# Maximizing Tumor control and Limiting Toxicity With SBRT for Pancreas Cancer

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Geisinger Health – Geisinger Cancer Institute
Past President and Chairman: The Radiosurgery Society

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## Objectives

- Current role of radiation in Pancreas Cancer
- Significance of local control and control of distant metastasis
- SBRT for pancreas cancer
- Clinical scenarios for exploring future role

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## Fundamental Principles

- Surgery is the primary curative treatment for Cancer
- Systemic therapy is essential component in the multimodality management of cancer
- Radiation therapy is more about protecting normal tissue than treating cancer

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**Estimated New Cases**

| Males | | | Females | | |
|---|---|---|---|---|---|
| Prostate | 248,530 | 26% | Breast | 281,550 | 30% |
| Lung & bronchus | 119,100 | 12% | Lung & bronchus | 116,660 | 13% |
| Colon & rectum | 79,520 | 8% | Colon & rectum | 69,980 | 8% |
| Urinary bladder | 64,280 | 7% | Uterine corpus | 66,570 | 7% |
| Melanoma of the skin | 62,260 | 6% | Melanoma of the skin | 43,850 | 5% |
| Kidney & renal pelvis | 48,780 | 5% | Non-Hodgkin lymphoma | 35,930 | 4% |
| Non-Hodgkin lymphoma | 45,630 | 5% | Thyroid | 32,130 | 3% |
| Oral cavity & pharynx | 38,800 | 4% | Pancreas | 28,480 | 3% |
| Leukemia | 35,530 | 4% | Kidney & renal pelvis | 27,300 | 3% |
| Pancreas | 31,950 | 3% | Leukemia | 25,560 | 3% |
| **All Sites** | **970,250** | **100%** | **All Sites** | **927,910** | **100%** |

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**Estimated Deaths**

| Males | | | Females | | |
|---|---|---|---|---|---|
| Lung & bronchus | 69,410 | 22% | Lung & bronchus | 62,470 | 22% |
| Prostate | 34,130 | 11% | Breast | 43,600 | 15% |
| Colon & rectum | 28,520 | 9% | Colon & rectum | 24,460 | 8% |
| Pancreas | 25,270 | 8% | Pancreas | 22,950 | 8% |
| Liver & intrahepatic bile duct | 20,300 | 6% | Ovary | 22,950 | 5% |
| Leukemia | 13,900 | 4% | Uterine corpus | 12,940 | 4% |
| Esophagus | 12,410 | 4% | Liver & intrahepatic bile duct | 9,930 | 3% |
| Urinary bladder | 12,260 | 4% | Leukemia | 9,760 | 3% |
| Non-Hodgkin lymphoma | 12,170 | 4% | Non-Hodgkin lymphoma | 8,550 | 3% |
| Brain & other nervous system | 10,500 | 3% | Brain & other nervous system | 8,100 | 3% |
| **All Sites** | **319,420** | **100%** | **All Sites** | **289,150** | **100%** |

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## Perspective

**Table 1.** Median survival of patients in different stages of pancreatic cancer.

| Stage | Incidence | Median survival |
|---|---|---|
| Localized/resectable | 10% | 15-19 months |
| Locally advanced | 30% | 6-10 month |
| Metastatic | 60% | 3-6 months |

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## Clinical Scenarios Where SBRT can play a role in Pancreas Cancer

- Resectable Pancreas cancer
  - Neoadjuvant SBRT
  - Adjuvant SBRT
- Borderline resectable Pancreas Cancer
- Locally advanced
- Metastatic Pancreas Cancer
  - Oligometastatic Pancreas Cancer
- Local recurrence

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## Local Disease Staging

Intergroup radiographic criteria

| | Potentially Resectable | BORDERLINE RESECTABLE | Locally Advanced |
|---|---|---|---|
| **SMV-PV** | T-V-I < 180° | **T-V-I ≥ 180° and / or reconstructable occlusion** | Unreconstructable Occlusion |
| **SMA** | No T-V-I | **T-V-I < 180°** | T-V-I ≥ 180° |
| **CHA** | No T-V-I | **Reconstructable short-segment T-V-I of any degree** | Unreconstructable |
| **Celiac Trunk** | No T-V-I | **T-V-I < 180°** | T-V-I ≥ 180 |

T-V-I: tumor-vessel interface

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| Resectability Status | Arterial | Venous |
|---|---|---|
| Resectable | • No arterial tumor contact (celiac axis [CA], superior mesenteric artery [SMA], or common hepatic artery [CHA]). | • No tumor contact with the superior mesenteric vein (SMV) or portal vein (PV) or ≤180° contact without vein contour irregularity. |
| Borderline Resectable[b] | Pancreatic head/uncinate process:<br>• Solid tumor contact with CHA without extension to CA or hepatic artery bifurcation allowing for safe and complete resection and reconstruction.<br>• Solid tumor contact with the SMA of ≤180°<br>• Solid tumor contact with variant arterial anatomy (ex: 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.<br>Pancreatic body/tail:<br>• Solid tumor contact with the CA of ≤180°<br>• 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 locally advanced category). | • Solid tumor contact with the SMV or PV of >180°, contact of ≤180° with contour irregularity of the vein or thrombosis of the vein but with suitable vessel proximal and distal to the site of involvement allowing for safe and complete resection and vein reconstruction.<br>• Solid tumor contact with the inferior vena cava (IVC). |
| Locally Advanced[b,c] | Head/uncinate process:<br>• Solid tumor contact with SMA >180°<br>• Solid tumor contact with the CA >180°<br>Pancreatic body/tail:<br>• Solid tumor contact of >180° with the SMA or CA<br>• Solid tumor contact with the CA and aortic involvement | • Unreconstructible SMV/PV due to tumor involvement or occlusion (can be due to tumor or bland thrombus) |

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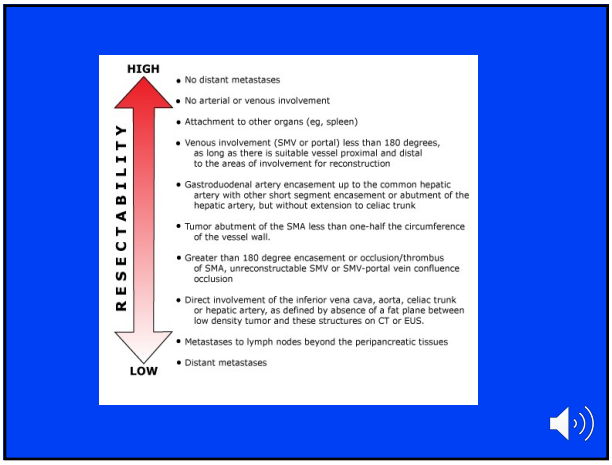


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## Locally Advanced Pancreas Cancer

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## Classic Trials: RT vs. ChemoRT and Chemo vs. ChemoRT

| Study and Treatment | No. of Patients | Median PFS (months) | Median OS (months) | 1-Year Survival (%) |
|---|---|---|---|---|
| FU-based CRT | | | | |
| Moertel et al[5]; phase III | | | | |
| RT 60 Gy | 25 | 2.9 | 5.3 | 10 |
| RT 40 Gy/FU | 83 | 5.3 | 8.4* | 35 |
| RT 60 Gy/FU | 86 | 7.75 | 11.4* | 46 |
| Klaassen et al[6]; phase III | | | | |
| FU | 44 | 4.4 | 8.2 | 32 |
| RT 40 Gy/FU | 47 | 4.2 | 8.3 | 26 |
| GITSG et al[7]; phase III | | | | |
| SMF | 21 | — | 7.4 | 19 |
| RT 54 Gy/FU and SMF | 22 | — | 9.7* | 41 |
| Cohen et al[19]; phase III | | | | |
| RT 59.4 Gy | 49 | 5 | 7.1 | — |
| RT 59.4 Gy/FU + mitomycin | 55 | 5.1 | 8.4 | — |

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## Contemporary Chemo-radiation Trials

| Trial | Treatment | No of Pts | Med OS |
|---|---|---|---|
| RTOG 9812 | 50.4Gy+Taxol | 122 | 11.3m |
| RTOG 0020 | 50.4Gy+Taxol/Gem | 154 | 11.7m |
| RTOG0411 | 50.4Gy+Xeloda/Avastin | 94 | 11.9m |
| FFCD-SSRO | 60Gy+5FU/Cisplat | 59 | 8.6m |
| ECOG 4201 | 50.4Gy+Gem | 34 | 11.0m |

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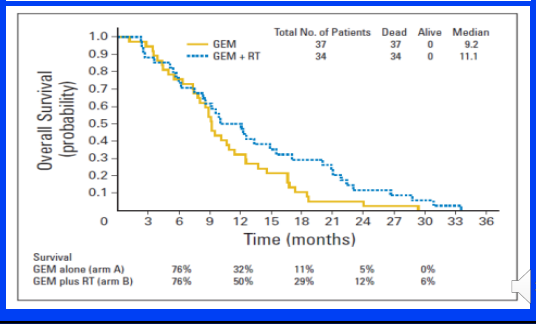
## Gemcitabine Alone Versus Gemcitabine Plus Radiotherapy in Patients With Locally Advanced Pancreatic Cancer: An Eastern Cooperative Oncology Group Trial

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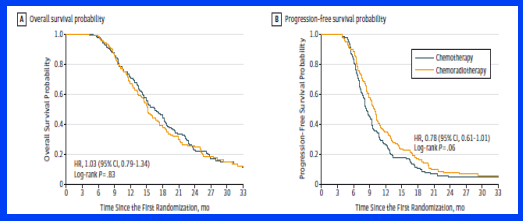
## The LAP07 Randomized Clinical Trial




- Would Better systemic therapy made a difference – Gem Abraxane, FOLFIRINOX
- Would earlier Radiation help?
- Shorter radiation (SBRT) without interrupting systemic therapy?

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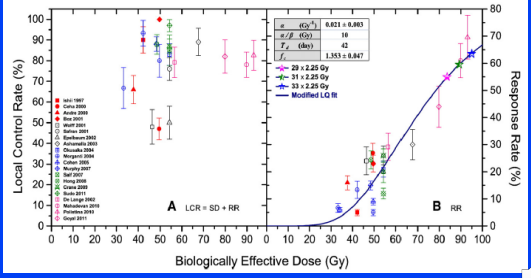
**Radiation dose responses for chemoradiation therapy of pancreatic cancer: An analysis of compiled clinical data using biophysical models**

Ion C. Moraru PhD, An Tai PhD, Beth Erickson MD, X. Allen Li PhD*

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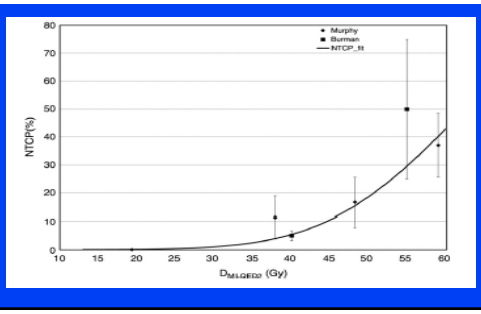
**Consolidating duodenal and small bowel toxicity data via isoeffective dose calculations based on compiled clinical data**

Phillip Prior PhD, An Tai PhD, Beth Erickson MD, X. Allen Li PhD*

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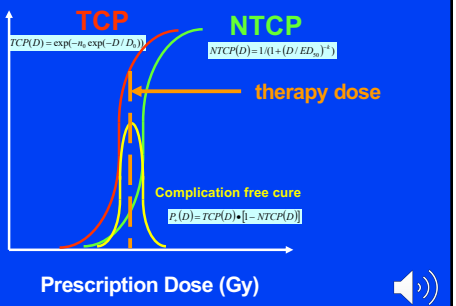
## Conventional RT (adjuvant!)

Orthovoltage -> Cobalt -> Linacs (standard fractionation)

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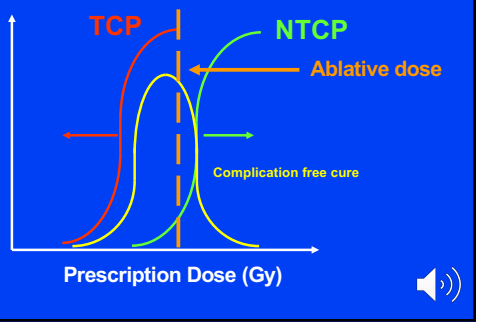
## Advanced RT (Primary?)

3DCRT -> IMRT -> SRS/SBRT (hypo-/hyper-fractionation)

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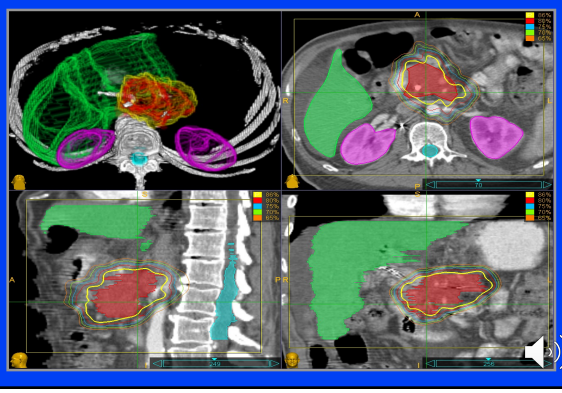
## SBRT



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## SBRT

- Stanford Phase I
- Stanford EBRT+ Boost
- Stanford Gem SBRT
- Danish Phase II
- UPMC
- Sinai, Baltimore
- BIDMC Upfront SBRT
- BIDMC Gem SBRT
- Tampa
- Hopkins/Stanford/Memorial

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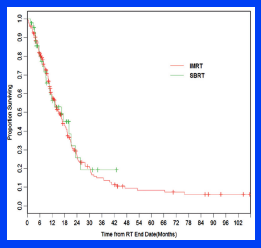
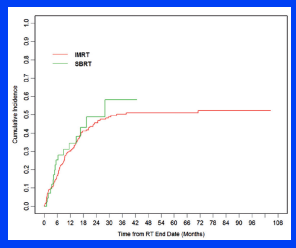
**Stereotactic body radiation vs. intensity-modulated radiation for unresectable pancreatic cancer**

Joseph J. Park[a], Carla Hajj[a], Marsha Reyngold[a], Weiji Shi[b], Zhiqang Zhang[b], John J. Cuaron[a],

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| Acute toxicity | IMRT ($n = 227$) | SBRT ($n = 44$) | $p$ Value |
|---|---|---|---|
| Grade 2+ GI | | | 0.008 |
| No | 171 (76%) | 41 (93%) | |
| Yes | 55 (24%) | 3 (7%) | |
| Grade 3+ GI | | | 1.00 |
| No | 221 (98%) | 44 (100%) | |
| Yes | 5 (2%) | 0 (0%) | |
| Grade 2+ fatigue | | | <0.0001 |
| No | 130 (58%) | 41 (93%) | |
| Yes | 96 (42%) | 3 (7%) | |
| Grade 3+ hematologic | | | 0.001 |
| No | 167 (74%) | 42 (95%) | |
| Yes | 59 (26%) | 2 (5%) | |

IMRT: intensity-modulated radiation therapy; SBRT: stereotactic body radiation therapy.

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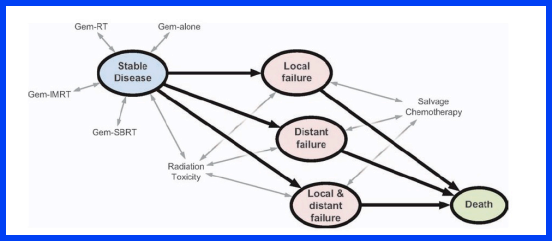
## Cost-Effectiveness of Modern Radiotherapy Techniques in Locally Advanced Pancreatic Cancer

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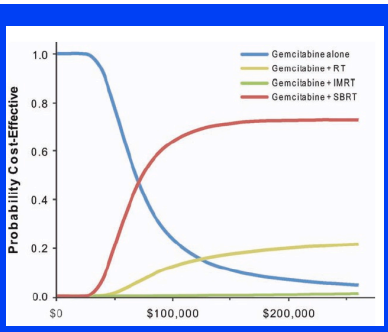
## Cost-Effectiveness of Modern Radiotherapy Techniques in Locally Advanced Pancreatic Cancer

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## Locally Advanced, Unresectable Pancreatic Cancer: American Society of Clinical Oncology Clinical Practice Guideline

*Edward P. Balaban, Pamela B. Mangu, Alok A. Khorana, Manish A. Shah, Somnath Mukherjee,*

*Recommendation 3.1:* If there is local disease progression after induction chemotherapy, but without evidence of systemic spread, then CRT or SBRT may be offered to patients who meet the following criteria: First-line chemotherapy treatment is completed or terminated because of progression or toxicity; ECOG PS ≤ 2; a comorbidity profile that is adequate, including adequate hepatic and renal function and hematologic status; and patient preference (Type: evidence based, benefits outweigh harms; Evidence quality: intermediate; Strength of recommendation: strong).

*Recommendation 3.2:* CRT or SBRT may be offered to patients who have responded to an initial 6 months of chemotherapy or have stable disease but have developed unacceptable chemotherapy-related toxicities or show a decline in performance status, as a consequence of chemotherapy toxicity (Type: evidence-based, benefits outweigh harms; Evidence quality: intermediate; Strength of recommendation: strong).

*Recommendation 3.3:* If there is response or stable disease after 6 months of induction chemotherapy, CRT or SBRT may be offered as an alternative to continuing chemotherapy alone for any patient with LAPC (Type: evidence based, benefits outweigh harms; Evidence quality: intermediate; Strength of recommendation: strong).

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ASTRO Guideline

## Radiation Therapy for Pancreatic Cancer: Executive Summary of an ASTRO Clinical Practice Guideline

**Table 2** Recommendations for indications for conventionally fractionated RT or SBRT

| KQ 1 recommendations | Strength of recommendation | Quality of evidence | Consensus |
|---|---|---|---|
| For patients with borderline resectable pancreatic cancer and select locally advanced pancreatic cancer appropriate for downstaging prior to surgery, a neoadjuvant therapy regimen of systemic chemotherapy followed by multifraction SBRT is conditionally recommended. | **Conditional** | **Low** | 77%* |
| For patients with locally advanced pancreatic cancer not appropriate for downstaging to eventual surgery, a definitive therapy regimen of systemic chemotherapy followed by either (1) conventionally fractionated RT with chemotherapy, (2) dose-escalated chemoradiation, or (3) multifraction SBRT without chemotherapy is conditionally recommended. | **Conditional** | **Low** | 85%* |

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| | | | |
|---|---|---|---|
| For patients with borderline resectable pancreatic cancer selected for SBRT, 3000-3300 cGy in 600-660 cGy fractions with a consideration for a simultaneous integrated boost of up to 4000 cGy to the tumor vessel interface is conditionally recommended. | **Conditional** | **Moderate** | 100%† |
| For patients with locally advanced pancreatic cancer selected for SBRT, 3300-4000 cGy in 660-800 cGy fractions is recommended. | **Strong** | **Moderate** | 100%† |
| For patients with borderline resectable pancreatic cancer selected for SBRT, a treatment volume including the gross tumor volume with a small margin is recommended. | **Strong** | **High** | 92%† |
| Implementation Remark: SBRT does not routinely treat elective nodes. | | | |
| For patients with locally advanced pancreatic cancer selected for SBRT, a treatment volume including the gross tumor volume with a small margin is recommended. | **Strong** | **High** | 100%† |

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| Description | Planning System Name | Constraints |
|---|---|---|
| Modified PTV | mPTV | V25 > 95% (range 25-40 Gy) |
| PTV | PTV | V20 > 95% |
| OAR | | Constraints |
| Duodenum | Duodenum | V15 <9cc |
| | | V20 <3cc |
| | | V33 <1cc |
| Small Bowel | Bowel | V15 <9cc |
| | | V20 <3cc |
| | | V33 <1cc |
| Stomach | Stomach | V15 <9cc |
| | | V20 <3cc |
| | | V33 <1cc |
| Liver | Liver | V12 <50% |
| Combined Kidneys | Kidneys | V12 <75% |
| Spinal Cord | Spinal_Cord | V20 <1cc |
| Spleen | Spleen | No constraint |

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## Australasian Gastrointestinal Trials Group (AGITG) and Trans-Tasman Radiation Oncology Group (TROG) Guidelines for Pancreatic Stereotactic Body Radiation Therapy (SBRT)

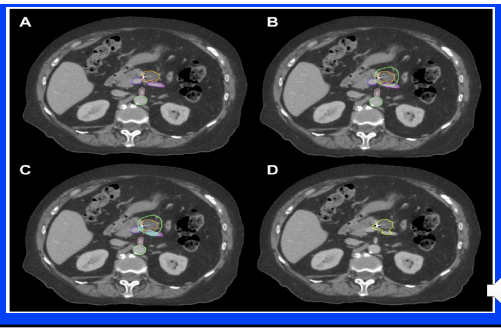


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**Table 2** Suggested dose constraints for pancreas SBRT

| Organ | Standardized name | Parameter | Constraint | | |
|---|---|---|---|---|---|
| | | Constraint | Per protocol, Gy | Minor variation, Gy | Major variation, Gy |
| Duodenum | Duodenum | Dmax (0.5 $cm^3$) | <33 | ≤35 | >35 |
| | | V30 | <5* | 5-10* | >10* |
| Stomach | Stomach | Dmax (0.5 $cm^3$) | <33 | ≤35 | >35 |
| | | V30 | <5* | 5-10* | >10* |
| Small bowel | SmallBowel | Dmax (0.5 $cm^3$) | <33 | ≤35 | >35 |
| | | V30 | <5* | 5-10* | >10* |
| Large bowel | LargeBowel | Dmax (0.5 $cm^3$) | ≤35 Gy | 35-38 Gy | >38 |
| Duodenum PRV† | Duodenum_PRV | Dmax (0.5 $cm^3$) | <38 Gy | 38-40 Gy | >40 |
| Small bowel PRV† | SmallBowel_PRV | Dmax (0.5 $cm^3$) | <38 Gy | 38-40 Gy | >40 |
| Large bowel PRV† | LargeBowel_PRV | Dmax (0.5 $cm^3$) | <38 Gy | 38-40 Gy | >40 |
| Stomach PRV† | Stomach_PRV | Dmax (0.5 $cm^3$) | <38 Gy | 38-40 Gy | >40 |
| Spinal cord PRV | SpinalCord_05 | Dmax (0.5 $cm^3$) | <20 Gy | ≤25 Gy | >25 |
| Combined kidneys | Kidneys_Comb | V12‡ | <25§ | 25-30§ | >30§ |
| Single kidney | Kidney_L<br>Kidney_R | V10‡ | <10§ | 10-25§ | >25§ |
| Liver | Liver | V12‡ | <40§ | ≤50§ | >50§ |

*Abbreviations:* Dmax = maximum dose; PRV = planning organ-at-risk volume; SBRT = stereotactic body radiation therapy.

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## What Dose/Fractionation for Tumor control?

- Location.
- Radiosensitivity
- Organs at Risk
- Image guidance.
- Respiratory motion management

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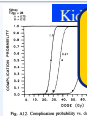
The Emami et al., 1991 paper was part of a full issue of Red Journal on 3D Planning

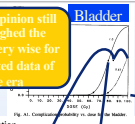
The Recipe

Kidney



Expert opinion still outweighed the model. Very wise for the limited data of the era

Bladder



Models from Burman 1991 (eye fitting)

N/A

Table 1. Normal tissue tolerance to therapeutic irradiation

| Organ | TD 5/5 Volume 1/3 | TD 5/5 Volume 2/3 | TD 5/5 Volume 3/3 | TD 50/5 Volume 1/3 | TD 50/5 Volume 2/3 | TD 50/5 Volume 3/3 | Selected endpoint |
|---|---|---|---|---|---|---|---|
| Kidney I | 5000 | 3000* | 2300 | — | 4000* | 2800 | Clinical nephritis |
| Kidney II | | | | | | | |
| Bladder | N/A | 8000 | 6500 | N/A | 8500 | 8000 | Symptomatic |

Emami B, Lyman J, Brown A, Coia L, Goitein M, Munzenrider JE, Shank B, Solin LJ, Wesson M. Tolerance of normal tissue to therapeutic irradiation. Int J Radiat Oncol Biol Phys. 1991;21:109-122.

*Became most widely cited Red Journal paper of all time!*

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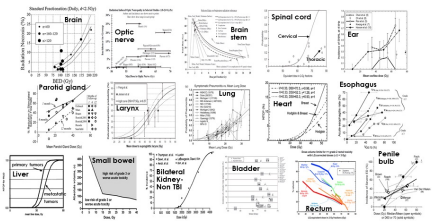
QUANTITATIVE ANALYSES OF NORMAL TISSUE EFFECTS IN THE CLINIC




*Guest Editors:*

Lawrence B. Marks, M.D. Randall K. Ten Haken, Ph.D.

*Associate Guest Editor:*

Mary K. Martel, Ph.D.

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QUANTITATIVE ANALYSES OF NORMAL TISSUE EFFECTS IN THE CLINIC

**Risk Tolerance in Radiation Oncology: A Multi-Institutional Survey**

**Conley WK, Donovan GK, FitzGerald KT, Guss ZD, Kwok Y, DeWeese TL, Terezakis SA.**

**IJROBP 2017 Oct 1;99(2 Suppl):E393. ASTRO 2017.**

- 35 question survey was piloted and electronically distributed to all radiation oncologists (n=94) at three academic medical systems in 2017
- Physicians most frequently use dose constraints from QUANTEC for conventional RT (94%)

*Guest Editors:*

Lawrence B. Marks, M.D. Randall K. Ten Haken, Ph.D.

*Associate Guest Editor:*

Mary K. Martel, Ph.D.

25 Years of CyberKnife, Jinsu Grimm, PhD

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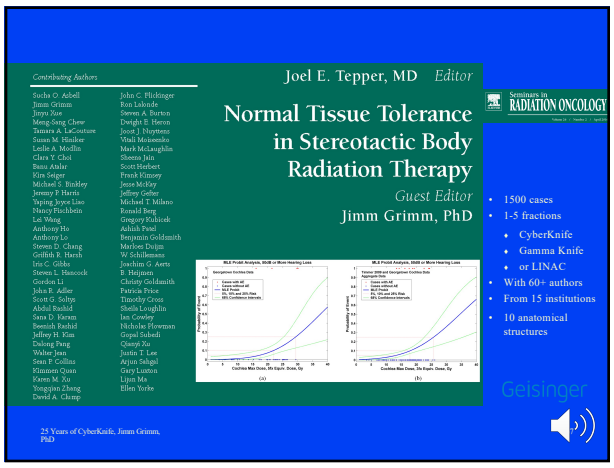
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Normal Tissue Tolerance in Stereotactic Body Radiation Therapy
Guest Editor
Jimm Grimm, PhD
Seminars in RADIATION ONCOLOGY
1500 cases
1-5 fractions
CyberKnife
Gamma Knife
or LINAC
With 60+ authors
From 15 institutions
10 anatomical structures
Geisinger
25 Years of CyberKnife, Jimm Grimm, PhD

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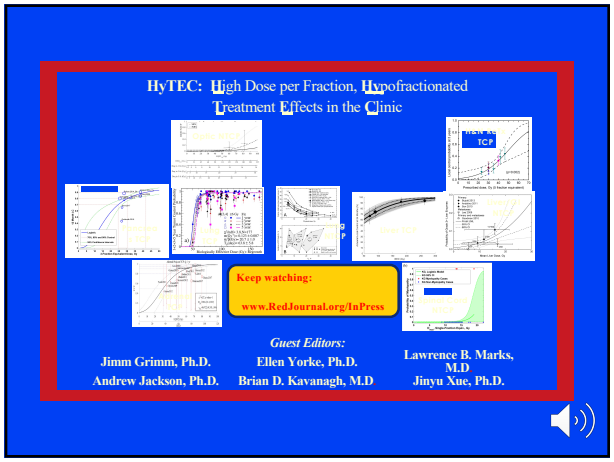
HyTEC: High Dose per Fraction, Hypofractionated Treatment Effects in the Clinic
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Andrew Jackson, Ph.D.
Ellen Yorke, Ph.D.
Brian D. Kavanagh, M.D
Lawrence B. Marks, M.D
Jinyu Xue, Ph.D.

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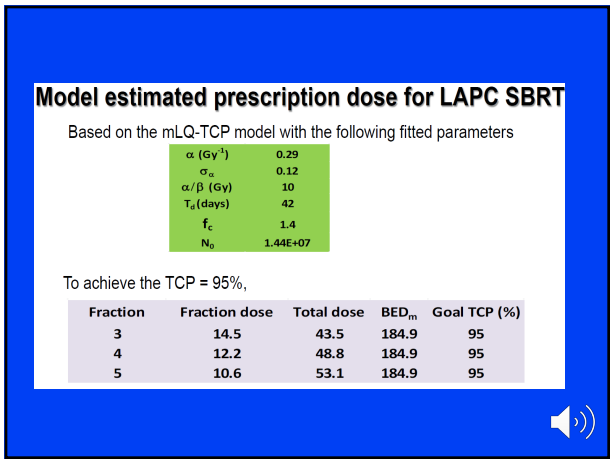
Model estimated prescription dose for LAPC SBRT
Based on the mLQ-TCP model with the following fitted parameters
α (Gy-1) 0.29
σα 0.12
α/β (Gy) 10
Tα (days) 42
fc 1.4
N0 1.44E+07
To achieve the TCP = 95%,
Fraction | Fraction dose | Total dose | BEDm | Goal TCP (%)
3 | 14.5 | 43.5 | 184.9 | 95
4 | 12.2 | 48.8 | 184.9 | 95
5 | 10.6 | 53.1 | 184.9 | 95

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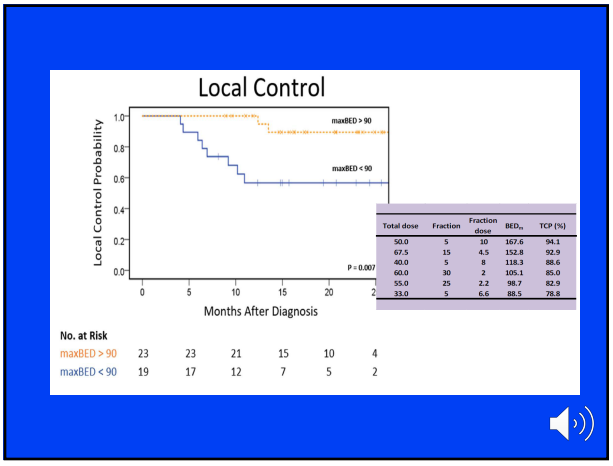


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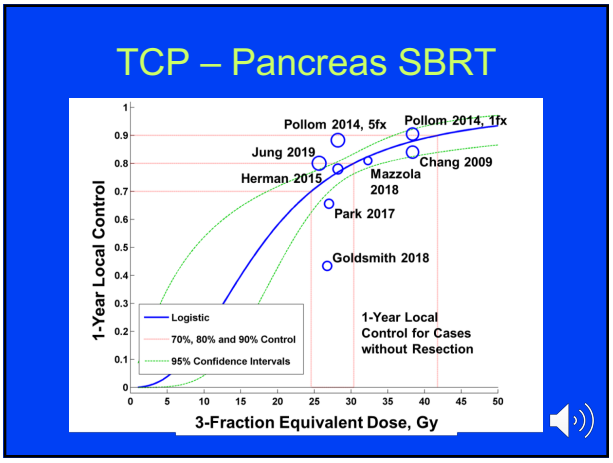


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## TCP – Pancreas SBRT

| Number of Fractions | Total Dose (Gy) | 3-Fraction Equiv. Dose (Gy) | 1 Year LC without Surgery | 1 Year LC with Surgery |
|---|---|---|---|---|
| 1 | 25 | 38.4 | 88% | 92% |
| 3 | 36 | 36 | 86% | 92% |
| 3 | 30 | 30 | 79% | 92% |
| 1 | 20 | 30 | 79% | 92% |
| 5 | 33 | 28.2 | 77% | 91% |
| 5 | 30 | 25.8 | 73% | - |
| 3 | 24 | 24 | 69% | - |
| 5 | 25 | 21.7 | 63% | - |
| 1 | 15 | 21.7 | 63% | - |

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# HyTEC Pancreas TCP

**HyTEC: Organ-Specific Paper** **HyTEC: Pancreas TCP**

**Maximizing Tumor Control and limiting complications with SBRT for Pancreatic Cancer**

Anand Mahadevan, M.D., Shalini Moningi, M.D., Jimm Grimm, Ph.D., X. Allen Li, Ph.D., Kenneth M. Forster, Ph.D., Manisha Palta, M.D., Phil Prior, Ph.D., Karyn A. Goodman, M.D., M.S., Amol Narang, M.D., Dwight E. Heron, M.D, MBA, FACRO, FACR., Simon S. Lo, M.D., James Urbanic, M.D., Joseph M. Herman, M.D., M.Sc, MSHCM

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# NTCP
# Grade 3+ Duodenal Toxicity

**Table** All Grade 3-4 Complications, Sorted by Fiducials and $D_{5\ cc}$

| Endpoint | CTCAE v3 Grade | Total Equivalent Dose in 3 Fractions, Gy | | | | | | Number of Fiducials |
|---|---|---|---|---|---|---|---|---|
| | | $D_{50\%}$ | $D_{10\%}$ | $D_{30\ cc}$ | $D_{5\ cc}$ | $D_{1\ cc}$ | $D_{0.035\ cc}$ | |
| Duodenal stricture | 4 | 1.8 | 6.0 | 4.2 | 6.8 | 8.3 | 11.2 | 1 |
| Duodenitis | 3 | 6.4 | 14.2 | 8.5 | 16.5 | 26.7 | 34.6 | 1 |
| Bleeding | 3 | 8.6 | 18.5 | 17.3 | 26.6 | 28.3 | 29.6 | 1 |
| Obstructive jaundice | 3 | 9.4 | 18.3 | 15.7 | 21.1 | 22.6 | 23.8 | 4 |
| Fatigue and diarrhea* | 3 | 8.1 | 17.0 | 10.7 | 21.4 | 29.0 | 35.9 | 2 |
| Duodenal hemorrhage | 3 | 10.7 | 21.5 | 16.5 | 25.7 | 27.7 | 29.4 | 3 |
| Duodenal stricture | 4 | 11.1 | 23.6 | 13.8 | 26.0 | 29.1 | 31.6 | 3 |

*This patient experienced both grade 3 fatigue and grade 3 diarrhea. CTCAE, Common Terminology Criteria for Adverse Events

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# Tolerance Based Approach

| 800 cGy x 3 (total dose 2400 Gy) | 1000 cGy x 3 (total dose 3000 Gy) | 1200 cGy x 3 (total dose 3600 Gy) |
|---|---|---|
|  |  |  |

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## Pancreas TCP: Feasible Dose Range Predictions from 2010

(IJROBP 2010 Nov 1;78(3):735-42)

| | Number of Fractions | Total Dose (Gy) | 3-Fraction Equiv. Dose (Gy) | 1 Year LC without Surgery | 1 Year LC with Surgery |
|---|---|---|---|---|---|
| | 1 | 25 | 38.4 | 88% | 92% |
| Tail | 3 | 36 | 36 | 86% | 92% |
| Body | 3 | 30 | 30 | 79% | 92% |
| | 1 | 20 | 30 | 79% | 92% |
| | 5 | 33 | 28.2 | 77% | 91% |
| | 5 | 30 | 25.8 | 73% | - |
| Head | 3 | 24 | 24 | 69% | - |
| | 5 | 25 | 21.7 | 63% | - |
| | 1 | 15 | 21.7 | 63% | - |

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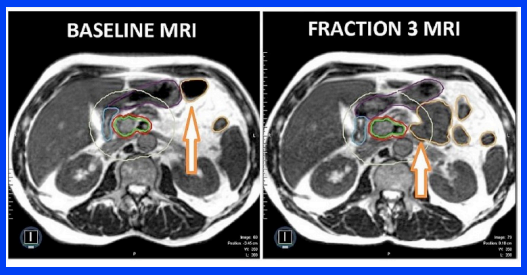
MRI-guided radiotherapy

Fast and robust online adaptive planning in stereotactic MR-guided adaptive radiation therapy (SMART) for pancreatic cancer

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## Using adaptive magnetic resonance image-guided radiation therapy for treatment of inoperable pancreatic cancer

Soumon Rudra[1] | Naomi Jiang[2] | Stephen A. Rosenberg[3] | Jeffrey R. Olsen[1]

| RT technique | Prescription dose & fractionation | Number of patients | Median $BED_{10}$ [range] |
|---|---|---|---|
| Conventionally fractionated | 40-55 Gy in 25-28 fractions | 13 | 55.5 [38.2-67.1] |
| Conventional SBRT | 30-35 Gy in 5 fractions | 6 | 55.8 [48.0-59.5] |
| High-dose SBRT | 40-52 Gy in 5 fractions | 16 | 77.6 [72.0-106.1] |
| Hypofractionated | 50-67.5 Gy in 10-15 fractions | 9 | 82.7 [67.8-97.9] |

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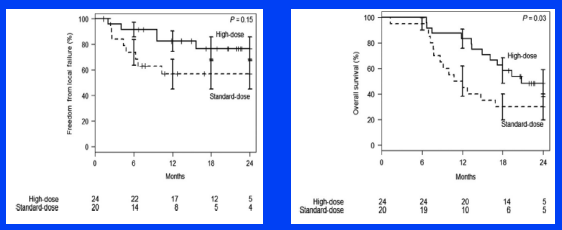
**Using adaptive magnetic resonance image-guided radiation therapy for treatment of inoperable pancreatic cancer**

Soumon Rudra[1] | Naomi Jiang[2] | Stephen A. Rosenberg[3] | Jeffrey R. Olsen[1]

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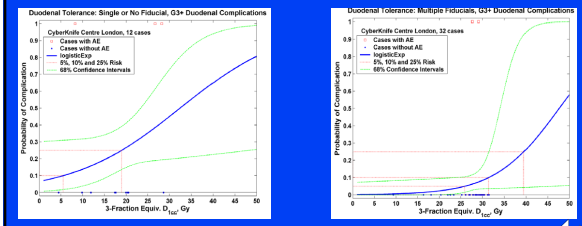
**Dose-Volume Histogram Analysis of Stereotactic Body Radiotherapy Treatment of Pancreatic Cancer: A Focus on Duodenal Dose Constraints**

Christy Goldsmith, MBBS, FRCR, MRCP, BSc,*,† Patricia Price, MD, FRCR, FRCP,*,† Timothy Cross, MSc, BSc,* Sheila Loughlin, BSc, MSc*

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## Summary

- Minimizing Normal Tissue has advanced High dose per fraction targeted radiation
- Improved therapeutic ratio
- Accurate image guidance and Motion management are keys to high quality successful SBRT
- Understanding Abscopal, Bystander, Vascular/Interstitial effects.
- Need better clarification of TCP and “Emami” type NTCP data.

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Thank you

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