions.

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**Note:** All recommendations are category 2A unless otherwise indicated.

**Clinical Trials:** NCCN believes that the best management of any patient with cancer is in a clinical trial. Participation in clinical trials is especially encouraged.
Definitions

**Primary Tumor (T)**
- TX: Primary tumor cannot be assessed
- T0: No evidence of primary tumor
- Tis: Carcinoma in situ**
- T1: Tumor limited to the pancreas, 2 cm or less in greatest dimension
- T2: Tumor limited to the pancreas, more than 2 cm in greatest dimension
- T3: Tumor extends beyond the pancreas but without involvement of the celiac axis or the superior mesenteric artery
- T4: Tumor involves the celiac axis or the superior mesenteric artery (unresectable primary tumor)

**Regional Lymph Nodes (N)**
- NX: Regional lymph nodes cannot be assessed
- N0: No regional lymph node metastasis
- N1: Regional lymph node metastasis

**Distant Metastasis (M)**
- M0: No distant metastasis
- M1: Distant metastasis

<table>
<thead>
<tr>
<th>Anatomic Stage/Prognostic Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
</tr>
<tr>
<td>Stage II</td>
</tr>
<tr>
<td>Stage III</td>
</tr>
<tr>
<td>Stage IV</td>
</tr>
</tbody>
</table>

Notes

** Stage IA**
- T1 N0 M0

** Stage IB**
- T2 N0 M0

** Stage III**
- T4 Any N M0

** Stage IV**
- Any T Any N M1

**Tumors of the head of the pancreas are those arising to the right of the superior mesenteric-portal vein confluence.**

**American Cancer Society**

Financial support for AJCC 7th Edition Staging Posters provided by the American Cancer Society
# MCW Clinical/Imaging Staging

## Table 1. Medical College of Wisconsin CT-based clinical staging of pancreatic cancer.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resectable</strong></td>
<td>Tumor-artery relationship: No radiographic evidence of arterial abutment (celiac, SMA, or hepatic artery)</td>
</tr>
<tr>
<td></td>
<td>Tumor-vein relationship: Tumor-induced narrowing, if present, is &lt;50% of the circumference of the SMV, PV, or SMV-PV confluence</td>
</tr>
<tr>
<td><strong>Borderline Resectable</strong></td>
<td>Artery: Tumor abutment (&lt;180° of the circumference) of SMA or celiac artery. Tumor abutment or short segment encasement (≥180°) of the hepatic artery</td>
</tr>
<tr>
<td></td>
<td>Vein: Tumor induced narrowing of &gt;50% of SMV, PV, or SMV-PV or short segment occlusion of SMV, PV, SMV-PV with suitable PV (above) and SMV (below) to allow for safe vascular reconstruction</td>
</tr>
<tr>
<td></td>
<td>Extrapancreatic findings: CT scan findings suspicious, but not diagnostic of, metastatic disease (for example, small indeterminate liver lesions which are too small to characterize)</td>
</tr>
<tr>
<td><strong>Locally Advanced</strong></td>
<td>Artery: Tumor encasement (≥180° of the circumference) of SMA or celiac artery</td>
</tr>
<tr>
<td></td>
<td>Vein: Occlusion of SMV, PV, or SMV-PV without suitable vessels above and below the tumor to allow for reconstruction (no distal or proximal target for vascular reconstruction)</td>
</tr>
<tr>
<td></td>
<td>Extrapancreatic findings: No evidence of peritoneal, hepatic, extra-abdominal metastases</td>
</tr>
<tr>
<td><strong>Metastatic</strong></td>
<td>Evidence of peritoneal or distant metastases</td>
</tr>
</tbody>
</table>

**Abbreviations:** SMA, superior mesenteric artery; SMV, superior mesenteric vein; PV, portal vein; SMV-PV, superior mesenteric-portal vein confluence.
<table>
<thead>
<tr>
<th></th>
<th>Tissue Plane</th>
<th>Abutment ($\leq 180^\circ$)</th>
<th>Encasement ($&gt; 180^\circ$)</th>
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<td>Locally Adv</td>
</tr>
</tbody>
</table>

If reconstruction possible
Locally Advanced
Type A vs. B

<table>
<thead>
<tr>
<th>Vascular structures, any one of which, determine the stage of disease for localized PC</th>
<th>Borderline resectable</th>
<th>Locally advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tumor-artery anatomy</strong></td>
<td>SMA (usually pertains to a tumor of the head or uncinate process)</td>
<td>≤180 degree (abutment)</td>
</tr>
<tr>
<td></td>
<td>Celiac artery (usually pertains to a tumor of the pancreatic body)</td>
<td>≤180 degree (abutment)</td>
</tr>
<tr>
<td></td>
<td>HA (usually pertains to a tumor of the pancreatic neck/head)</td>
<td>Short segment abutment/encasement without extension to celiac artery or HA bifurcation</td>
</tr>
<tr>
<td><strong>Tumor-vein anatomy</strong></td>
<td>SMV-PV</td>
<td>&gt;50% narrowing of SMV, PV, SMV/PV with a distal and proximal target for reconstruction</td>
</tr>
</tbody>
</table>

Traditionally considered for resection after neoadjuvant therapy

| Yes | No |

Modified from Tsai et al.¹

NA, not applicable; HA, hepatic artery.
Keys to success

Standardized Radiographic Staging

*Standardized interpretation and reporting using an accepted staging system
Radiologists interpreting the study working in conjunction with the care team (Surgical Oncology, GI, Rad Onc, Med Onc)

* Sub-specialized radiologists
How would you classify this tumor (yellow arrow)?

- Metastatic
- Locally Advanced
- Borderline Resectable
- Resectable
How would you classify this tumor (yellow arrow)?

- Metastatic: A
- Locally Advanced: B
- Borderline Resectable: C
- Resectable: D
How would you classify this tumor (yellow arrow)?

- Metastatic
- Locally Advanced
- Borderline Resectable
- Resectable
<table>
<thead>
<tr>
<th>Classification</th>
</tr>
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<tbody>
<tr>
<td>Metastatic</td>
</tr>
<tr>
<td>Locally Advanced</td>
</tr>
<tr>
<td>Borderline</td>
</tr>
<tr>
<td>Resectable</td>
</tr>
</tbody>
</table>

How would you classify this tumor?
Resectable
Patient 1

Late Arterial Phase

Portal-Venous Phase
Resectable adenocarcinoma of the pancreatic head/uncinate process (arrow) confined to the pancreas. Note the low attenuation tumor is distinct from the SMA and SMV with persistent fat plane (arrowhead).
Resectable adenocarcinoma of the pancreatic head/uncinate process (arrow) confined to the pancreas. Note the low attenuation tumor is distinct from the SMA and SMV with persistent fat plane (arrowhead).
Resectable adenocarcinoma of the pancreatic head/uncinate process (arrow) confined to the pancreas. Note the low attenuation tumor is distinct from the SMA and SMV with persistent fat plane (arrowhead).
How would you classify this tumor (yellow arrow)?

- Metastatic
- Locally Advanced
- Borderline Resectable
- Resectable
Borderline Resectable
Abutment vs. Encasement

A

B

C

T

A

T

A
Patient 1

Late Arterial Phase

Portal-Venous Phase
Patient 2
Initial Staging Exam

Late Arterial Phase

Portal-Venous Phase
Completion Neoadjuvant Rx

Late Arterial Phase

Portal-Venous Phase
Patient 2

Initial Exam

Completion Neo-Adjuvant

Portal-Venous Phase
Patient 2
Post-Op Scan

- Segmental PV-SMV resection with re-anastomosis
- Spleno-renal shunt
How would you classify this tumor (yellow arrow)?

- Metastatic
- Locally Advanced
- Borderline Resectable
- Resectable
Locally Advanced
Locally advanced pancreatic adenocarcinoma of the uncinate process with tumor encasement of the SMA (arrow). Note the low-attenuation soft-tissue with encases the SMA for 360 degrees of the vessels. Note plastic biliary stent (curved arrow).
Locally advanced pancreatic adenocarcinoma of the uncinate process with tumor encasement of the SMA (arrow). Note the low-attenuation soft-tissue with encases the SMA for 360 degrees of the vessels.
Locally advanced pancreatic adenocarcinoma at the junction of the pancreatic neck/body with tumor encasement of the CHA (arrow) and PV-SV-SMV confluence (arrowhead). Note the low-attenuation soft tissue with encases the CHA and PV-SV-SMV confluence for 360 degrees of the vessels.

Patient 2
Locally advanced pancreatic adenocarcinoma at the junction of the pancreatic neck/body with tumor encasement of the CHA (arrow) and PV-SV-SMV confluence with severe focal narrowing (arrowhead). Note the low-attenuation soft-tissue with encases the CHA and PV-SV-SMV confluence for 360 degrees of the vessels.
How would you classify this tumor (yellow arrow)?

- Metastatic: A
- Locally Advanced: B
- Borderline Resectable: C
- Resectable: D
Metastatic
Patient 1
Patient 2
Patient 2

Metastatic Peritoneal Implants
How would you classify this tumor?

- Metastatic
- Locally Advanced
- Borderline Resectable
- Resectable
Imaging after GI Intervention

Difficult to Stage
Arterial Anatomy

- Normal (Type 1)
- Right HA replaced to SMA
- Completely replaced CHA to SMA
- Accessory or direct origin of Left HA to Left Gastric A.
- Branches of SMA which may be involved with tumor
Venous Anatomy

- Portal Vein
- Splenic Vein
- SMV and draining branches
  - 1st jejunal branch
- IMV
Standardized Reporting

Pancreatic Cancer SR creates a CHECKLIST to comprehensively STAGE and report all findings that may affect SURGICAL PLANNING.
Structured Reporting of Multiphasic CT for Pancreatic Cancer: Potential Effect on Staging and Surgical Planning

Olga R. Brook, MD Alexander Brook, PhD Charles M. Vollmer, MD Tara S. Kent, MD Norberto Sanchez, MD Ivan Pedrosa, MD

From the Departments of Radiology (O.R.B., A.B.) and Surgery (T.S.K., N.S.), Beth Israel Deaconess Medical Center, Boston, Mass; Department of Surgery, University of Pennsylvania, Philadelphia, Pa (C.M.V.); and Department of Radiology, University of Texas Southwestern Medical Center, 2201 Inwood Rd, 2nd Floor, Suite 202, Dallas, TX 75330-5085 (I.P.).

Conclusion

Structured reporting of pancreatic multiphasic CT provided superior evaluation of pancreatic cancer and facilitated surgical planning. Surgeons were more confident regarding decisions about tumor resectability when they reviewed structured reports before review of multiphasic CT images.
The Case for Structured Reports

Structured Reporting of Multiphasic CT for Pancreatic Cancer: Potential Effect on Staging and Surgical Planning

<table>
<thead>
<tr>
<th>Feature</th>
<th>Nonstructured Reports (n = 72)</th>
<th>Structured Reports (n = 48)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of tumor</td>
<td>69 (96)</td>
<td>48 (100)</td>
<td>.15</td>
</tr>
<tr>
<td>Probable diagnosis</td>
<td>53 (74)</td>
<td>48 (100)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Tumor staging</td>
<td>56 (78)</td>
<td>48 (100)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Node staging</td>
<td>64 (89)</td>
<td>48 (100)</td>
<td>.02</td>
</tr>
<tr>
<td>Metastasis staging</td>
<td>63 (88)</td>
<td>48 (100)</td>
<td>.01</td>
</tr>
<tr>
<td>Superior mesenteric artery involvement</td>
<td>52 (72)</td>
<td>48 (100)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Superior mesenteric vein and portal vein involvement</td>
<td>52 (72)</td>
<td>48 (100)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Presence of vessels with thrombosis</td>
<td>36 (50)</td>
<td>48 (100)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Presence of replaced right hepatic artery</td>
<td>15 (21)</td>
<td>42 (88)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Presence of any vascular aberrancy</td>
<td>40 (56)</td>
<td>47 (98)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Presence of atherosclerosis</td>
<td>28 (39)</td>
<td>26 (54)</td>
<td>.1</td>
</tr>
<tr>
<td>Distance from tumor to superior mesenteric vein</td>
<td>0 (0)</td>
<td>9 (19)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No. of key features</td>
<td>7.3 ± 2.1*</td>
<td>10.6 ± 0.9*</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Published in: Olga R. Brook; Alexander Brook; Charles M. Vollmer; Tara S. Kent; Norberto Sanchez; Ivan Pedrosa; Radiology 2015, 274, 464-472.
DOI: 10.1148/radiol.14140206 2014 by the Radiological Society of North America, Inc.
Example SR

Medical College of Wisconsin – Pancreatic Cancer Staging

Examination(s): [1. CT angiography abdomen with IV contrast.
2. CT pelvis with IV contrast. ]

Clinical Information: [Pancreatic mass: Initial staging. ]

Comparison: [None. ]

Technique:
- IV contrast: [125 mL Omniscan 350. ]
- Oral contrast: [None. ]
- Technical comments: [Dual-phase imaging of the abdomen. ]
- 3D imaging: [Multiplanar MIP, curved planar, and 3D volume rendered images are created by the 3D lab. ]

Dose reduction: [This CT exam was performed using one or more of the following dose-reduction techniques: Automated exposure control, adjustment of the mA and/or kV according to patient size, and/or use of iterative reconstruction technique. ]

Findings:

PANCREAS

Primary tumor: [A 0 cm (low-attenuation) mass in the [***] [somes], image # 1].

Pancreatic duct: [Dilated: 6 mm. ]

[No other pancreatic mass is identified. The pancreas is otherwise normal. ]

MESENTERIC ARTERIES

Arterial anastomosis: [Normal Type I. ]

Arterial tumor abutment or encasement:

Celiac, common/proper hepatic, proximal splenic, left gastric and gastroduodenal arteries: [None. Abutment (less than or equal to 180 degrees). Encasement (greater than 180 degrees). ]

Superior mesenteric artery: [None Abutment (less than or equal to 180 degrees). Encasement (greater than 180 degrees). ]

Other findings: [NONE or Tumor abutment or encasement of additional arteries (i.e., IPAA, GDA, jejunal, middle colic, or ileocolic branches). ]

MESENTERIC VEINS

Venous anatomy:

Superior mesenteric vein (SMV) 1st jejunal branch: [posterior to SMA. ]

Inferior mesenteric vein (IMV) drains into the SMV inferior to the [mesocolic confluence. ]

Venous tumor abutment or encasement:

SMV-PV splenic vein confluence: [None Abutment (less than or equal to 180 degrees). Encasement (greater than 180 degrees). ]

First jejunal vein branch: [None Abutment (less than or equal to 180 degrees). Encasement (greater than 180 degrees). ]

SMV, PV, or segmental SMV-PV occlusion: [None. ]

Other findings: [NONE or Tumor abutment or encasement of jejunal, middle colic, gastroepiploic, or ileal branches of the SMV or Long (short segment approximately x cm) of tumor free SMV inferior (cauda) to diseased segment. ]

Portal venous system: [Normal and patent. ]

Inferior vena cava (IVC): [Normal. ]

HEPATOBILIARY SYSTEM

Focal liver lesion: [None. ]

Biliary tree: [No evidence of bile duct dilatation. ]

Gallbladder: [Present. ]

LOCOREGIONAL SPREAD

Lymph nodes: [None. ]

Peritoneum: [Negative. No nodularity or thickening. ]

Omentum: [Negative. No nodularity or thickening. ]

Arteries: [None. ]

OTHER FINDINGS

Stomach, small bowel, and large bowel: [Normal wall thickness, caliber, and enhancement. ]

Genitourinary system: [Normal. ]

Adrenal glands: [Normal. ]

Spleen: [Normal. ]

Lower chest: [Normal. ]

Bones: [No significant lesion. ]

Impressions:

1. Pancreatic head mass measuring [ cm consistent with [pancreatic adenocarcinoma]. ]
2. [No metastatic disease. ]
3. [No adenopathy. ]
4. [No arterial or venous abutment or encasement. ]
5. [Other impression statements. ]
Emerging Technologies

Dual Energy CT
PET/MR
CT – Dual Energy

Courtesy of Dr. Naveen Kulkarni
**PET/MR**

- First PET/MR in Wisconsin
- Purchase cost $5.5M
- Any PET agent can be utilized (i.e., FDG or Ga-Dotatate)
- Reimbursed for same indications as PET-CT
Late Arterial Phase

Portal-Venous Phase
PET/MR
Thank You!

Any Questions?
Courtesy of Dr. Naveen Kulkarni