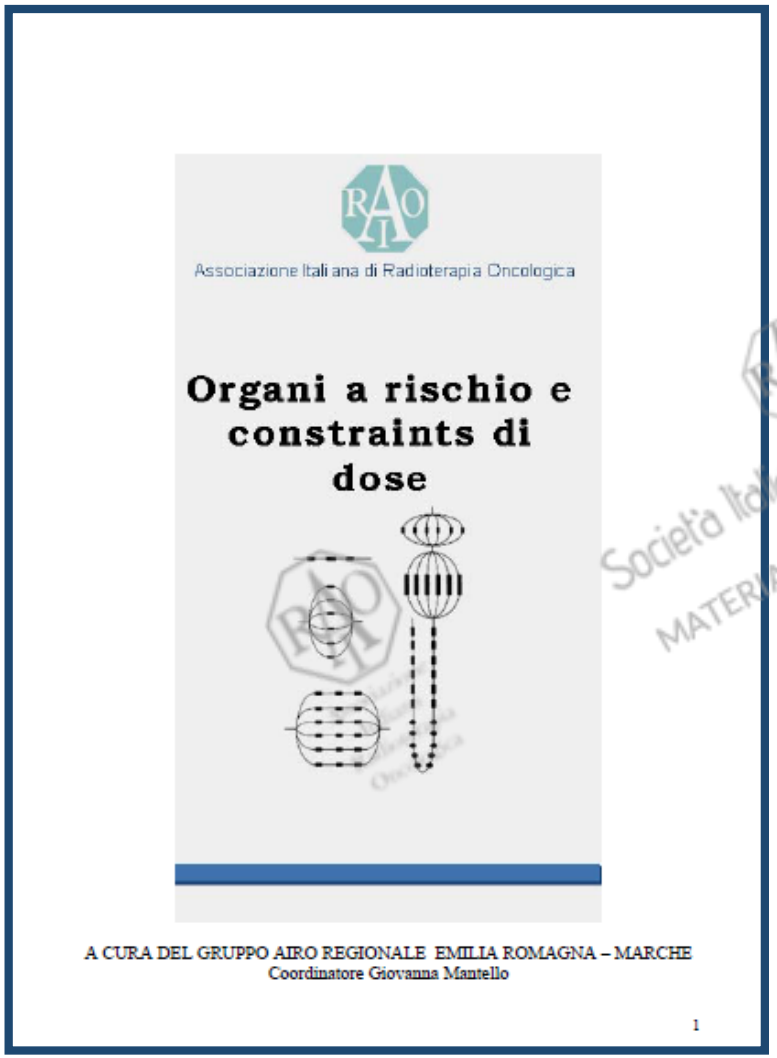
Radioterapia ipofrazionata del DISTRETTO TORACE – ADDOME: come cambiano i constraints di dose?

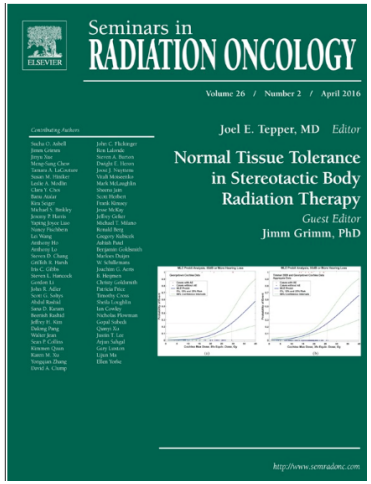
Giovanna Mantello

Attivita' gruppo AIRO Regionale Emilia Romagna - Marche



2009

2016



DISTRETTO TORACE – ADDOME

esofago

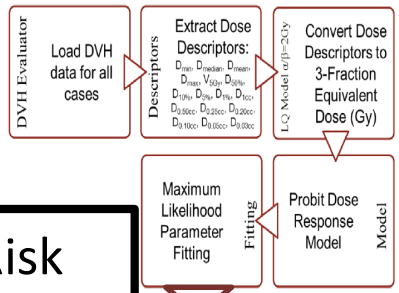
duodeno

intestino

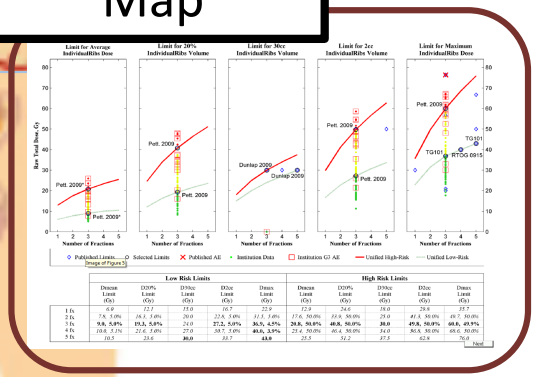
Coste – gabbia toracica

Trachea - bronchi

Grossi vasi



DVH Risk Map

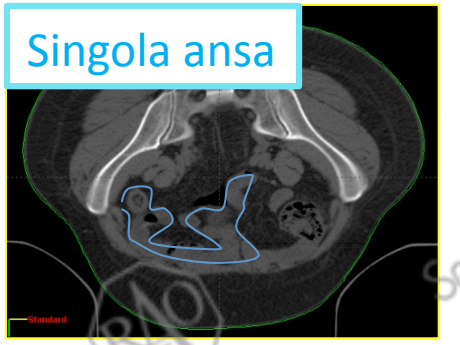


CHALLENGES DEFINING VOLUMES

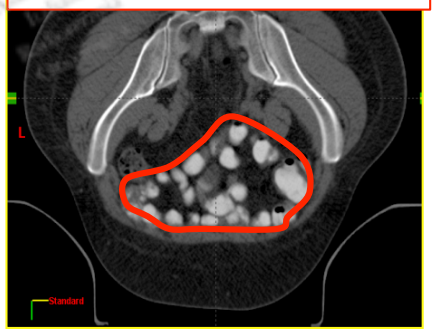
3. **Challenges Defining Volumes-** Describes how the organ is typically defined (or segmented) on treatment planning images. Includes a discussion of uncertainties/challenges in organ definition (e.g. changes in organ volume/shape during therapy), and the associated impact on DVH's and dose/volume/outcome analyses.

QUANTEC

Singola ansa

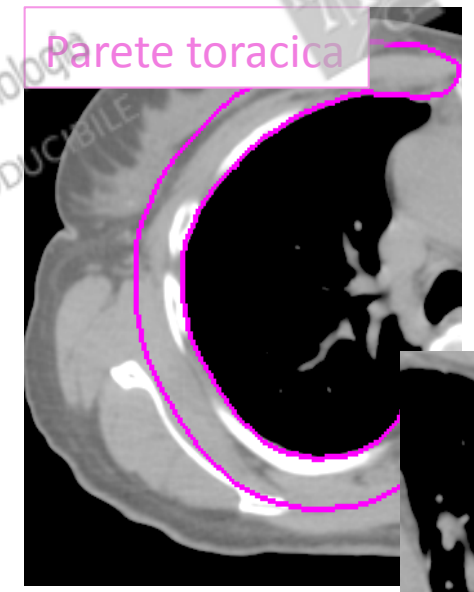


Cavita' peritoneale



?

Parete toracica



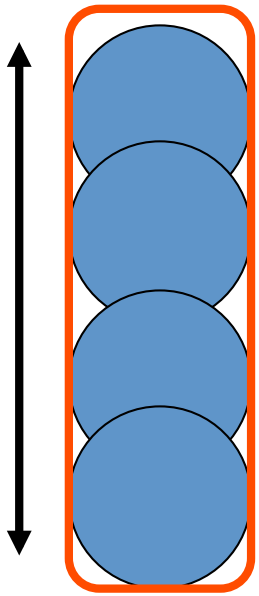
Singola Costa

INTERNATIONAL JOURNAL OF Radiation Oncology BIOLOGY·PHYSICS
Official Journal of the American Society for Radiation Oncology ASTRO

ITV

TARGET

OAR (PRV)

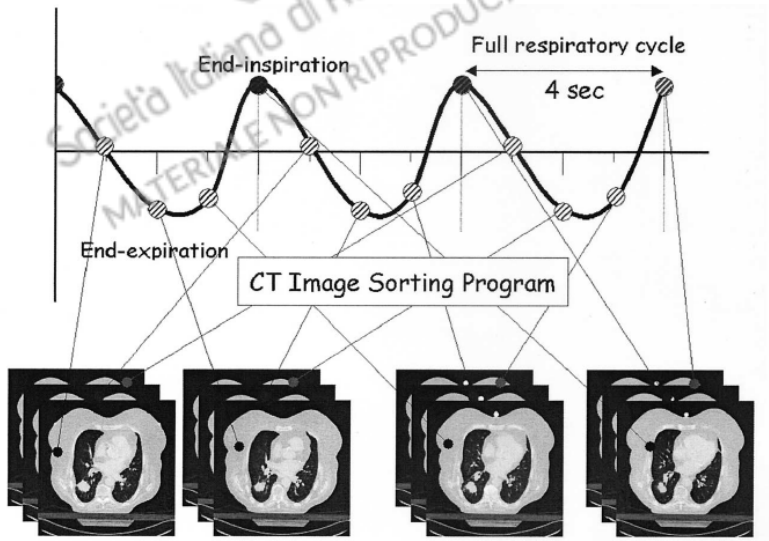


End-exhale

Mid-exhale

Mid-inhale

End-inhale



Mid-exhale "End-exhale" "Mid-inhale" End-inhale

Int. J. Radiation Oncology Biol. Phys., Vol. 60, No. 4, pp. 1283–1290, 2004

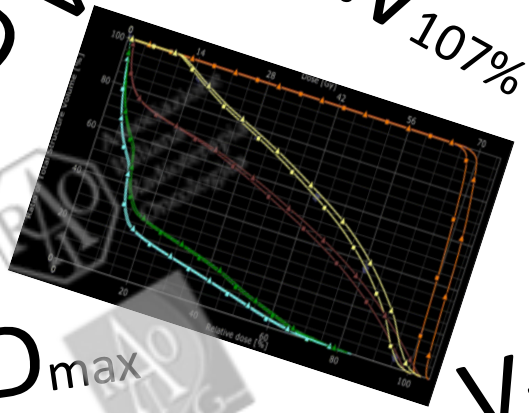
Metriche per la valutazione clinica del piano

gEUD BED $V_{95\%}$ $D_{50\%}$ $V_{107\%}$ V_{20Gy}

MLD $D_{98\%}$ $D_{2\%}$

Conformity Index

D_{2cc} D_{mean} D_{max} V_{30Gy}



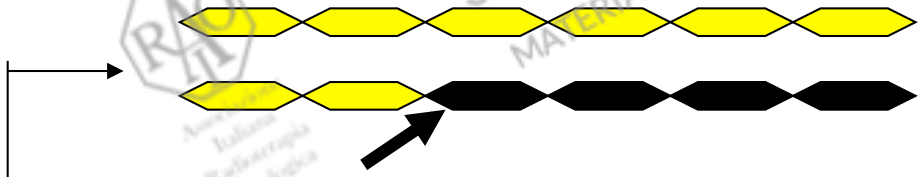
Trattamenti stereotassici→volumi piccoli

I volumi da prendere in considerazione dipendono dall'OAR:

bowel→20cc – 1cc
spinal cord→ 1cc – 0,1cc
ribs→ 30cc – 2cc

Si prendono in considerazione anche volumi più grandi per cautelarsi contro l'eventuale effetto «Bath and shower»

% → CC



Dmax

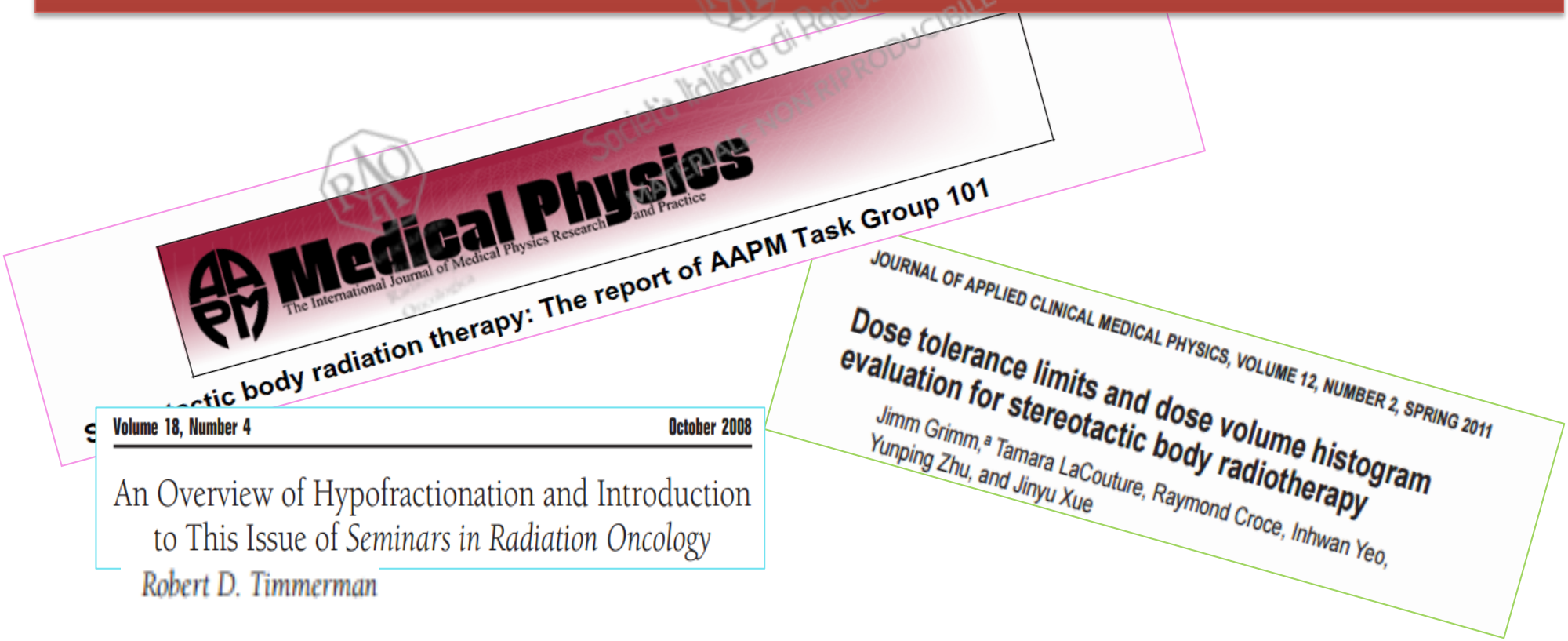
Dx<= y

The used Dx notation means that volume x of the anatomical structure exceeds dose D. Volume x can be a percentage of the total volume, such as 50% or 10%, or it can be absolute volume like1cc or 0.1cc.
Small absolute volumes (2cc ,1cc or 0.1 cc) are frequently used, in place of percentage of OAR volume, as they are generally expected to be more important for SBRT. [sem rad oncol 2016]

IPOFRAZIONAMENTO

Quale cons?

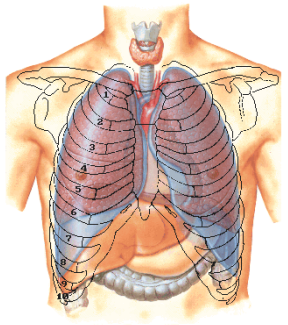
Quale rischio?



Dose-Response Model for Chest Wall Tolerance of Stereotactic Body Radiation Therapy

Frank Kimsey, MD, FACR,* Jesse McKay, MS,* Jeffrey Gefter, MD, FACRO,* Michael T. Milano, MD, PhD,† Vitali Moiseenko, PhD,‡ Jimm Grimm, PhD,§ and Ronald Berg, PhD, FACR*

Seminars in
RADIATION
ONCOLOGY



ENDPOINT / TOSSICITA' RADIOINDOTTA PARETE TORACICA

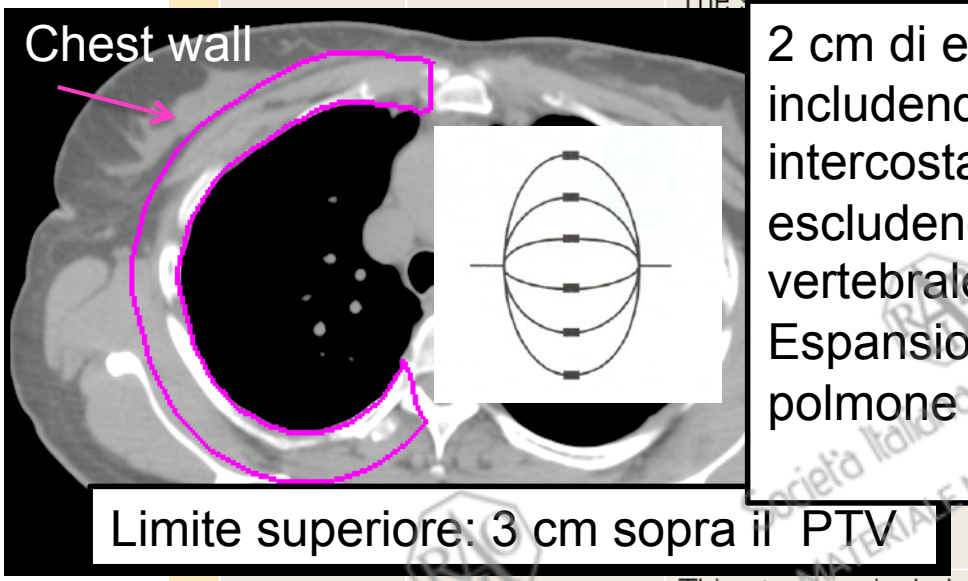
- Frattura costale con o senza dolore

- Dolore in assenza di frattura → neuropatia radioindotta ai nervi intercostali o branche nervose o entrambe

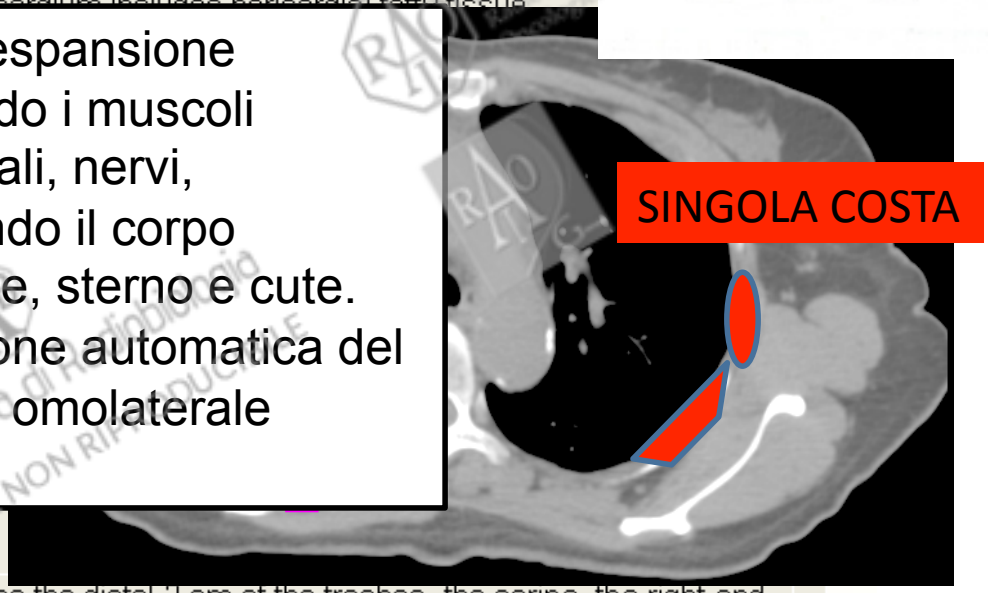
Considerare **fattori di rischio individuali e legati alla malattia**:
- Obesità
- Alto BMI
- Sesso femminile
- Malattie del tessuto connettivo
- Osteoporosi
- Fumo
- Tumore in stretta prossimità della parete toracica

RTOG 1106 Optional OARs

Structure	Description	Structure definition and contouring instructions
		The structure of pericardium includes pericardial fatty tissue
Pbtree	Proximal Bronchial Tree	This structure includes the distal 2 cm of the trachea, the carina, the right and left mainstem bronchi, the right and left upper lobe bronchi, the intermedius bronchus, the right middle lobe bronchus, the lingular bronchus, and the right and left lower lobe bronchi
CW2cm	Chest wall 2 cm outside of lung	Chest wall can be autosegmented from the ipsilateral lung with a 2-cm expansion in the lateral, anterior, and posterior directions. Anteriorly and medially, it ends at the edge of the sternum. Posteriorly and medially, it stops at the edge of the vertebral body with inclusion of the spinal nerve root exit site. CW2cm which include intercostal muscles, nerves exclude vertebrate bodies, sternum and skin. This can be accomplished through auto-expansion of the ipsilateral lung (within 3 cm range of PTV).



2 cm di espansione includendo i muscoli intercostali, nervi, escludendo il corpo vertebrale, sterno e cute. Espansione automatica del polmone omolaterale



Timmerman 2008
No cons

Volume 18, Number 4

An Overview of Hypofractionation and Introduction to This Issue of *Seminars in Radiation Oncology*

Seminars in RADIATION ONCOLOGY

Robert D. Timmerman

Serial Tissue	Volume (mL)	Volume Max (Gy)	Max Point Dose (Gy)	Endpoint (≥Grade 3)
SINGLE-FRACTION TREATMENT				
Optic pathway	<0.2	8	10	Neuritis
Cochlea			12	Hearing loss
Brainstem	<1	10	15	Cranial neuropathy
Spinal cord	<0.25	10	14	Myelitis
	<1.2	7		
Cauda equina	<5	14	16	Neuritis
Sacral plexus	<3	14.4	16	Neuropathy
Esophagus*	<5	14.5	19	Stenosis/fistula
Ipsilateral brachial plexus	<3	14.4	16	Neuropathy
Heart/pericardium	<15	16	22	Pericarditis
Great vessels	<10	31	37	Aneurysm
Trachea and ipsilateral bronchus*	<4	8.8	22	Stenosis/fistula
Skin	<10	14.4	16	Ulceration
Stomach	<10	13	16	Ulceration/fistula
Duodenum*	<5	8.8	16	Ulceration
Jejunum/ileum*	<5	9.8	19	Enteritis/obstruction
Colon*	<20	11	22	Colitis/fistula
Rectum*	<20	11	22	Proctitis/fistula
Bladder wall	<15	8.7	22	Cystitis/fistula
Penile bulb	<3	14	34	Impotence
Femoral heads (right and left)	<10	14		Necrosis
Renal hilum/vascular trunk	<2/3 volume	10.6		Malignant hypertension
Parallel Tissue	**Critical Volume (mL)**	**Critical Volume Dose Max (Gy)**		**Endpoint (≥Grade 3)**
Lung (right and left)	1,500	7		Basic lung function
Lung (right and left)	1,000	7.4		Pneumonitis
Liver	700	9.1		Basic liver function
Renal cortex (right and left)	200	8.4		Basic renal function
Serial Tissue	**Volume (mL)**	**Volume Max (Gy)**	**Max Point Dose (Gy)**	**Endpoint (≥Grade 3)**

THREE-FRACTION TREATMENT				
Optic pathway	<0.2	15 (5 Gy/fx)	19.5 (6.5 Gy/fx)	Neuritis
Cochlea			20 (6.67 Gy/fx)	Hearing loss
Brainstem	<1	18 (6 Gy/fx)	23 (7.67 Gy/fx)	Cranial neuropathy
Spinal cord	<0.25	18 (6 Gy/fx)	22 (7.33 Gy/fx)	Myelitis
	<1.2	11.1 (3.7 Gy/fx)		
Cauda equina	<5	21.9 (7.3 Gy/fx)	24 (8 Gy/fx)	Neuritis
Sacral plexus	<3	22.5 (7.5 Gy/fx)	24 (8 Gy/fx)	Neuropathy
Esophagus*	<5	21 (7 Gy/fx)	27 (9 Gy/fx)	Stenosis/fistula
Ipsilateral brachial plexus	<3	22.5 (7.5 Gy/fx)	24 (8 Gy/fx)	Neuropathy
Heart/pericardium	<15	24 (8 Gy/fx)	30 (10 Gy/fx)	Pericarditis
Great vessels	<10	39 (13 Gy/fx)	45 (15 Gy/fx)	Aneurysm

Serial Tissue	Volume (mL)	Volume Max (Gy)	Max Point Dose (Gy)	Endpoint (≥Grade 3)
FIVE-FRACTION TREATMENT				
Optic pathway	<0.2	20 (4 Gy/fx)	25 (5 Gy/fx)	Neuritis
Cochlea			27.5 (5.5 Gy/fx)	Hearing loss
Brainstem	<1	26 (5.2 Gy/fx)	31 (6.2 Gy/fx)	Cranial neuropathy
Spinal cord	<0.25	22.5 (4.5 Gy/fx)	30 (6 Gy/fx)	Myelitis
	<1.2	13.5 (2.7 Gy/fx)		
Cauda equina	<5	30 (6 Gy/fx)	34 (6.4 Gy/fx)	Neuritis
Sacral plexus	<3	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Esophagus*	<5	27.5 (5.5 Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula
Ipsilateral brachial plexus	<3	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Heart/pericardium	<15	32 (6.4 Gy/fx)	38 (7.6 Gy/fx)	Pericarditis
Great vessels	<10	47 (9.4 Gy/fx)	53 (10.6 Gy/fx)	Aneurysm
Trachea and ipsilateral bronchus*	<4	18 (3.6 Gy/fx)	38 (7.6 Gy/fx)	Stenosis/fistula
Skin	<10	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Stomach	<10	28 (5.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
Duodenum*	<5	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Jejunum/ileum*	<5	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	enteritis/obstruction
Colon*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	colitis/fistula
Rectum*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	proctitis/fistula
Bladder wall	<15	18.3 (3.65 Gy/fx)	38 (7.6 Gy/fx)	cystitis/fistula
Penile bulb	<3	30 (6 Gy/fx)	50 (10 Gy/fx)	Impotence
Femoral heads (right and left)	<10	30 (6 Gy/fx)		Necrosis
Renal hilum/vascular trunk	<2/3 volume	23 (4.6 Gy/fx)		Malignant hypertension
Parallel Tissue	**Critical Volume (mL)**	**Critical Volume Dose Max (Gy)**		**Endpoint (≥Grade 3)**
Lung (right and left)	1,500	12.5 (2.5 Gy/fx)		Basic lung function
Lung (right and left)	1000	13.5 (2.7 Gy/fx)		Pneumonitis
Liver	700	21 (4.2 Gy/fx)		Basic liver function
Renal cortex (right and left)	200	17.5 (3.5 Gy/fx)		Basic renal function

*Avoid circumferential irradiation.

Medical Physics
The International Journal of Medical Physics Research and Practice

Stereotactic body radiation therapy: The report of AAPM Task Group 101

AAPM TG101

1 fr Dmax 30 Gy; V22<1cc

3 fr Dmax 36,9 Gy; V28,8<1cc; V30<30cc

5 fr Dmax 43 Gy; V35<1cc

		One fraction						
Serial tissue	Max critical volume above threshold	Threshold dose (Gy)	Max point dose (Gy)[a]					
Optic pathway	<0.2 cc	8	10					
Cochlea			9					
Brainstem (not medulla)	<0.5 cc	10	15					
Spinal cord and medulla	<0.35 cc <1.2 cc	10 7	14					
Spinal cord subvolume (5–6 mm above and below level treated per Ryu)	<10% of subvolume	10	14	18 (6 Gy/fx)	21.9 (7.3 Gy/fx)	23 (4.6 Gy/fx)	30 (6 Gy/fx)	Myelitis
Cauda equina	<5 cc	14	16	21.9 (7.3 Gy/fx)	24 (8 Gy/fx)	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuritis
Sacral plexus	<5 cc	14.4	16	22.5 (7.5 Gy/fx)	24 (8 Gy/fx)	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Esophagus[b]	<5 cc	11.9	15.4	17.7 (5.9 Gy/fx)	25.2 (8.4 Gy/fx)	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula
Brachial plexus	<3 cc	14	17.5	20.4 (6.8 Gy/fx)	24 (8 Gy/fx)	27 (5.4 Gy/fx)	30.5 (6.1 Gy/fx)	Neuropathy
Heart/pericardium	<15 cc	16	22	24 (8 Gy/fx)	30 (10 Gy/fx)	32 (6.4 Gy/fx)	38 (7.6 Gy/fx)	Pericarditis
Great vessels	<10 cc	31	37	39 (13 Gy/fx)	45 (15 Gy/fx)	47 (9.4 Gy/fx)	53 (10.6 Gy/fx)	Aneurysm
Trachea and large bronchus[b]	<4 cc	10.5	20.2	15 (5 Gy/fx)	30 (10 Gy/fx)	16.5 (3.3 Gy/fx)	40 (8 Gy/fx)	Stenosis/fistula
Bronchus-smaller airways	<0.5 cc	12.4	13.3	18.9 (6.3 Gy/fx)	23.1 (7.7 Gy/fx)	21 (4.2 Gy/fx)	33 (6.6 Gy/fx)	Stenosis with atelectasis
Rib	<1 cc <30 cc	22	30	28.8 (9.6 Gy/fx) 30.0 (10.0 Gy/fx)	36.9 (12.3 Gy/fx)	35 (7 Gy/fx)	43 (8.6 Gy/fx)	Pain or fracture
Skin	<10 cc	23	26	30 (10 Gy/fx)	33 (11 Gy/fx)	36.5 (7.3 Gy/fx)	39.5 (7.9 Gy/fx)	Ulceration
Stomach	<10 cc	11.2	12.4	16.5 (5.5 Gy/fx)	22.2 (7.4 Gy/fx)	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
Duodenum[b]	<5 cc <10 cc	11.2 9	12.4	16.5 (5.5 Gy/fx) 11.4 (3.8 Gy/fx)	22.2 (7.4 Gy/fx)	18 (3.6 Gy/fx) 12.5 (2.5 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Jejunum/ileum[b]	<5 cc	11.9	15.4	17.7 (5.9 Gy/fx)	25.2 (8.4 Gy/fx)	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	Enteritis/ obstruction
Colon[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Colitis/fistula
Rectum[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Proctitis/fistula
Bladder wall	<15 cc	11.4	18.4	16.8 (5.6 Gy/fx)	28.2 (9.4 Gy/fx)	18.3 (3.65 Gy/fx)	38 (7.6 Gy/fx)	Cystitis/fistula
Penile bulb	<3 cc	14	34	21.9 (7.3 Gy/fx)	42 (14 Gy/fx)	30 (6 Gy/fx)	50 (10 Gy/fx)	Impotence
Femoral heads (right and left)	<10 cc	14		21.9 (7.3 Gy/fx)		30 (6 Gy/fx)		Necrosis
Renal hilum/vascular trunk	<2/3 volume	10.6	18.6 (6.2 Gy/fx)			23 (4.6 Gy/fx)		Malignant hypertension

		One fraction		Three fractions		Five fractions		
Serial tissue	Max critical volume above threshold	Threshold dose (Gy)	Max point dose (Gy)[a]	Threshold dose (Gy)	Max point dose (Gy)[a]	Threshold dose (Gy)	Max point dose (Gy)[a]	End point (≥Grade3)

		One fraction		Three fractions		Five fractions		
Parallel tissue	Minimum critical volume below threshold	Threshold dose (Gy)	Max point dose(Gy)[a]	Threshold dose(Gy)	Max point dose(Gy)[a]	Threshold dose(Gy)	Max point dose(Gy)[a]	End point (≥Grade 3)
Lung (right and left)	1500 cc	7	NA-Parallel tissue	11.6 (2.9 Gy/fx)	NA-Parallel tissue	12.5 (2.5 Gy/fx)	NA-Parallel tissue	Basic lung function
Lung (right and left)	1000 cc	7.4	NA-Parallel tissue	12.4 (3.1 Gy/fx)	NA-Parallel tissue	13.5 (2.7 Gy/fx)	NA-Parallel tissue	Pneumonitis
Liver	700 cc	9.1	NA-Parallel tissue	19.2 (4.8 Gy/fx)	NA-Parallel tissue	21 (4.2 Gy/fx)	NA-Parallel tissue	Basic liver function
Renal cortex (right and left)	200 cc	8.4	NA-Parallel tissue	16 (4 Gy/fx)	NA-Parallel tissue	17.5 (3.5 Gy/fx)	NA-Parallel tissue	Basic renal function

Radiotherapy and Oncology 91 (2009) 360–368

Lung cancer RT morbidity

Radiation-induced rib fractures after hypofractionated stereotactic body radiation therapy of non-small cell lung cancer: A dose– and volume–response analysis

Niclas Pettersson [a,*], Jan Nyman [b], Karl-Axel Johansson [a]
Department of Radiophysics, Sahlgrenska University Hospital, Sweden

33 pazienti arruolati
3DCRT / 4-6 campi / Pencil Beam Convolution
15Gy X 3 fr al 100% del PTV
Dose Isocentro = 63-65 Gy
81 coste irradiate >=21Gy
13 (7 pz) fratture osservate (follow up 15 mesi)

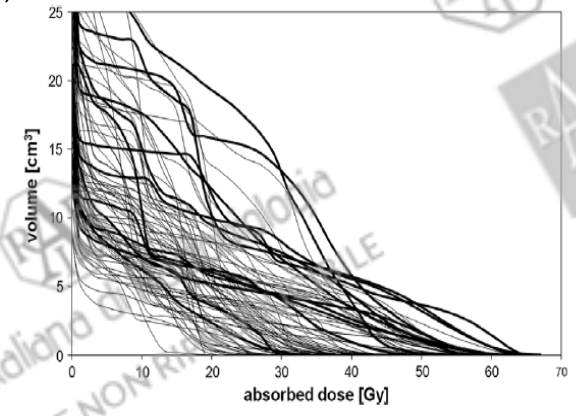
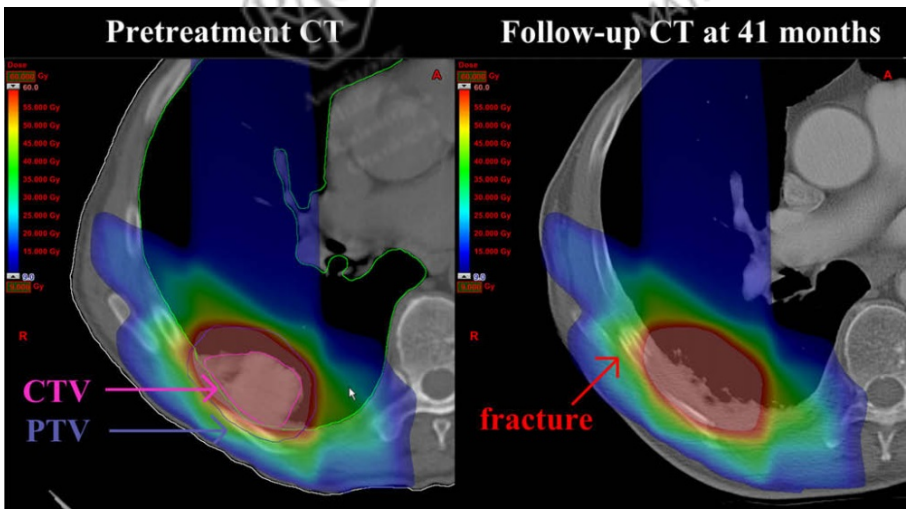


Fig. 2. All 81 cumulative DVHs for ribs with (thick curves) and without (thin curves) fracture.



Stretta correlazione con D 2 cc costa (OAR= singola costa)

D2 cc <= 21 Gy (7x3fr) =0 % rischio frattura

D2 cc =27,3 Gy (9.1x3 fr) = 5% rischio frattura

D2 cc = 48,9Gy (16.6x3fr) = 50% rischio frattura

Int. J. Radiation Oncology Biol. Phys., Vol. 82, No. 5, pp. 1783–1790, 2012

CLINICAL INVESTIGATION **Thoracic Cancer**

DOSE–VOLUME PARAMETERS PREDICT FOR THE DEVELOPMENT OF CHEST WALL PAIN AFTER STEREOTACTIC BODY RADIATION FOR LUNG CANCER

ROBERT W. MUTTER, M.D.,* FAN LIU, PH.D.,† ANDRES ABREU, B.S.,‡ ELLEN YORKE, PH.D.,† ANDREW JACKSON, PH.D.,† AND KENNETH E. ROSENZWEIG, M.D.§

Memorial Sloan Kettering Cancer Center

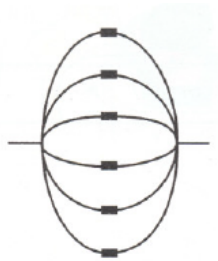
126 pz NSCLC

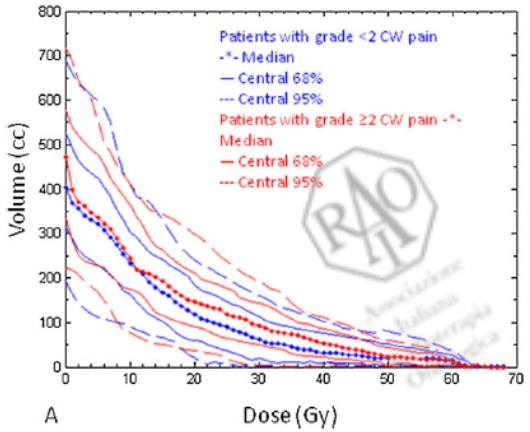
SBRT 40-60 Gy in 3-5 fr

Margine 2 cm (CW 2cm)

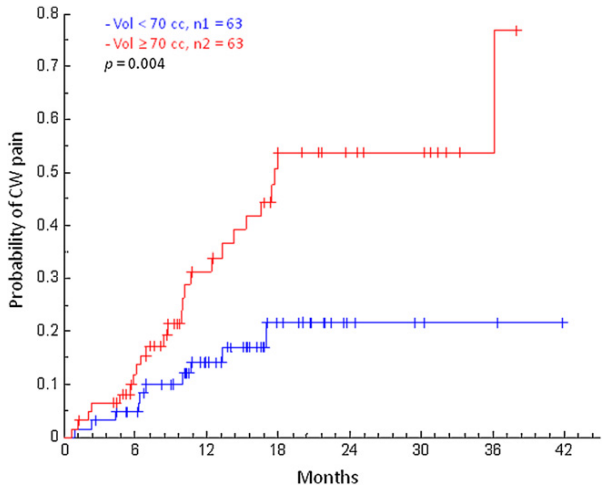
permette di stimare meglio la tossicità

Margine 3 cm (CW 3 cm)





COSTRUZIONE DVH ATLAS PER TOLLERANZA DELLA PARETE TORACICA

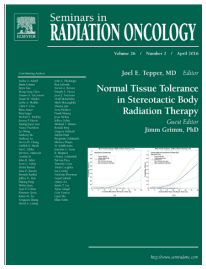


V30>70cc

V30<70cc

V30 = principale fattore predittivo di tossicità G2

V30 > 70 cc correlazione con dolore alla parete toracica G≥ 2 (p=0.004)



Clinical Datasets

Dose-Response Model for Chest Wall Tolerance of Stereotactic Body Radiation Therapy

Frank Kimsey, MD, FACR,* Jesse McKay, MS,* Jeffrey Gefter, MD, FACRO,* Michael T. Milano, MD, PhD,† Vitali Moiseenko, PhD,‡ Jimm Grimm, PhD,§ and Ronald Berg, PhD, FACR*

44 pz (Aprile 2011-Settembre 2016)
SBRT con Cyberknife
Erlanger Medical Center

CLINICAL INVESTIGATION Thoracic Cancer

DOSE–VOLUME PARAMETERS PREDICT FOR THE DEVELOPMENT OF CHEST WALL PAIN AFTER STEREOTACTIC BODY RADIATION FOR LUNG CANCER

Robert W. Mutter, M.D.,* Fan Liu, Ph.D.,† Andres Abreu, B.S.,‡ Ellen Yorke, Ph.D.,† Andrew Jackson, Ph.D.,† and Kenneth E. Rosenzweig, M.D.§

126 pz (Maggio 2006-Luglio 2009)
SBRT con Linac
MSKCC

170 pz

DVH Evaluator: Load DVH data for all cases

Descriptors: Extract Dose Descriptors: $D_{50\%}$ $D_{20\%}$, D_{70} cc, D_{30} cc D_2 cc, D_{max}

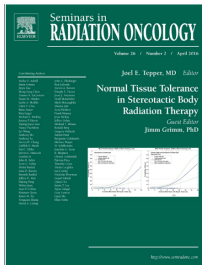
LQ Model with $\alpha/\beta = 3$ Gy: Convert Dose Descritors to 4-fraction Equivalent Dose (Gy)

Dose-Response Model

$$NTCP = \frac{e^{\left(4g_{50,v}\left(\frac{D_v}{TD_{50,v}}-1\right)\right)}}{\left(1+e^{\left(4g_{50,v}\left(\frac{D_v}{TD_{50,v}}-1\right)\right)}\right)}$$

Mode

DVH Risk Map
(a graph of the published limits with estimates of risk interpolated from the Dose-Response model)



Dose-Response Model for Chest Wall Tolerance of Stereotactic Body Radiation Therapy

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Table Model Parameters for Chest Wall in 4 Fractions

Dose Descriptor	TD_{50} (95% CI)	γ_{50} (95% CI)	LL_{max}	*P* Value (Median Splits)
$D_{70\ cc}$	65.1 (50.4-120.7)	0.68 (0.47-0.90)	−72.1432	<0.0001
$D_{30\ cc}$	77.6 (63.3-123.6)	0.80 (0.54-1.08)	−70.9904	<0.0001
$D_{2\ cc}$	87.9 (74.7-130.2)	1.00 (0.64-1.43)	−70.8734	0.0582
D_{max}	93.2 (78.3-152.5)	1.00 (0.60-1.46)	−72.3698	0.2075

ENDPOINT: DOLORE PARERE TORACICA → **D70cc e D30cc sono predittivi di tossicità ≥ 2**

D2cc non è predittivo di complicanze importanti

- D70 cc = 57 Gy(3 fr) e 72 Gy (5 fr) Rischio 50% complicanze ≥ G2
- D70 cc = 14,6 Gy(3 fr) e 17,6 Gy (5 fr) Rischio 10% complicanze ≥ G2

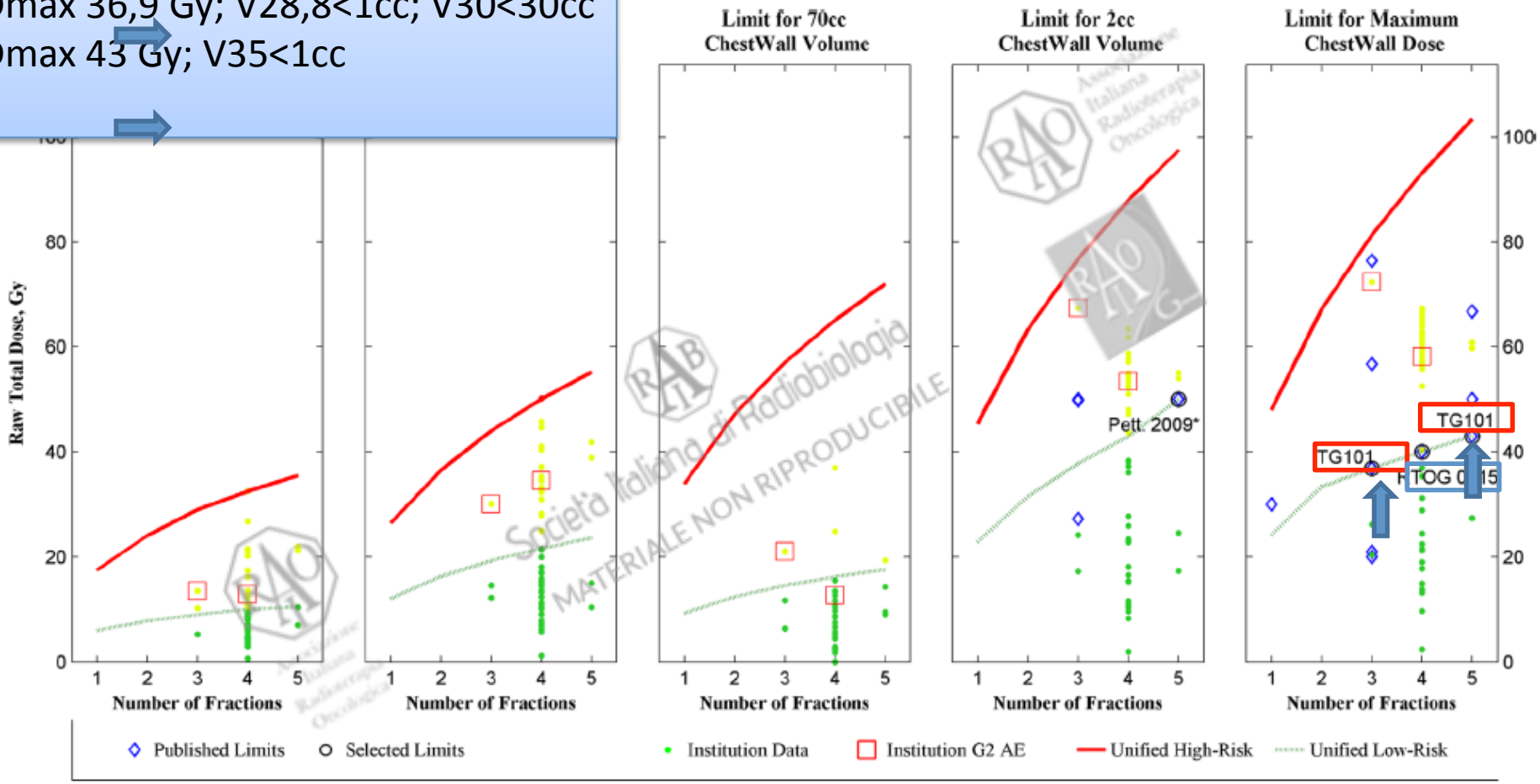
ENDPOINT: FRATTURA COSTALE → **D2cc**

OAR singola costa (+ PRV su TC 4D)

AAPM TG101
1 fr Dmax 30 Gy; V22<1cc

3 fr Dmax 36,9 Gy; V28,8<1cc; V30<30cc
5 fr Dmax 43 Gy; V35<1cc

H Risk Map



Dose descriptors

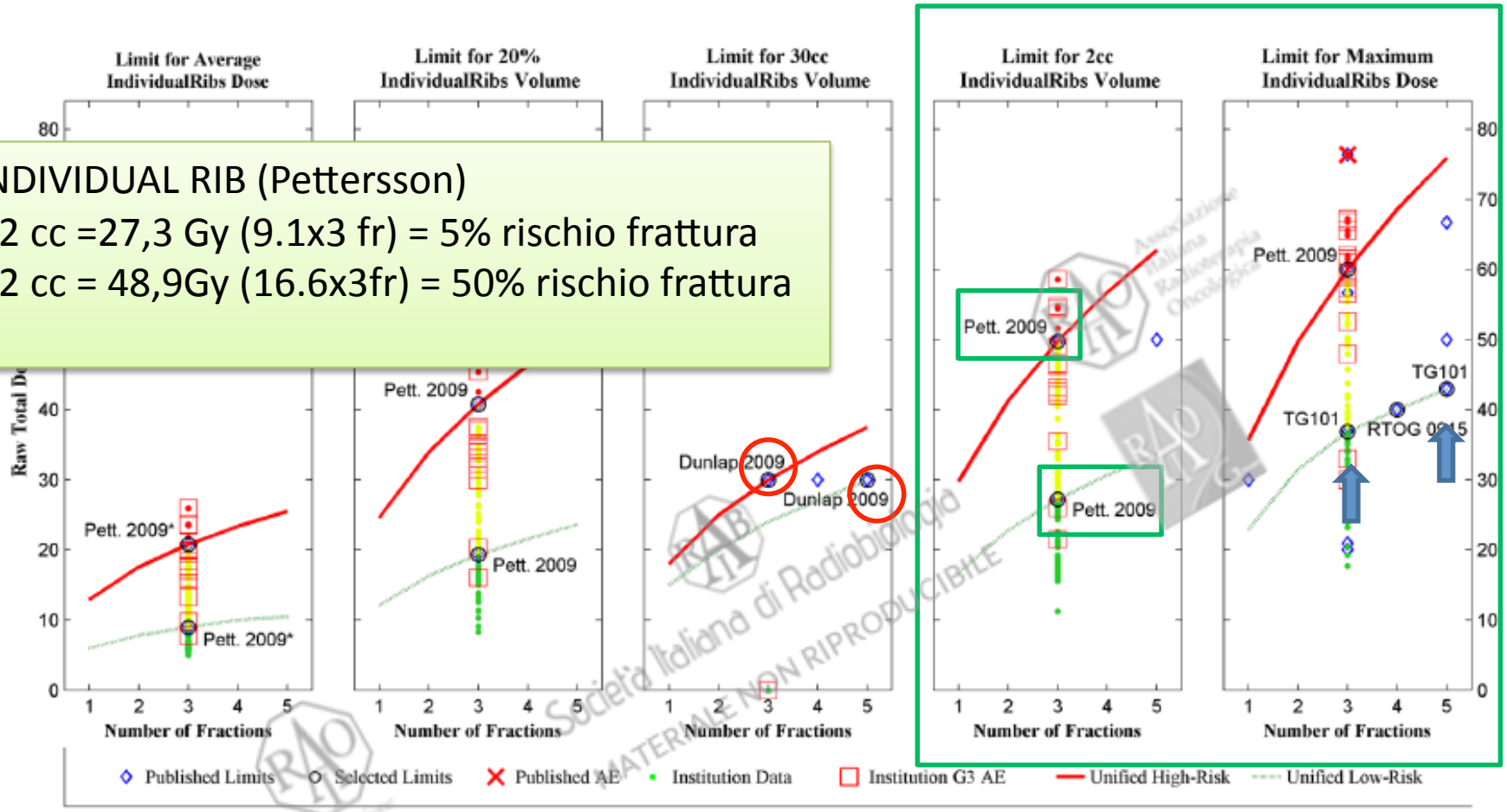
	Low Risk Limits					High Risk Limits				
	D50% Limit (Gy)	D20% Limit (Gy)	D70cc Limit (Gy)	D2cc Limit (Gy)	Dmax Limit (Gy)	D50% Limit (Gy)	D20% Limit (Gy)	D70cc Limit (Gy)	D2cc Limit (Gy)	Dmax Limit (Gy)
1 fx	6.0	12.1	9.3, 10.0%	22.9, 10.0%	24.2, 10.0%	17.5	26.5	34.0, 50.0%	45.4, 50.0%	48.0, 50.0%
2 fx	7.8	16.3	12.4, 10.0%	31.5, 10.0%	33.4, 10.0%	24.0	36.5	47.2, 50.0%	63.3, 50.0%	67.1, 50.0%
3 fx	9.0	19.3	14.6, 10.0%	37.8, 10.0%	**36.9, 8.4%**	29.0	44.0	57.0, 50.0%	76.8, 50.0%	81.4, 50.0%
4 fx	10.0	21.6	16.2, 10.0%	43.0, 10.0%	**40.0, 7.6%**	32.5	50.0	65.1, 50.0%	87.9, 50.0%	93.2, 50.0%
5 fx	10.5	23.6	17.6, 10.0%	**50.0, 11.2%**	**43.0, 7.3%**	35.5	55.2	72.1, 50.0%	97.5, 50.0%	103.5, 50.0%

Next

INDIVIDUAL RIB (Pettersson)

D2 cc =27,3 Gy (9.1x3 fr) = 5% rischio frattura

D2 cc = 48,9Gy (16.6x3fr) = 50% rischio frattura



	Low Risk Limits					High Risk Limits				
	Dmean Limit (Gy)	D20% Limit (Gy)	D30cc Limit (Gy)	D2cc Limit (Gy)	Dmax Limit (Gy)	Dmean Limit (Gy)	D20% Limit (Gy)	D30cc Limit (Gy)	D2cc Limit (Gy)	Dmax Limit (Gy)
1 fx	*6.0*	*12.1*	*15.0*	*16.7*	*22.9*	*12.9*	*24.6*	*18.0*	*29.8*	*35.7*
2 fx	*7.8, 5.0%*	*16.3, 5.0%*	*20.0*	*22.8, 5.0%*	*31.5, 5.0%*	*17.6, 50.0%*	*33.9, 50.0%*	*25.0*	*41.3, 50.0%*	*49.7, 50.0%*
3 fx	**9.0, 5.0%**	**19.3, 5.0%**	*24.0*	**27.2, 5.0%**	**36.9, 4.5%**	**, 50.0%**	**40.8, 50.0%**	**30.0**	**49.8, 50.0%**	**60.0, 49.9%**
4 fx	*10.0, 5.1%*	*21.6, 5.0%*	*27.0*	*30.7, 5.0%*	**40.0, 3.9%**	*23.4, 50.0%*	*46.4, 50.0%*	*34.0*	*56.8, 50.0%*	*68.6, 50.0%*
5 fx	*10.5*	*23.6*	**30.0**	*33.7*	**43.0**	*25.5*	*51.2*	*37.5*	*62.8*	*76.0*

Next

Figure 5 Full DVH Risk Map for individual ribs, with clinical data and estimates of risk from Pettersson 2009. (Color version of figure is available online.)

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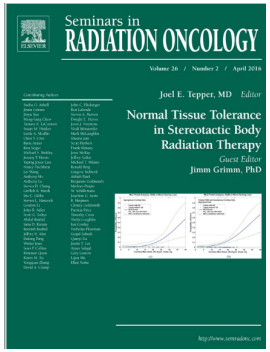
ONCOLOGY

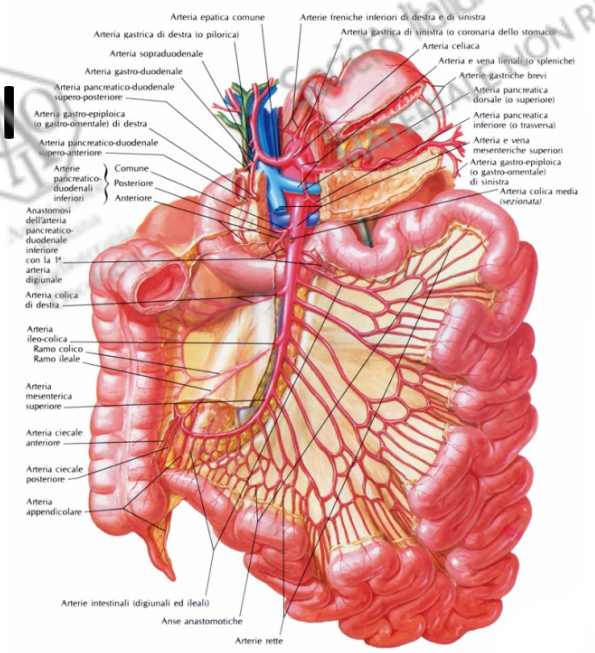


Small Bowel Dose Tolerance for Stereotactic Body Radiation Therapy

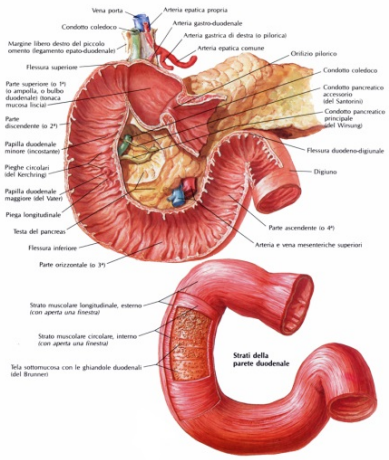
Tamara A. LaCouture, MD, Jinyu Xue, PhD, Gopal Subedi, MS, Qianyi Xu, PhD, Justin T. Lee, MS, Gregory Kubicek, MD, and Sucha O. Asbell, MD

Semin Radiat Oncol 26:157-164 2016

small bowel



Duodeno

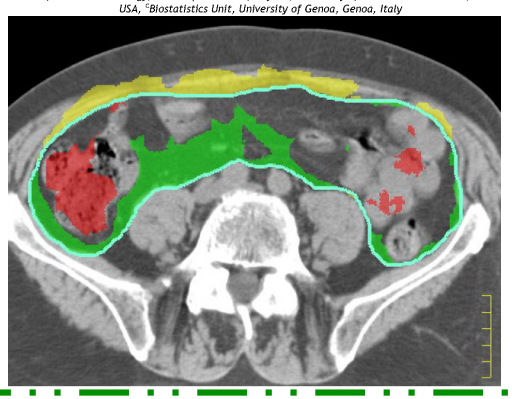


contouring

Comparison of three strategies to delineate the bowel for whole pelvis IMRT of prostate cancer

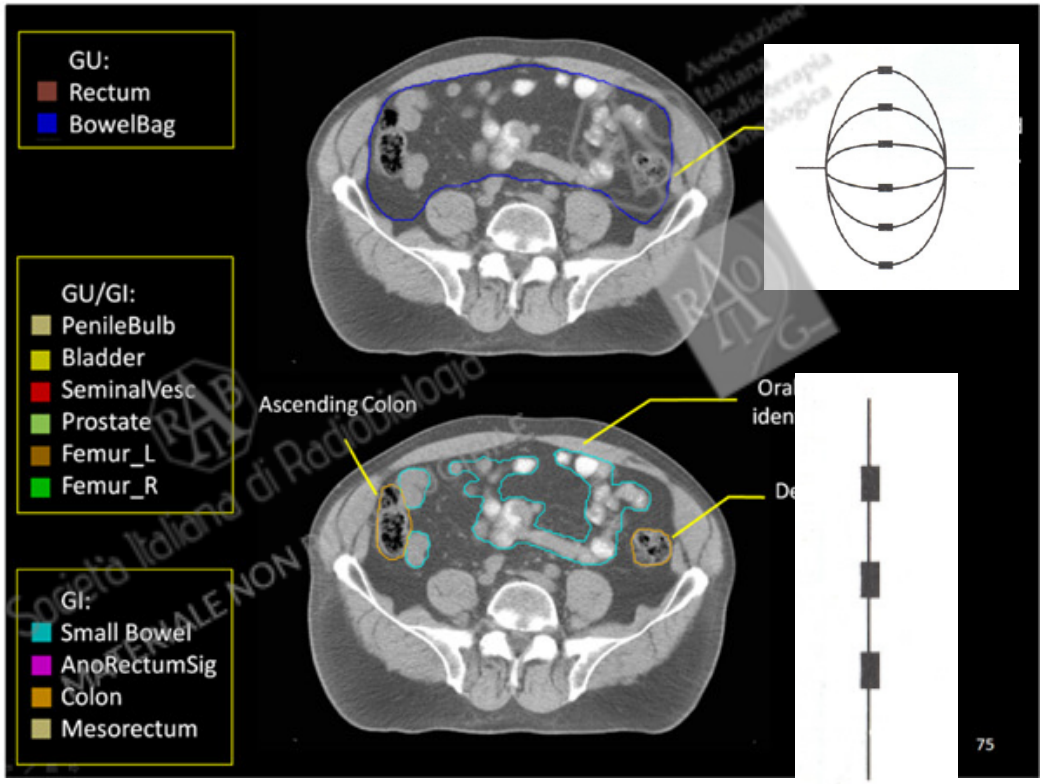
Giuseppe Sanguineti[a,*], Michael Little[a], Eugene J. Endres[b], Maria Pia Sormani[c], Brent C. Parker[b]

[a]Department of Radiation Oncology, and [b]Department of Physics, University of Texas Medical Branch, Galveston, TX, USA, [c]Biostatistics Unit, University of Genoa, Genoa, Italy



MOBILITA' DELL'ORGANO

Tossicita'/endpoint



- La RT induce una **MUCOSITE (**alterazione architettura villi, appiattimento della mucosa, ridotta capacità assorbimento acidi biliari, alterazione flora batterica**)** che provoca crampi e diarrea, con interferenza con l'assorbimento di nutrienti → 1-2 sett dall'inizio della RT
- Settimane-mesi: la RT induce **FIBROSI** che causa adesione e limita la mobilità delle anse e ostruzione (endoarterite obliterante che determina appunto una ischemia tissutale, necrosi e fibrosi della sottomucosa)
- Tossicità tardiva: **diarrea persistente, ulcerazioni, fistole, perforazioni e sanguinamento**

ELSEVIER

Seminars in RADIATION ONCOLOGY

Volume 18, Number 4 October 2008

An Overview of Hypofractionation and Introduction to This Issue of *Seminars in Radiation Oncology*

Timmerman 2008

1 fr Dmax 19Gy; V9,8<5cc

3 fr Dmax 27Gy; V16,2<5cc

5 fr Dmax 35Gy; V19,5<5cc

Table 2 Mostly Unvalidated Normal Tissue Dose Constraints for SBRT

	Serial Tissue	Volume (mL)	Volume Max (Gy)	M	
1 fr	Stomach	<10	13	16	Ulceration/fistula
	Duodenum*	<5	8.8	16	Ulceration
	Jejunum/ileum*	<5	9.8	19	Enteritis/obstruction
	Colon*	<20	11	22	Colitis/fistula
	Rectum*	<20	11	22	Proctitis/fistula
	Esophagus*	<5	14.5	19	Stenosis/fistula
3 fr	Stomach	<10	21 (7 Gy/fx)	24 (8 Gy/fx)	Ulceration/fistula
	Duodenum*	<5	15 (5 Gy/fx)	24 (8 Gy/fx)	Ulceration
	Jejunum/ileum*	<5	16.2 (5.4 Gy/fx)	27 (9 Gy/fx)	Enteritis/obstruction
	Colon*	<20	20.4 (6.8 Gy/fx)	30 (10 Gy/fx)	Colitis/fistula
	Rectum*	<20	20.4 (6.8 Gy/fx)	30 (10 Gy/fx)	Proctitis/fistula
	Esophagus*	<5	21 (7 Gy/fx)	27 (9 Gy/fx)	Stenosis/fistula
5 fr	Stomach	<10	28 (5.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
	Duodenum*	<5	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
	Jejunum/ileum*	<5	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	enteritis/obstruction
	Colon*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	colitis/fistula
	Rectum*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	proctitis/fistula
	Esophagus*	<5	27.5 (5.5 Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula

Medical Physics
The International Journal of Medical Physics Research and Practice

Serial tissue	Max critical volume above threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose (Gy)[a]	Three fractions: Threshold dose (Gy)	Three fractions: Max point dose (Gy)[a]	Five fractions: Threshold dose (Gy)	Five fractions: Max point dose (Gy)[a]	End point (≥Grade3)
Optic pathway	<0.2 cc	8	10	15.3 (5.1 Gy/fx)	17.4 (5.8 Gy/fx)	23 (4.6 Gy/fx)	25 (5 Gy/fx)	Neuritis
Cochlea			9		17.1 (5.7 Gy/fx)		25 (5 Gy/fx)	Hearing loss
Brainstem (not medulla)	<0.5 cc	10						
Spinal cord and medulla	<0.35 cc <1.2 cc	10 7						
Spinal cord subvolume (5–6 mm above and below level treated per Ryu)	<10% of subvolume	10						
Cauda equina	<5 cc	14						
Sacral plexus	<5 cc	14.4						
Esophagus[b]	<5 cc	11.9	1					
Brachial plexus	<3 cc	14	1					
Heart/pericardium	<15 cc	16	2					
Great vessels	<10 cc	31	3					
Trachea and large bronchus[b]	<4 cc	10.5	2					
Bronchus-smaller airways	<0.5 cc	12.4	1					
Rib	<1 cc <30 cc	22	3					
Skin	<10 cc	23	2					
Stomach	<10 cc	11.2	12.4	16.5 (5.5 Gy/fx)	22.2 (7.4 Gy/fx)	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
Duodenum[b]	<5 cc <10 cc	11.2 9	12.4	16.5 (5.5 Gy/fx) 11.4 (3.8 Gy/fx)	22.2 (7.4 Gy/fx)	18 (3.6 Gy/fx) 12.5 (2.5 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Jejunum/ileum[b]	<5 cc	11.9	15.4	17.7 (5.9 Gy/fx)	25.2 (8.4 Gy/fx)	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	Enteritis/ obstruction
Colon[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Colitis/fistula
Rectum[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Proctitis/fistula
Bladder wall	<15 cc	11.4	18.4	16.8 (5.6 Gy/fx)	28.2 (9.4 Gy/fx)	18.3 (3.65 Gy/fx)	38 (7.6 Gy/fx)	Cystitis/fistula
Penile bulb	<3 cc	14	34	21.9 (7.3 Gy/fx)	42 (14 Gy/fx)	30 (6 Gy/fx)	50 (10 Gy/fx)	Impotence
Femoral heads (right and left)	<10 cc	14		21.9 (7.3 Gy/fx)		30 (6 Gy/fx)		Necrosis
Renal hilum/vascular trunk	<2/3 volume	10.6	18.6 (6.2 Gy/fx)			23 (4.6 Gy/fx)		Malignant hypertension

AAPM TG101

1 fr Dmax 15,4Gy; V11,9<5cc

3 fr Dmax 25,2Gy; V17,7<5cc

5 fr Dmax 35Gy; V19,5<5cc

Serial tissue	Max critical volume above threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose (Gy)[a]	Three fractions: Threshold dose (Gy)	Three fractions: Max point dose (Gy)[a]	Five fractions: Threshold dose (Gy)	Five fractions: Max point dose (Gy)[a]	End point (≥Grade3)
Parallel tissue	Minimum critical volume below threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose(Gy)[a]	Three fractions: Threshold dose(Gy)	Three fractions: Max point dose(Gy)[a]	Five fractions: Threshold dose(Gy)	Five fractions: Max point dose(Gy)[a]	End point (≥Grade 3)
Lung (right and left)	1500 cc	7	NA-Parallel tissue	11.6 (2.9 Gy/fx)	NA-Parallel tissue	12.5 (2.5 Gy/fx)	NA-Parallel tissue	Basic lung function
Lung (right and left)	1000 cc	7.4	NA-Parallel tissue	12.4 (3.1 Gy/fx)	NA-Parallel tissue	13.5 (2.7 Gy/fx)	NA-Parallel tissue	Pneumonitis
Liver	700 cc	9.1	NA-Parallel tissue	19.2 (4.8 Gy/fx)	NA-Parallel tissue	21 (4.2 Gy/fx)	NA-Parallel tissue	Basic liver function
Renal cortex (right and left)	200 cc	8.4	NA-Parallel tissue	16 (4 Gy/fx)	NA-Parallel tissue	17.5 (3.5 Gy/fx)	NA-Parallel tissue	Basic renal function

QUANTEC (2010):

V12.5 Gy < 30 cc in singola frazione;

D max < 30 Gy per 3-5 frazioni

Review della letteratura:

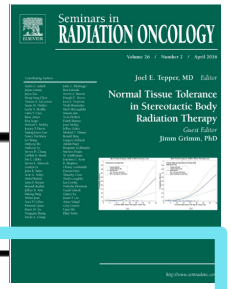


Table 1 Historical Summary of Small Bowel Toxicity

Study	Number of Patients	Dose (Gy)	Number of Fractions	Volume (cc or %)	Small Bowel D_{max}	Adverse Events > Grade	Number of Patients With Adverse Events	Comments
Koong et al[12]		25	1	$V_{50\%}$ 14.5 Gy $V_{5\%}$ 22.5 Gy		None		
Hoyer et al[13]	22	45	3	Median target volume ≥ 30 Gy = 136 cc	30 Gy to small part of stomach or duodenum	≥G2 = 18%	4	Severe mucositis of duodenum and nonfatal perforation
Hoyer et al[14]	64	45	3		30 Gy to minimal volume	≥G2 = 48% ≥G3 = 3%	≥G2 = 29 ≥G3 = 2	G3 = duodenal ulceration
Chang et al[15]	77 (61 SBRT 16 SBRT + EBRT)	25	1	$V_{22.5\ Gy}$ < 5% $V_{12.5\ Gy}$ < 50% 50% IDL < nonadjacent wall		Acute ≥ G2 late G2 late G3	4 (5%) 3 (4%) 7 (95)	1 Of 4 acute and 3 of 10 late ≥G2 toxicity received EBRT and SBRT
Kopek et al[16]	27	45	3	$V_{21\ Gy}$ ≤ 1 cc		≥G3 ulceration 22% ≥G3 stenosis 11%	6 and 4	$D_{1\ cc}$ = 37.4 Gy in patients with ulceration
Mahadevan[17]	36	24-36	3		D_{max} < 30 Gy	G3	Acute 3 (8%) late 2	Prescription dose determined by GTV
		ian 24 Gy)						
Schellenberg et al[20]	20	25	1	$V_{22.5}$ < 5% $V_{12.5}$ < 50%			1 (5%)	G4 duodenal ulceration gemcitabine chemotherapy
Barney 2012[21]	47	50	5	V_{38} ≤ 5 cc $V_{32.5}$ ≤ 15 cc V_{20} ≤ 30 cc	D_{max} ≤ 42 Gy	≥G3 late	5	1 Stenosis, 2 perforations both had bevacizumab
Barney et al[22]	76				D_{max} BED_3 ≤ 125 Gy	≥G3	7 (9%)	If VEGF1 delivered within 3 months of SBRT COT rate 38%
Dholakia et al[23]	49	33	5	V_{33} ≤ 1 cc V_{20} ≤ 3 cc V_{15} ≤ 9 cc		>G2 acute >G2 late	16.3% 5 (11%)	3 Cases G3 ulcer, 1 case G4 fistula
Bae et al[24]	202	33-60 (median 45 Gy)	3	V_{20} < 14 cc V_{25} < 7 cc V_{30} < 5 cc V_{35} < 1 cc D_{max} < 45 Gy	D_{max} < 45 Gy	≥G3 = 4 ≥G4 = 2	6 (15%)	Best predictor of toxicity $V_{25\ Gy}$ > 20 cc and D_{max} of 35–38 Gy with 5%-10% severe toxicity
Wild et al[25]	15	25	5	V_{15} < 9 cc V_{20} < 3 cc V_{33} < 1 cc		G3	No acute 1 (6%) late	Reirradiation with varied chemo

Studio di dose escalation da 15 Gy a 25 Gy singola frazione in SBRTsu pz con LAPC,
25 Gy = nessuna severa tox (Scala RTOG)
Se V22,5 Gy <= 5% e V14,5 Gy>=50% per duodeno e intestino tenue

Koong et al, 2004 Int J Radiat Oncol Biol Phys, 58(4)

Table 1 Historical Summary of Small Bowel Toxicity

Study	Number of Patients	Dose (Gy)	Number of Fractions	Volume (cc or %)	Small Bowel D_{max}	Adverse Events > Grade	Number of Patients With Adverse Events	Comments
Koong et al[12]		25	1	$V_{50\%}$ 14.5 Gy $V_{5\%}$ 22.5 Gy		None		
Hoyer et al[13]	22	45	3	Median target volume ≥	30 Gy to small part of	≥G2 = 18%	4	Severe mucositis of duodenum and
Manadevan[14]	36	24-36	3		D_{max} < 30 Gy	G3	Acute 3 (8%) late 2 (6%)	Prescription dose determined by GTV duodenal proximity and volume
Murphy et al[18]	73	25	1	$V_{22.5\ Gy}$ < 5% $V_{12.5}$ < 50%	D_{max} < 23 Gy reduced toxicity from 49%-12%	G2-4 V_{15} < 9.1 cc and V_{20} < 3.3 cc reduced risk from 52%-11%	12	86% Of patients received gemcitabine
Rwigema et al[19]						G3	3 (4.2%)	1 Nausea, 1 abdominal pain, 1 gastroparesis, but no ulceration
Schellenberg et al[20]								duodenal ulceration gemcitabine chemotherapy
Barney 2012[21]								tenosis, 2 perforations both had evacizumab
Barney et al[22]								EGF1 delivered within 3 months of SBRT COT rate 38%
Dholakia et al[23]								Cases G3 ulcer, 1 case G4 fistula
Bae et al[24]								st predictor of toxicity $V_{25\ Gy}$ > 20 cc nd D_{max} of 35–38 Gy with 5%-10% evere toxicity
Wild et al[25]								rradiation with varied chemo

Murphy et coll. usano stesse dosi e constraints (**V14,5 Gy>=50% e V22,5 Gy<= 5%)** ma per pazienti trattati con gemcitabina in precedenza.

→**Dmax <23 Gy** riduce la tossicità >= G2 a 12 mesi dal 49% al 12%.

→**V15<9.1cc e V20<3.3cc** riduce la tossicità >= G2 a 12 mesi dal 52% al 11%.

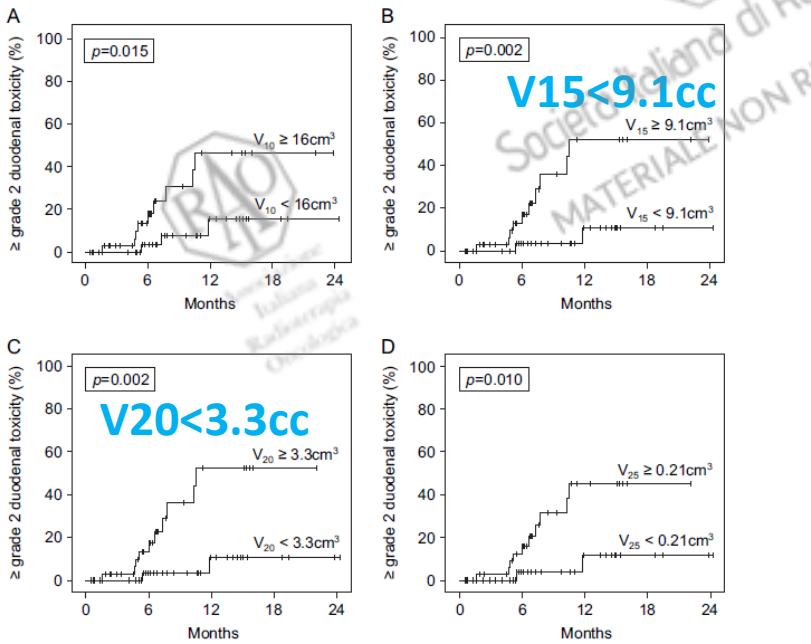


Fig. 2. Volume predicts duodenal toxicity. Kaplan-Meier analysis of toxicity stratified by (A) V_{10}, (B) V_{15}, (C) V_{20}, and (D) V_{25}, where V_{10} represents the volume of duodenum that received 10 Gy.

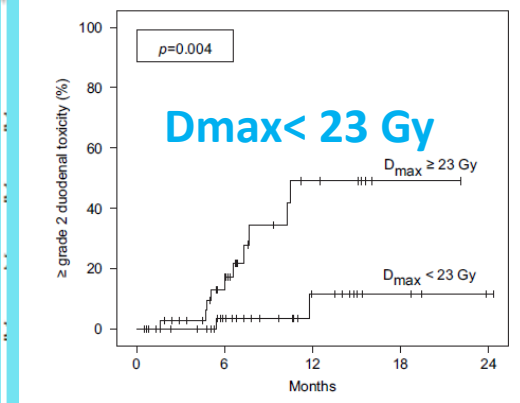


Fig. 3. Maximum dose predicts duodenal toxicity. Kaplan-Meier analysis of toxicity according to the maximum dose to 1 cm^3 of duodenum (D_{max}).

Murphy et al, 2010 Int J Radiat Oncol Byol Phis, 78(5)

Table 1 Historical Summary of Small Bowel Toxicity

Study	Number of Patients	Dose (Gy)	Number of Fractions	Volume (cc or %)	Small Bowel D_{max}	Adverse Events > Grade	Number of Patients With Adverse Events	Comments
Koong et al[12]		25	1	$V_{50\%}$ 14.5 Gy $V_{5\%}$ 22.5 Gy		None		
Hoyer et al[13]	22	45	3	Median target volume ≥ 30 Gy = 136 cc	30 Gy to small part of stomach or duodenum	≥G2 = 18%	4	Severe mucositis of duodenum and nonfatal perforation
Hoyer et al[14]	64	45	3		30 Gy to minimal volume	≥G2 = 48% ≥G3 = 3%	≥G2 = 29 ≥G3 = 2	G3 = duodenal ulceration
Chang et al[15]	77 (61 SBRT 16 SBRT + EBRT)	25	1	$V_{22.5\ Gy}$ < 5% $V_{12.5\ Gy}$ < 50% 50% IDL < nonadjacent wall		Acute ≥ G2 late G2 late G3	4 (5%) 3 (4%) 7 (9%)	1 of 4 acute and 3 of 10 late ≥G2 toxicity received EBRT and SBRT
Kopek et al[16]	27	45	3	$V_{21\ Gy}$ ≤ 1 cc		≥G3 ulceration 22% ≥G3 stenosis 11%	6 and 4	$D_{1\ cc}$ = 37.4 Gy in patients with ulceration
Mahadevan[17]	36	24-36	3		D_{max} < 30 Gy	G3	Acute 3 (8%) late 2 (6%)	Prescription dose determined by GTV duodenal proximity and volume
		24 Gy)						
Schellenberg et al[20]	20	25	1	$V_{22.5}$ < 5% $V_{12.5}$ < 50%			1 (5%)	G4 duodenal ulceration gemcitabine chemotherapy
Barney 2012[21]	47	50	5	V_{38} ≤ 5 cc $V_{32.5}$ ≤ 15 cc V_{20} ≤ 30 cc	D_{max} ≤ 42 Gy	≥G3 late	5	1 Stenosis, 2 perforations both had bevacizumab
Barney et al[22]	76				D_{max} BED_3 ≤ 125 Gy	≥G3	7 (9%)	If VEGF1 delivered within 3 months of SBRT COT rate 38%
Dholakia et al[23]	49	33	5	V_{33} ≤ 1 cc V_{20} ≤ 3 cc V_{15} ≤ 9 cc		>G2 acute >G2 late	16.3% 5 (11%)	3 Cases G3 ulcer, 1 case G4 fistula
Bae et al[24]	202	33-60 (median 45 Gy)	3	V_{20} < 14 cc V_{25} < 7 cc V_{30} < 5 cc V_{35} < 1 cc D_{max} < 45 Gy	D_{max} < 45 Gy	≥G3 = 4 ≥G4 = 2	6 (15%)	Best predictor of toxicity $V_{25\ Gy}$ > 20 cc and D_{max} of 35–38 Gy with 5%-10% severe toxicity
Wild et al[25]	15	25	5	V_{15} < 9 cc V_{20} < 3 cc V_{33} < 1 cc		G3	No acute 1 (6%) late	Reirradiation with varied chemo

Studio di fase II su LAPC **45 Gy in tre frazioni**,
Gli autori rilevano tossicita severa elevata (**ulcerazione duodenale e perforazione non fatale**) per
Dmax > 30 Gy

Hoyer et al, 2005 Radiother Oncol 75(1)
Hoyer et al, 2006 Acta Oncol 45(7)
Semin Radiat Oncol 26:157-164

Table 1 Historical Summary of Small Bowel Toxicity

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Chang et al[15]	77 (61 SBRT 16 SBRT + EBRT)	25	1	$V_{22.5\ Gy}$ < 5% $V_{12.5\ Gy}$ < 50% 50% IDL < nonadjacent wall		Acute ≥ G2 late G2 late G3	4 (5%) 3 (4%) 7 (95)	1 Of 4 acute and 3 of 10 late ≥G2 toxicity received EBRT and SBRT
Kopek et al[16]	27	45	3	$V_{21\ Gy}$ ≤ 1 cc		≥G3 ulceration 22% ≥G3 stenosis 11%	6 and 4	$D_{1\ cc}$ = 37.4 Gy in patients with ulceration
Manadevan[17]	30	24-30	3		D_{max} < 30 Gy	G3	Acute 3 (8%) late 2 (6%)	Prescription dose determined by GTV duodenal proximity and volume
Murphy et al[18]	73	25	1	$V_{22.5\ Gy}$ < 5% $V_{12.5}$ < 50%	D_{max} < 23 Gy reduced toxicity from 49%-12%	G2-4 V_{15} < 9.1 cc and V_{20} < 3.3 cc reduced risk from 52%-11%	12	86% Of patients received gemcitabine
Rwigema et al[19]	71	18-25 (median 24 Gy)	1		D_{max} ≤ 15.1 Gy (median). D_{max} ranged from 7.7-21.6 Gy	G3	3 (4.2%)	1 Nausea, 1 abdominal pain, 1 gastroparesis, but no ulceration
Dholakia et al[23]	49	33	5	V_{33} ≤ 1 cc V_{20} ≤ 3 cc V_{15} ≤ 9 cc		>G2 acute >G2 late	16.3% 5 (11%)	3 Cases G3 ulcer, 1 case G4 fistula
Bae et al[24]	202	33-60 (median 45 Gy)	3	V_{20} < 14 cc V_{25} < 7 cc V_{30} < 5 cc V_{35} < 1 cc D_{max} < 45 Gy	D_{max} < 45 Gy	≥G3 = 4 ≥G4 = 2	6 (15%)	Best predictor of toxicity $V_{25\ Gy}$ > 20 cc and D_{max} of 35–38 Gy with 5%-10% severe toxicity
Wild et al[25]	15	25	5	V_{15} < 9 cc V_{20} < 3 cc V_{33} < 1 cc		G3	No acute 1 (6%) late	Reirradiation with varied chemo

Studio condotto su pazienti con colangio carcinoma, **45Gy (3 frazioni)** SBRT cons=V21Gy<=1cc
→non associazione statisticamente significativa tra tossicità severa e volume duodenale trattato

nei pazienti con ulcerazione si registrava **D 1cc >= 37,4 Gy.**

Kopek et al, 2010 Radiother Oncol 94(1)

Table 1 Historical Summary of Small Bowel Toxicity

Study	Number of Patients	Dose (Gy)	Number of Fractions	Volume (cc or %)	Small Bowel D_{max}	Adverse Events > Grade	Number of Patients With Adverse Events	Comments
[illegible][12]				[illegible]		None		
2012[21]				$V_{20} \leq 30$ cc				bevacizumab
Barney et al[22]	76				D_{max} $BED_3 \leq 125$ Gy	≥G3	7 (9%)	If VEGF1 delivered within 3 months of SBRT COT rate 38%
Dholakia et al[23]	49	33	5	$V_{33} \leq 1$ cc $V_{20} \leq 3$ cc V_{15} < 9 cc		>G2 acute >G2 late	16.3% 5 (11%)	3 Cases G3 ulcer, 1 case G4 fistula
Bae et al[24]	202	33-60 (median [illegible])	3	$V_{20} < 14$ cc $V_{25} < 7$ cc V_{30} < 5 cc $V_{35} < 1$ cc D_{max} < 45 Gy	$D_{max} < 45$ Gy	≥G3 = 4 ≥G4 = 2	6 (15%)	Best predictor of toxicity $V_{25\ Gy} > 20$ cc and D_{max} of 35–38 Gy with 5%-10% severe toxicity
Wild et al[25]	15	25	5	$V_{15} < 9$ cc $V_{20} < 3$ cc V_{33} < 1 cc		G3	No acute 1 (6%) late	Reirradiation with varied chemo

SBRT 33 - 60 Gy (3 frazioni)

con tossicita' severa nel 18% dei pazienti trattati in 3 giorni consecutivi

Dmax 35 e Dmax 38 Gy rispettivamente associata al 5% e 10% di sviluppo di tossicità severa.

Miglior valore predittivo della tossicità intestinale era la **V25Gy>20 mL(*P* = 0.004).**

Per $V_{25} \leq 20$ ml: la tossicita si riduce da 50% a 4 %.

Per durata della SABR 4–8 giorni vs 3 consecutivi (tossicita' 0 % vs. 18 %, *P* = 0.037).

→ 48 ore tra una seduta e l'altra

Bae et al, 2013 Int J Colorect Dis 28(12)

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Seminars in RADIATION ONCOLOGY

Small Bowel Dose Tolerance for Stereotactic Body Radiation Therapy

Tamara A. LaCouture, MD, Jinyu Xue, PhD, Gopal Subedi, MS, Qianyi Xu, PhD, Justin T. Lee, MS, Gregory Kubicek, MD, and Sucha O. Asbell, MD

Clinical Investigation: Gastrointestinal Cancer

Increased Bowel Toxicity in Patients Treated With a Vascular Endothelial Growth Factor Inhibitor (VEGFI) After Stereotactic Body Radiation Therapy (SBRT)

Brandon M. Barney, MD,* Svetomir N. Markovic, MD, PhD,† Nadia N. Laack, MD,* Robert C. Miller, MD,* Jann N. Sarkaria, MD,* O. Kenneth Macdonald, MD,‡ Heather J. Bauer, RN,* and Kenneth R. Olivier, MD*

Int J Radiat Oncol Biol Phys 87(1):73-80, 2013

Clinical Datasets

MD Anderson Cancer Center Making Cancer History® — Cooper

109 pz (2008-2014)-18 lost
91* pz MDA at CUH

- 1-5 fr SBRT

84 Tp (76pz) (2005-2012)
From Barney 2013
Mayo Clinic

- 5 fr SBRT

*liver (68%), pancreas (15%), and other upper-abdomen structures (17%).

DVH for 175 exposures

DVH Evaluator — Load DVH data for all cases

Descriptors — Extract Dose Descriptors: D_{5cc}, D_{2cc}, D_{max}

LQ Model with $\alpha/\beta = 3$ Gy — Convert Dose Descritors to 3-fraction Equivalent Dose (Gy)

Probit Dose-Response Model — $NTCP = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{t} e^{-x^2/2}dx$

DVH Risk Map

DVH Risk Map

QUANTEC (2010):

V12.5 Gy < 30 cc in singola frazione;
D max < 30 Gy per 3-5 frazioni

Timmerman 2008
1 fr Dmax 19Gy; V9,8<5cc

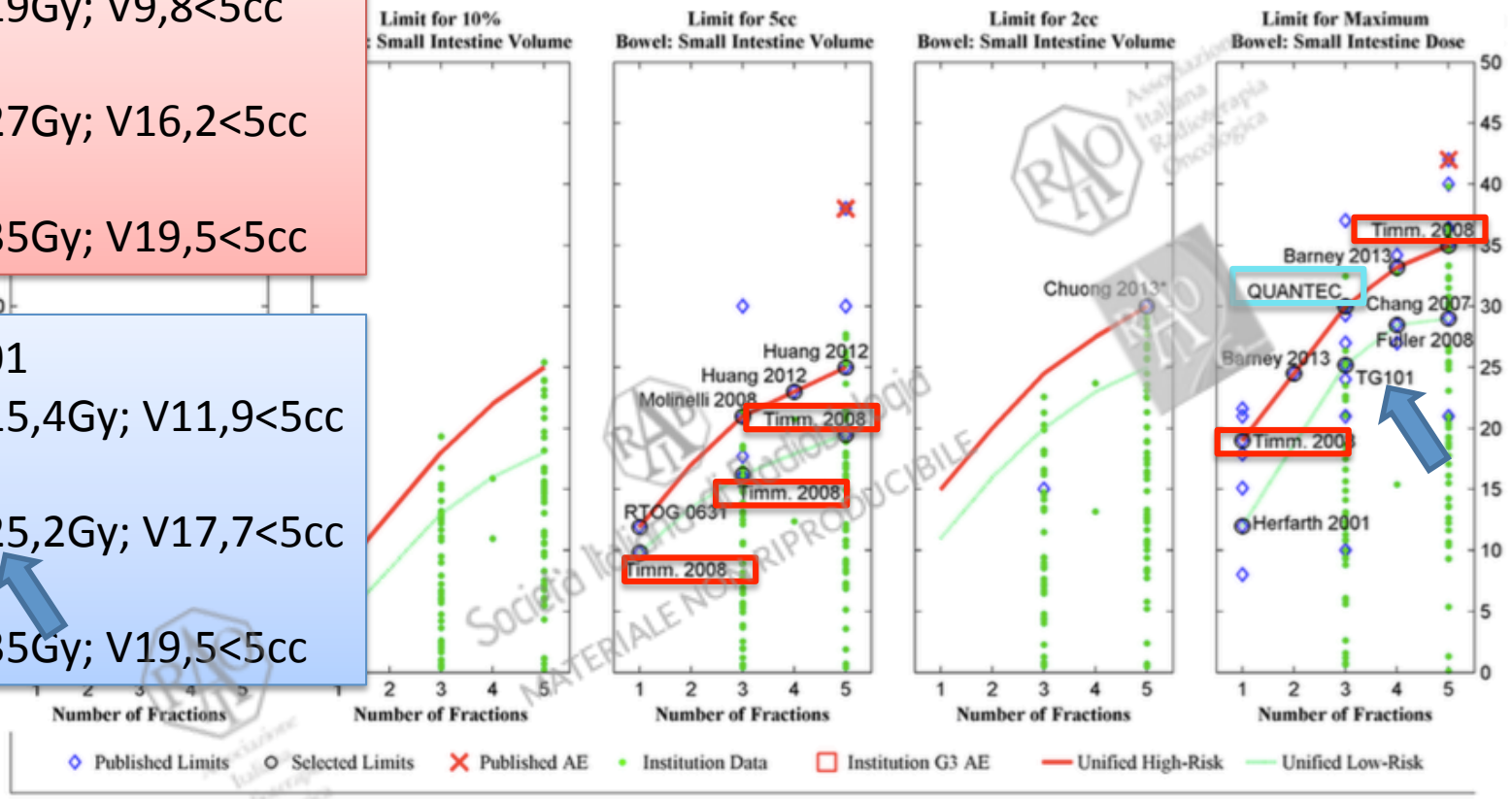
3 fr Dmax 27Gy; V16,2<5cc

5 fr Dmax 35Gy; V19,5<5cc

AAPM TG101
1 fr Dmax 15,4Gy; V11,9<5cc

3 fr Dmax 25,2Gy; V17,7<5cc

5 fr Dmax 35Gy; V19,5<5cc



	Low Risk Limits					High Risk Limits				
	D50% Limit (Gy)	D10% Limit (Gy)	D5cc Limit (Gy)	D2cc Limit (Gy)	Dmax Limit (Gy)	D50% Limit (Gy)	D10% Limit (Gy)	D5cc Limit (Gy)	D2cc Limit (Gy)	Dmax Limit (Gy)
1 fx	3.0	4.0	9.8, 2.1%	11.0, 2.3%	12.0, 1.4%	4.0	8.0	11.9, 4.4%	15.0, 7.5%	19.0, 8.2%
2 fx	6.0	8.5	13.5, 2.3%	16.0, 3.0%	18.6, 2.3%	8.0	13.0	17.0, 5.5%	20.0, 6.9%	24.5, 6.4%
3 fx	9.0	13.0	16.2, 2.5%	20.0, 3.7%	25.2, 3.6%	12.0	18.0	21.0, 6.5%	24.5, 7.7%	30.0, 7.0%
4 fx	11.0	16.0	17.9, 2.4%	23.0, 4.0%	28.5, 3.7%	15.0	22.0	23.0, 5.9%	27.5, 7.6%	33.2, 6.5%
5 fx	12.0	18.0	19.5, 2.4%	25.0, 3.9%	29.0, 2.8%	17.0	25.0	25.0, 5.8%	30.0, 7.5%	35.0, 5.6%

Figure 3 DVH Risk Map for small bowel dose tolerance in 1-5 fractions. (Color version of figure is available online.)

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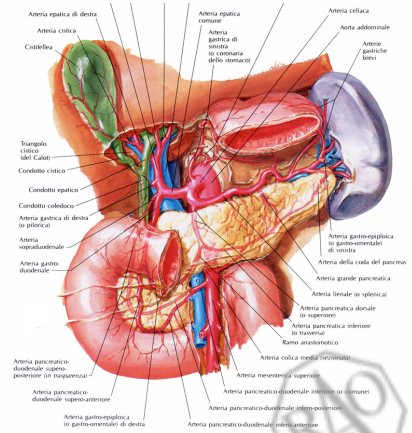
Seminars in RADIATION ONCOLOGY

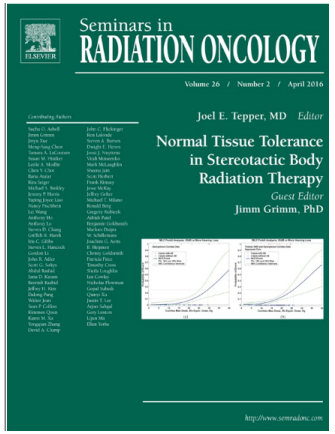
Dose-Volume Histogram Analysis of Stereotactic Body Radiotherapy Treatment of Pancreatic Cancer: A Focus on Duodenal Dose Constraints

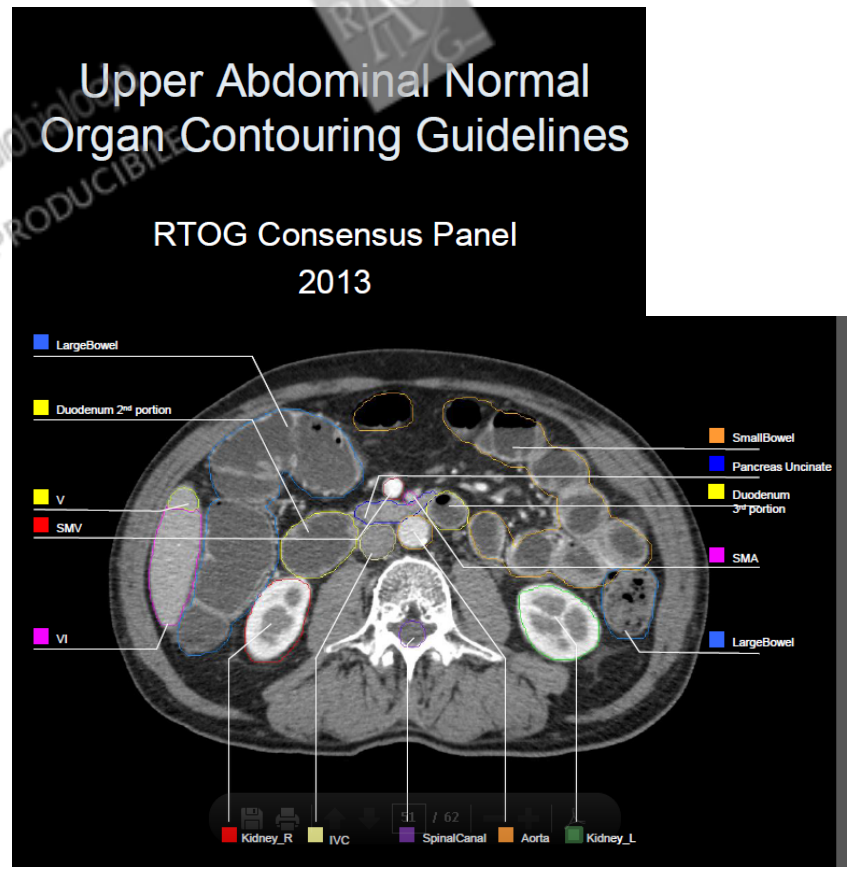
Christy Goldsmith, MBBS, FRCR, MRCP, BSc,*,† Patricia Price, MD, FRCR, FRCP,*,† Timothy Cross, MSc, BSc,* Sheila Loughlin, BSc, MSc,* Ian Cowley, MA, MSci, PhD,* and Nicholas Plowman, MA, MD, FRCP, FRCR*,‡



DUODENO

- 1st portion: begins after the pylorus, is retroperitoneal after the 1st approximate 5 cm where it is is suspended by hepatoduodenal ligament.
- 2nd (descending) portion: starts at superior duodenal flexure, is attached to the head of pancreas, is about 7.5 cm long, located to right of the IVC at levels L1 to L3.
- 3rd (transverse) portion: crosses in front of the aorta & IVC and is posterior to the SMA & SMV, is about 10 cm, and marks the end of the C-loop of the duodenum.
- 4th (ascending) portion: travels superiorly until it is adjacent to the inferior pancreatic body, is about 2.5 cm long, lies anteriorly to the IMV until the IMV moves medially at the transition to the jejunum.





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Volume 18, Number 4

An Overview of Hypofractionation and Introduc
to This Issue of *Seminars in Radiation Oncology*

Timmerman 2008

1 fr Dmax 16Gy; V8,8<5cc

3 fr Dmax 24Gy; V15<5cc

5 fr Dmax 32Gy; V18<5cc

Table 2 Mostly Unvalidated Normal Tissue Dose Constraints f

	Serial Tissue	Volume (mL)	Volum		
1 fr	Stomach	<10	13	16	Ulceration/fistula
	Duodenum*	<5	8.8	16	Ulceration
	Jejunum/ileum*	<5	9.8	19	Enteritis/obstruction
	Colon*	<20	11	22	Colitis/fistula
	Rectum*	<20	11	22	Proctitis/fistula
	Esophagus*	<5	14.5	19	Stenosis/fistula
3 fr	Stomach	<10	21 (7 Gy/fx)	24 (8 Gy/fx)	Ulceration/fistula
	Duodenum*	<5	15 (5 Gy/fx)	24 (8 Gy/fx)	Ulceration
	Jejunum/ileum*	<5	16.2 (5.4 Gy/fx)	27 (9 Gy/fx)	Enteritis/obstruction
	Colon*	<20	20.4 (6.8 Gy/fx)	30 (10 Gy/fx)	Colitis/fistula
	Rectum*	<20	20.4 (6.8 Gy/fx)	30 (10 Gy/fx)	Proctitis/fistula
	Esophagus*	<5	21 (7 Gy/fx)	27 (9 Gy/fx)	Stenosis/fistula
5 fr	Stomach	<10	28 (5.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
	Duodenum*	<5	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
	Jejunum/ileum*	<5	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	enteritis/obstruction
	Colon*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	colitis/fistula
	Rectum*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	proctitis/fistula
	Esophagus*	<5	27.5 (5.5 Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula

Medical Physics
The International Journal of Medical Physics Research and Practice

Stereotactic body radiation therapy: The report of AAPM Task Group 101

Serial tissue	Max critical volume above threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose (Gy)[a]	Three fractions: Threshold dose (Gy)	Three fractions: Max point dose (Gy)[a]	Five fractions: Threshold dose (Gy)	Five fractions: Max point dose (Gy)[a]	End point (≥Grade3)
Optic pathway						Gy/fx)	25 (5 Gy/fx)	Neuritis
Cochlea							25 (5 Gy/fx)	Hearing loss
Brainstem (not medulla)						Gy/fx)	31 (6.2 Gy/fx)	Cranial neuropathy
Spinal cord and medulla						Gy/fx)	30 (6 Gy/fx)	Myelitis
Spinal cord subvolume (5–6 mm above and below level treated per Ryu)						Gy/fx)		
Cauda equina						Gy/fx)	30 (6 Gy/fx)	Myelitis
Sacral plexus						Gy/fx)	32 (6.4 Gy/fx)	Neuritis
Esophagus[b]						Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Brachial plexus						Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula
Heart/pericardium						Gy/fx)	30.5 (6.1 Gy/fx)	Neuropathy
Great vessels						Gy/fx)	38 (7.6 Gy/fx)	Pericarditis
Trachea and large bronchus[b]						Gy/fx)	53 (10.6 Gy/fx)	Aneurysm
Bronchus-smaller airways						Gy/fx)	40 (8 Gy/fx)	Stenosis/fistula
Rib						Gy/fx)	33 (6.6 Gy/fx)	Stenosis with atelectasis
	<30 cc			30.0 (10.0 Gy/fx)			43 (8.6 Gy/fx)	Pain or fracture
Skin	<10 cc	23	26	30 (10 Gy/fx)	33 (11 Gy/fx)	36.5 (7.3 Gy/fx)	39.5 (7.9 Gy/fx)	Ulceration
Stomach	<10 cc	11.2	12.4	16.5 (5.5 Gy/fx)	22.2 (7.4 Gy/fx)	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
Duodenum[b]	<5 cc	11.2	12.4	16.5 (5.5 Gy/fx)	22.2 (7.4 Gy/fx)	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Jejunum/ileum[b]	<5 cc	11.9	15.4	17.7 (5.9 Gy/fx)	25.2 (8.4 Gy/fx)	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	Enteritis/ obstruction
Colon[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Colitis/fistula
Rectum[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Proctitis/fistula
Bladder wall	<15 cc	11.4	18.4	16.8 (5.6 Gy/fx)	28.2 (9.4 Gy/fx)	18.3 (3.65 Gy/fx)	38 (7.6 Gy/fx)	Cystitis/fistula
Penile bulb	<3 cc	14	34	21.9 (7.3 Gy/fx)	42 (14 Gy/fx)	30 (6 Gy/fx)	50 (10 Gy/fx)	Impotence
Femoral heads (right and left)	<10 cc	14		21.9 (7.3 Gy/fx)		30 (6 Gy/fx)		Necrosis
Renal hilum/vascular trunk	<2/3 volume	10.6	18.6 (6.2 Gy/fx)			23 (4.6 Gy/fx)		Malignant hypertension

AAPM TG101

1 fr Dmax 12,4Gy; V11,2<5cc

3 fr Dmax 22,2Gy; V16,5<5cc

5 fr Dmax 32Gy; V18<5cc

Serial tissue	Max critical volume above threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose (Gy)[a]	Three fractions: Threshold dose (Gy)	Three fractions: Max point dose (Gy)[a]	Five fractions: Threshold dose (Gy)	Five fractions: Max point dose (Gy)[a]	End point (≥Grade3)

Parallel tissue	Minimum critical volume below threshold	One fraction: Threshold dose (Gy)	One fraction: Max point dose(Gy)[a]	Three fractions: Threshold dose(Gy)	Three fractions: Max point dose(Gy)[a]	Five fractions: Threshold dose(Gy)	Five fractions: Max point dose(Gy)[a]	End point (≥Grade 3)
Lung (right and left)	1500 cc	7	NA-Parallel tissue	11.6 (2.9 Gy/fx)	NA-Parallel tissue	12.5 (2.5 Gy/fx)	NA-Parallel tissue	Basic lung function
Lung (right and left)	1000 cc	7.4	NA-Parallel tissue	12.4 (3.1 Gy/fx)	NA-Parallel tissue	13.5 (2.7 Gy/fx)	NA-Parallel tissue	Pneumonitis
Liver	700 cc	9.1	NA-Parallel tissue	19.2 (4.8 Gy/fx)	NA-Parallel tissue	21 (4.2 Gy/fx)	NA-Parallel tissue	Basic liver function
Renal cortex (right and left)	200 cc	8.4	NA-Parallel tissue	16 (4 Gy/fx)	NA-Parallel tissue	17.5 (3.5 Gy/fx)	NA-Parallel tissue	Basic renal function

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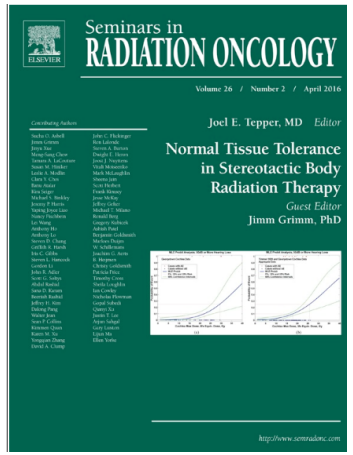
Seminars in RADIATION ONCOLOGY

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,* Ian Cowley, MA, MSci, PhD,* and Nicholas Plowman, MA, MD, FRCP, FRCR*,‡



Harley Street Clinic:
44 pts unresectable pancreatic tumors (March 2009 - March 2013 by CyberKnife)

- **41 pts** **18-36 Gy in 3 frs (BED 24.5 – 79.2 Gy, α/β = 10 Gy for tumor control)**
- **3 pts** **22,5-25 Gy in 5 frs (reirradiation) (BED 32.6 – 37.5 Gy)**

9 pts SINGLE FIDUCIAL
3 pts NO FIDUCIALS – SPINAL Tracking (Palliative RT)
vs
29 pts MULTIPLE FIDUCIALS

Duodenum dose tolerance limits:

Dmax = small volume of 0.035 cc

$D_{0.035\ cc} \leq 24$ Gy,
$D_{5cc} \leq 16.5$ Gy,
$D_{10cc} \leq 11.4$ Gy

RTOG 0631 e dal TG- 101 Timmerman 2008

ENDPOINTS CTCAE V3
Duodenal stricture, Duodenitis, Bleeding,Obstructive jaundice Fatigue and diarrhea , Duodenal hemorrhage, Duodenal stricture

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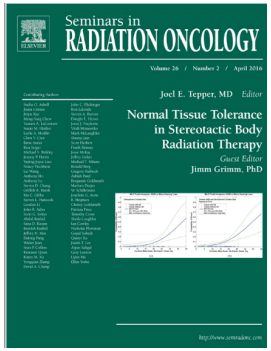


Toxicity

$D_{0.035\ cc} \leq 24$ Gy,
$D_{5cc} \leq 16.5$ Gy,
$D_{10cc} \leq 11.4$ Gy

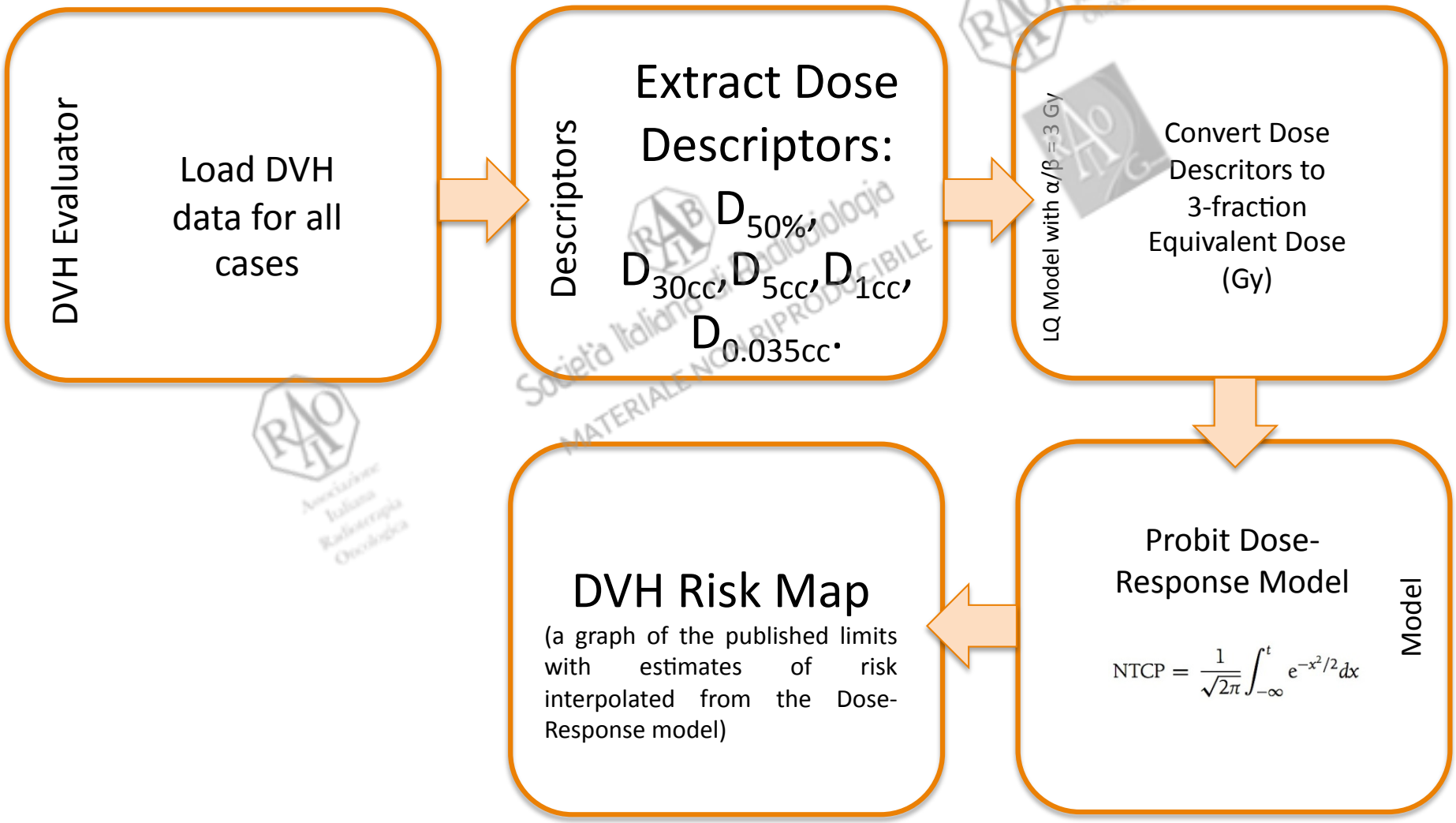
Table All Grade 3-4 Complications, Sorted by Fiducials and $D_{5\ cc}$

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

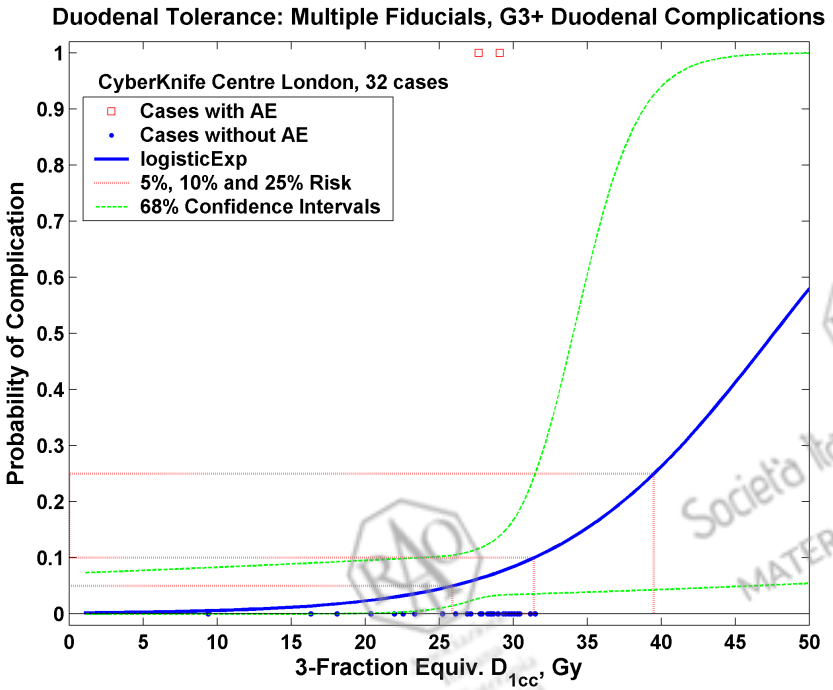
*This patient experienced both grade 3 fatigue and grade 3 diarrhea. CTCAE, Common Terminology Criteria for Adverse Events

In all, 7 Grade 3-4 complications occurred potentially attributable to SBRT

A logistic model was constructed in the dose-volume histogram (DVH) Evaluator software for the duodenal D50%, D30 cc, D5 cc, D1 cc , and maximum point dose D0.035cc.

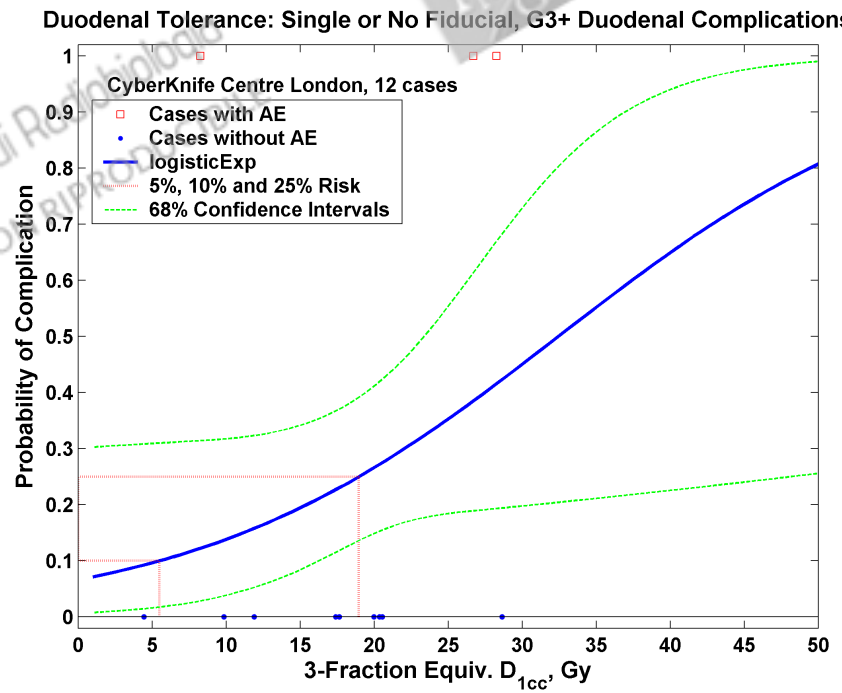


With ≥ 2 Fiducials, the duodenal hemorrhage or stricture had the most clear dose response



D_{1cc} – MULTIPLE FIDUCIALS

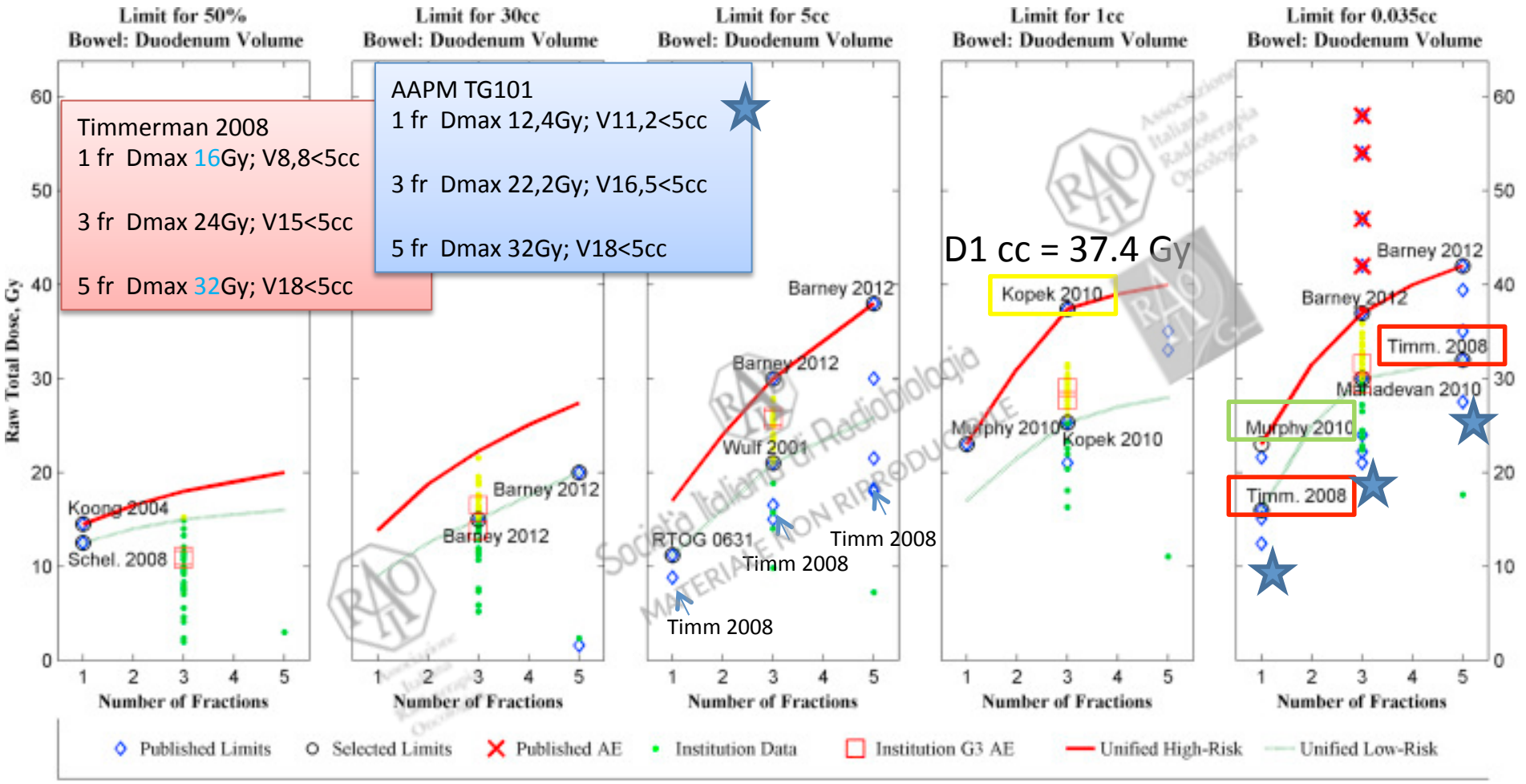
D_{1cc} (30 Gy in 3 frs) = 9% risk of complications



D_{1cc} – SINGLE or NO FIDUCIALS

D_{1cc} (30 Gy in 3 frs) = 45% risk of complications

DVH Risk Map



	Low Risk Limits					High Risk Limits				
	D50% Limit (Gy)	D30cc Limit (Gy)	D5cc Limit (Gy)	D1cc Limit (Gy)	D0.035cc Limit (Gy)	D50% Limit (Gy)	D30cc Limit (Gy)	D5cc Limit (Gy)	D1cc Limit (Gy)	D0.035cc Limit (Gy)
1 fx	**12.5, 32.3%**	*9.0, 6.1%*	**11.2, 0.6%**	*17.0, 6.4%*	**16.0, 5.3%**	**14.5, 48.3%**	*13.8, 11.0%*	*17.0, 14.6%*	**23.0, 21.4%**	**23.0, 8.8%**
2 fx	*14.0, 19.3%*	*12.5, 6.3%*	*16.1, 0.9%*	*21.5, 4.9%*	*25.0, 6.2%*	*16.5, 30.2%*	*18.8, 11.0%*	*24.0, 18.8%*	*31.0, 19.5%*	*31.5, 8.7%*
3 fx	*15.0, 15.2%*	**15.0, 6.5%**	**21.0, 1.8%**	**25.3, 4.7%**	**30.0, 6.2%**	*18.0, 24.3%*	*22.3, 11.0%*	**30.0, 26.5%**	**37.4, 19.8%**	**37.0, 8.4%**
4 fx	*15.5, 12.7%*	*17.5, 6.8%*	*23.4, 1.7%*	*28.0, 3.5%*	*31.0, 5.6%*	*19.0, 20.9%*	*25.1, 11.0%*	*34.0, 26.8%*	*39.0, 14.2%*	*40.0, 7.8%*
5 fx	*16.0, 11.4%*	**20.0, 7.3%**	*25.8, 1.8%*	*28.0, 3.4%*	**32.0, 5.2%**	*20.0, 19.3%*	*27.4, 11.0%*	**38.0, 30.2%**	*40.0, 10.9%*	**42.0, 7.3%**

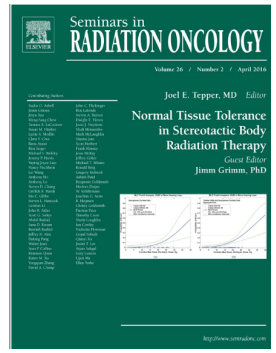
Next

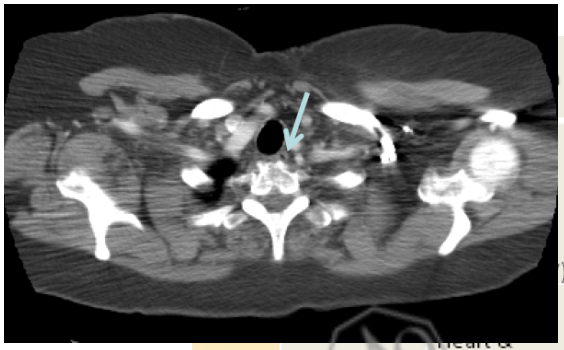
ELSEVIER

Seminars in RADIATION ONCOLOGY

Esophageal Dose Tolerance in Patients Treated With Stereotactic Body Radiation Therapy

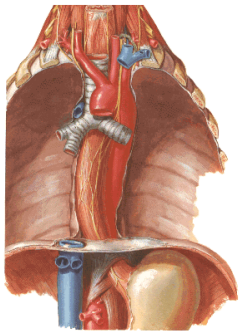
Joost J. Nuyttens, MD, PhD,* Vitali Moiseenko, PhD,† Mark McLaughlin, MD,‡ Sheena Jain, MD,§ Scott Herbert, MD,‖ and Jimm Grimm, PhD§

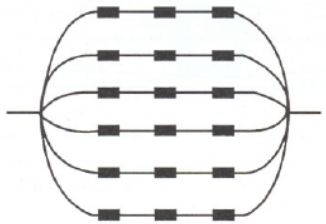




RTOG® RADIATION THERAPY ONCOLOGY GROUP

		Both lungs should be contoured using pulmonary windows. The right and left lungs can be contoured separately, but they should be considered as one structure for lung dosimetry. All inflated and collapsed, fibrotic and emphysematic lungs should be contoured, small vessels extending beyond the hilar regions should be induded; however, pre GTV, hilars and trachea/main bronchus should not be included in this structure.
Heart	Heart & Pericardium	The heart will be contoured along with the pericardial sac. The superior aspect (or base) will begin at the level of the inferior aspect of the pulmonary artery passing the midline and extend inferiorly to the apex of the heart.
Esophagus	Esophagus	The esophagus should be contoured from the beginning at the level just below the cricoid to its entrance to the stomach at GE junction. The esophagus will be contoured using mediastinal window/level on CT to correspond to the mucosal, submucosa, and all muscular layers out to the fatty adventitia.
Spinalcord	Spinal Canal	The spinal cord will be contoured based on the bony limits of the spinal canal. The spinal cord should be contoured starting at the level just below cricoid (base of skull for apex tumors) and continuing on every CT slice to the bottom of L2. Neuroformanines should not be included.
Brachialplex	Brachial Plexus	This is only required for patients with tumors of upper lobes. Only the ipsilateral brachialplex is required. This will include the spinal nerves exiting the neuroforamine from top of C5 to top of T2. In contrast to prior RTOG lung studies of contouring the major trunks of the brachial plexus with inclusion of subclavian and axillary vessels, this trial requests contouring the nerves according to the CT anatomy on every other CT slice. The structure should extend at least 3 cm above the PTV.





A serial-parallel string of subunits

Table 3 Overview of the Grade and Type of Toxicity Reported in the Literature

Studies	Number of Patients	Total Dose (Gy)	Number of Fractions	Grade of Toxicity					Type of ≥3 Grade Toxicity				
				Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Fistula	Ulcer	Stenosis	Bleeding	Esophagitis
Abelson et al[25]	31	16-50	1-5			1		2	1	1			
Cox et al[26]	20	24	1		13	6	4	1	4	4	4		
Onimaru et al[27]	45	48-60	6-8					1		1			
Le et al[1]	33	15-25	1					1	1				
Gomez et al[12]	114	18-24	1		7	1	1			1			1
Wu et al[24]	125	36-60	3-5		13*	2			1			1	
Modh et al[28]	125	45	4		14	2			1			1	
Stephans et al[23]	52	37.5-60	3-10			2			2				
Wulf et al[14]	27	28-30	3-4			1				1			
Park et al †[13]	111	50	4-5		4	1							1
Park et al ‡[13]	140	54	3		2								
Baumann et al[29]	138	30-48	2-4		5*								
Bral et al[11]	17	45	4		2*								
Li et al[30]	82	70	7		4								
Chang et al[31]	82	50	4		3								
Shen et al[32]	28	30-45	10-12	2	3								
Milano et al[33]	53	30-63	15-20	3	2								
Xia et al[34]	43	50	5	5	1								
Unger et al[44]	20	30-40	5		1								
Haasbeek et al[36]	63	60	8	1									
Andratschke et al[37]	92	24-45	3-5	2									
Nishimura et al[38]	133	40-50	5		0								
Takayama et al[39]	37	48	12		0								
Total	1795					16	5	5	10	8	4	2	2

*Grades 1 and 2 toxicity.
†Central lesions.
‡Peripheral lesions.

Table 4 Overview of the Reported Dose and Toxicity to the Esophagus in Individual Patients

Studies	Number of Fractions	D_{max} (Gy)		$D_{1\ cc}$		$D_{5\ cc}$		Grade of Toxicity	Type of Toxicity
		Total Dose (Gy)	BED_3 (Gy)	Total Dose (Gy)	BED_3 (Gy)	Total Dose (Gy)	BED_3 (Gy)		
Modh et al[28]	5	18	40					3	Bleeding
Wulf et al[14]	4	28	93					3	Ulcer
Abelson et al[25]	1	18.5	133			11.4	55	5	Ulcer
Stephans et al[23]	10	51.5	140	48.1	125	37.3	84	3	Fistula
Stephans et al[23]	10	52	142	50	133	21.5	37	3	Fistula
Onimaru et al[27]	8	50.5	157	42.5	118	29.9	67	5	Ulcer
Abelson et al[25]	1	21	168			16.5	107	5	Fistula
Modh et al[28]	5	46	187					3	Fistula
Gomez et al[12]	1			22.9	198			3	Esophagitis
Gomez et al[12]	1			24.3	221			4	Ulcer
Median BED			141		133		67		

Dmax =141 Gy
D1cc =133 Gy
D5cc =67 Gy

Dmax di 39 Gy
D1cc di 38 Gy
D5cc di 25 Gy
equivalente dose assoluta in 5 frazioni,

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Seminars in RADIATION ONCOLOGY

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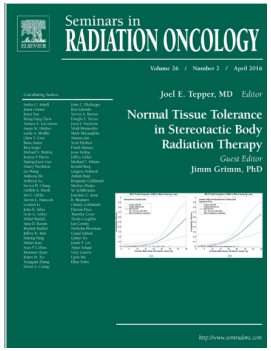


56 T polmone centrali

CyberKnife at the Erasmus MC Cancer Institute

July 2006 - September 2009.

6 Pazienti: 9 Gy x 5 frazioni

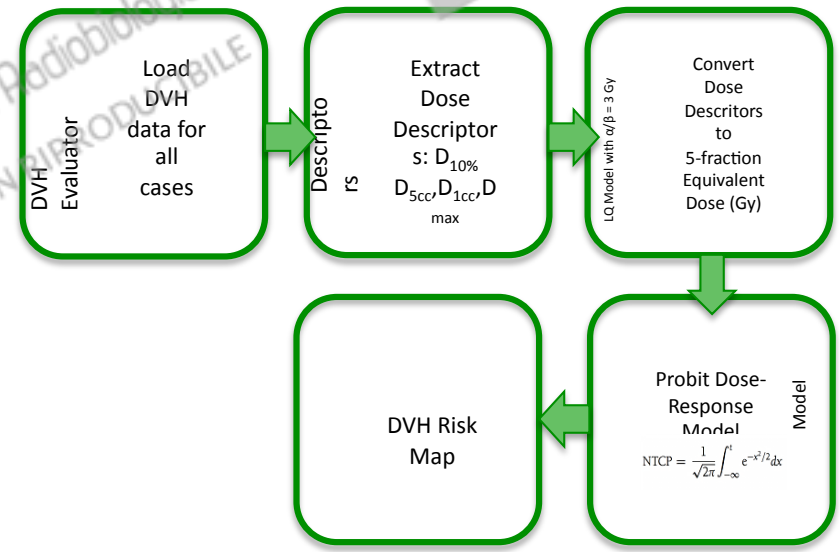
15 pazienti: 10 Gy x 5 frazioni

21 pazienti: 12 Gy x 5 frazioni

14 pazienti: 8 Gy x 6 frazioni (vicini all'esofago)

1 paziente: 8 Gy x 7 frazioni

1 paziente: 20 Gy x 3 frazioni



α/β =3 → analisi DVH → riferita a 5 frazioni

ENDPOINT=

TOSSICITA' ESOFAGEA CTCAE v3

Timmerman
1 fr Dmax 19Gy; V14.5<5cc

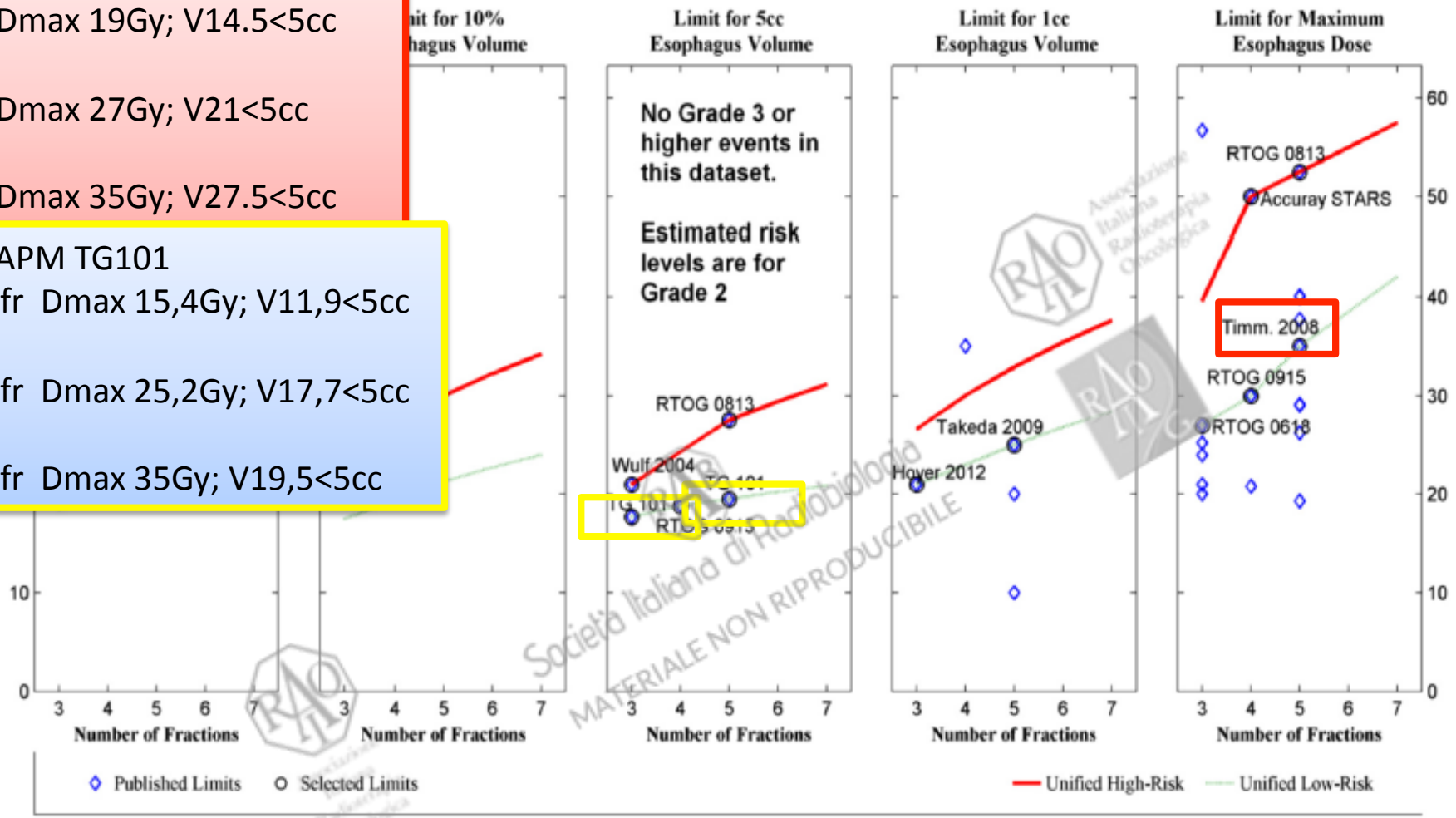
3 fr Dmax 27Gy; V21<5cc

5 fr Dmax 35Gy; V27.5<5cc

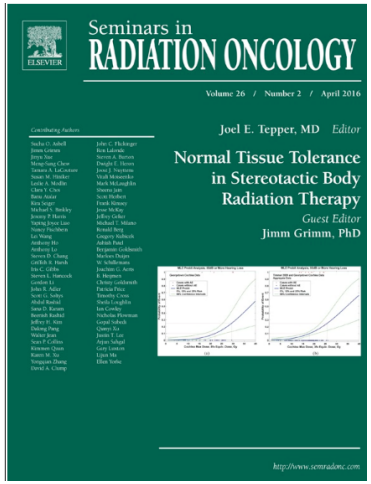
AAPM TG101
1 fr Dmax 15,4Gy; V11,9<5cc

3 fr Dmax 25,2Gy; V17,7<5cc

5 fr Dmax 35Gy; V19,5<5cc



	Low Risk Limits					High Risk Limits				
	EUD Limit (Gy)	D10% Limit (Gy)	D5cc Limit (Gy)	D1cc Limit (Gy)	Dmax Limit (Gy)	EUD Limit (Gy)	D10% Limit (Gy)	D5cc Limit (Gy)	D1cc Limit (Gy)	Dmax Limit (Gy)
3 fx	*18.5, 5.0%*	*17.5, 5.0%*	**17.7, 19.7%**	**21.0, 6.9%**	**27.0, 6.3%**	*23.8, 50.0%*	*24.3, 50.0%*	**21.0, 40.6%**	*26.6, 50.0%*	*39.6, >50%*
4 fx	*20.8, 5.0%*	*19.6, 5.0%*	**18.8, 15.5%**	*23.0, 5.2%*	**30.0, 5.3%**	*26.9, 50.0%*	*27.4, 50.0%*	*24.3, 45.0%*	*30.0, 50.0%*	**50.0, >50%**
5 fx	*22.6, 5.0%*	*21.3, 5.0%*	**19.5, 12.5%**	**25.0, 5.0%**	**35.0, 9.8%**	*29.4, 50.0%*	*30.0, 50.0%*	**27.5, >50%**	*32.9, 50.0%*	**52.5, >50%**
6 fx	*24.2, 5.0%*	*22.7, 5.0%*	*20.2, 10.9%*	*26.8, 5.0%*	*38.5, 11.9%*	*31.6, 50.0%*	*32.2, 50.0%*	*29.4, 50.0%*	*35.4, 50.0%*	*55.0, >50%*
7 fx	*25.6, 5.0%*	*24.0, 5.0%*	*20.9, 10.0%*	*28.4, 5.0%*	*42.0, 15.0%*	*33.5, 50.0%*	*34.2, 50.0%*	*31.2, 50.0%*	*37.6, 50.0%*	*57.5, >50%*



DISTRETTO TORACE – ADDOME

esofago

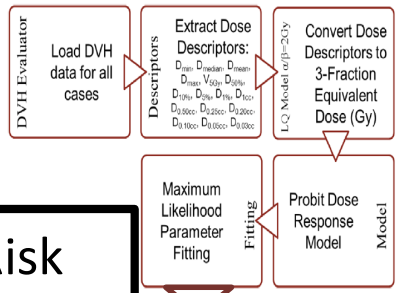
duodeno

intestino

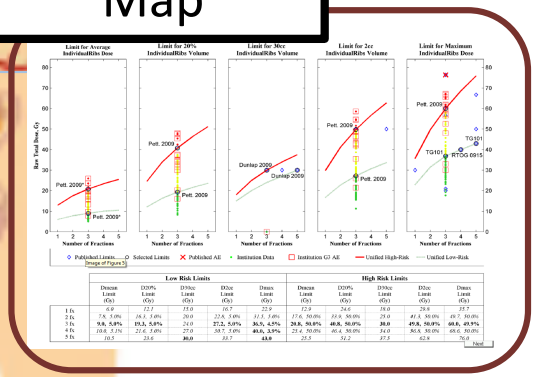
Coste – gabbia toracica

Trachea - bronchi

Grossi vasi



DVH Risk Map



Thanks!

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Coordinatore	Giovanna Mantello	
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Segretario - Consigliere	Elisa D'angelo	
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SOD Radioterapia

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Francesca Cucciarelli
Lisa Vicenzi
Mariangela La Macchia
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