IMRT Tekniğinde Farklı Enerji Kullanımına Bağlı Klinik Avantajların Biyolojik Modellerle (TCP,NTCP) İncelenmesi

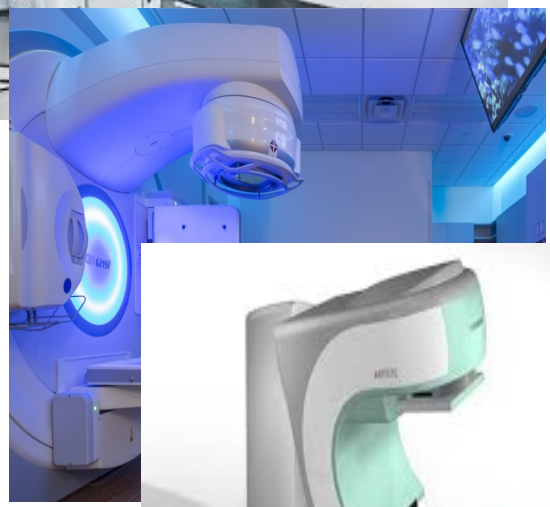
N. İlker ÇATAN [1], Mecit CANBOLAT [1],

(1) ONCOTECH Medikal Sistemler

XV. ULUSAL MEDİKAL FİZİK KONGRESİ

Radyoterapi

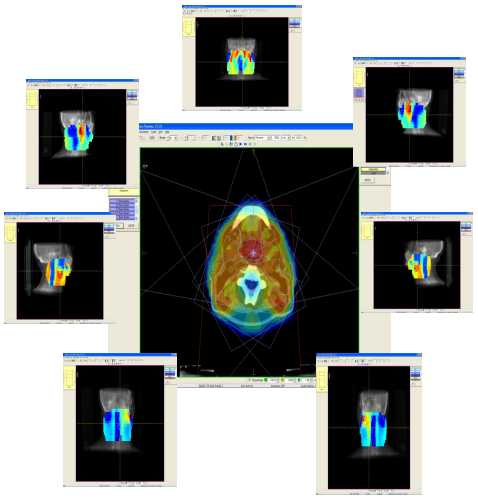
Tedavi Cihazları



Planlama Sistemleri

Tedavi Teknikleri

3D-CRT
Step&ShootIMRT
DynamicIMRT
IMAT
VMAT
SRS/SBRT



ONCOTECH
MEDİKAL SİSTEMLER | MEDICAL SYSTEMS

Klinik Seçimi

Tedavi Cihazları

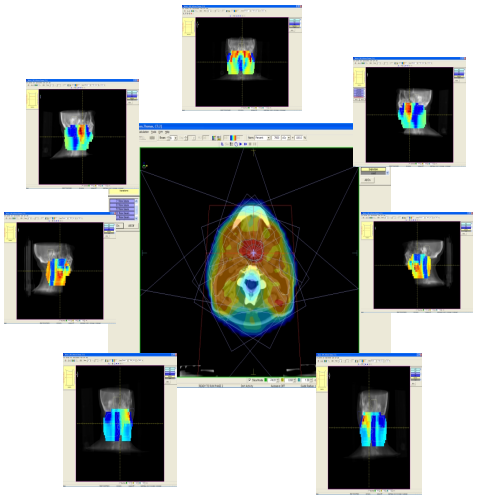
Modalite, Enerji, MLC

Planlama Sistemleri

Algoritmalar
Optimizasyon çeşitleri
Segmentasyon Metodları
Fiziksel ve/veya Biyolojik CF

Tedavi Teknikleri

3D-CRT
Step&ShootIMRT
DynamicIMRT
IMAT
VMAT
SRS/SBRT

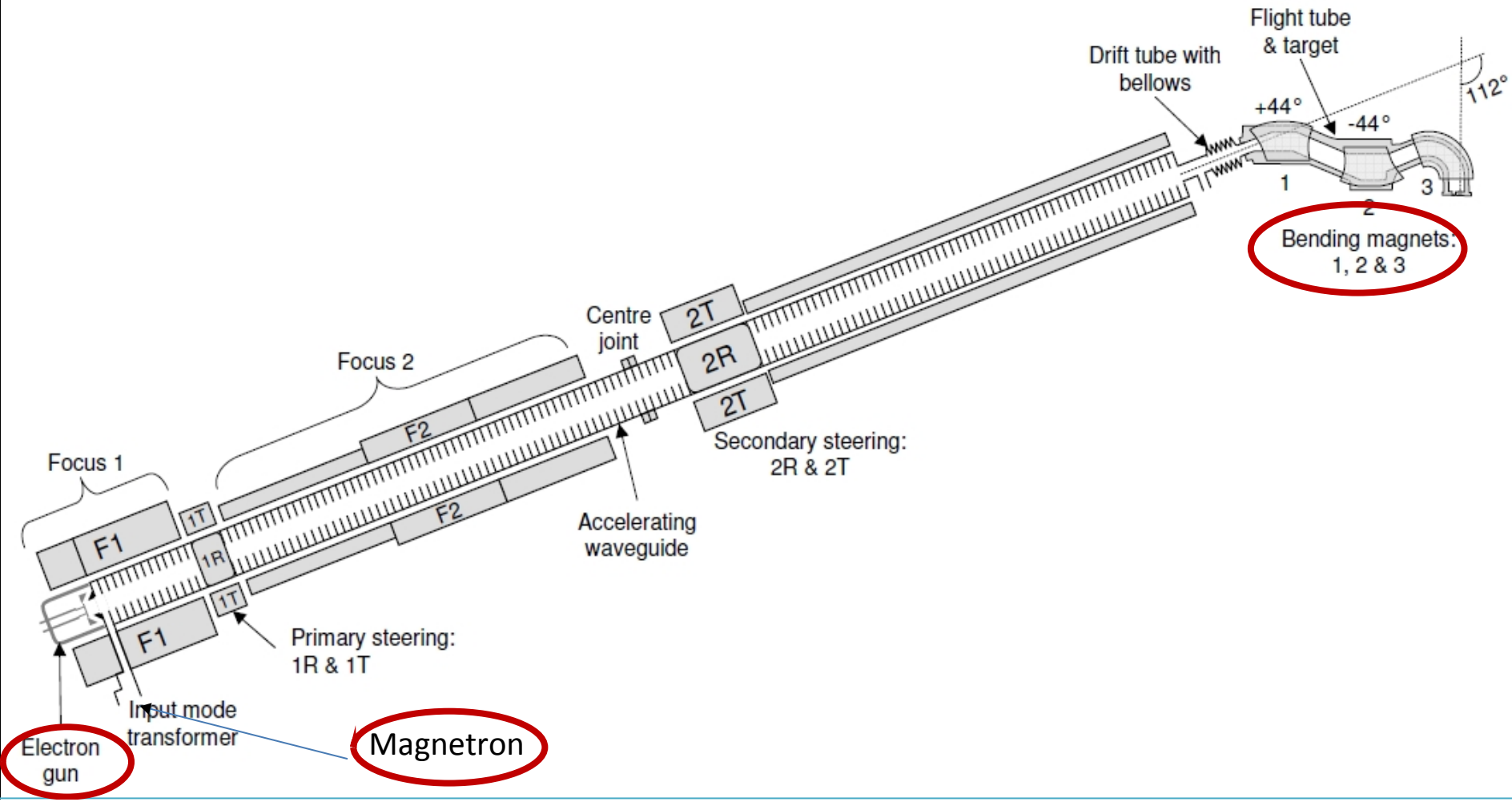


AMAÇ

Lineer Hızlandırıcılarda IMRT Tekniğinde Farklı Enerji Oluşturulması ve Hasta Tedavilerinde Kullanılabilirliği

Materyal-Metot

Foton Enerji Kalibrasyonu



Foton Enerji Kalibrasyonu ve Testleri

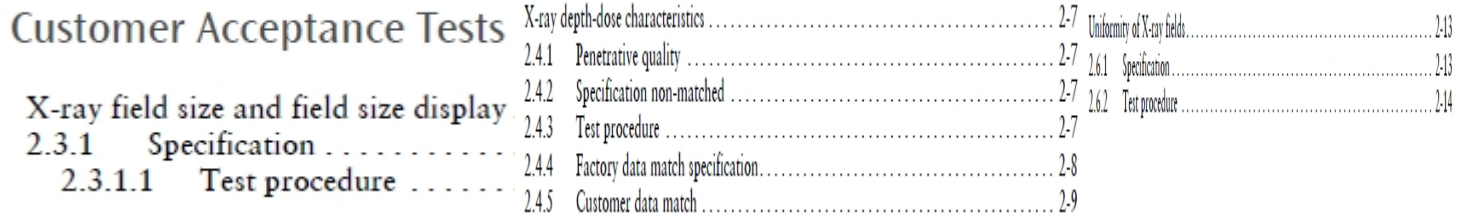
Enerji Kalibrasyonu

Enerji kabul testleri

BJR S-25 referans alındı.

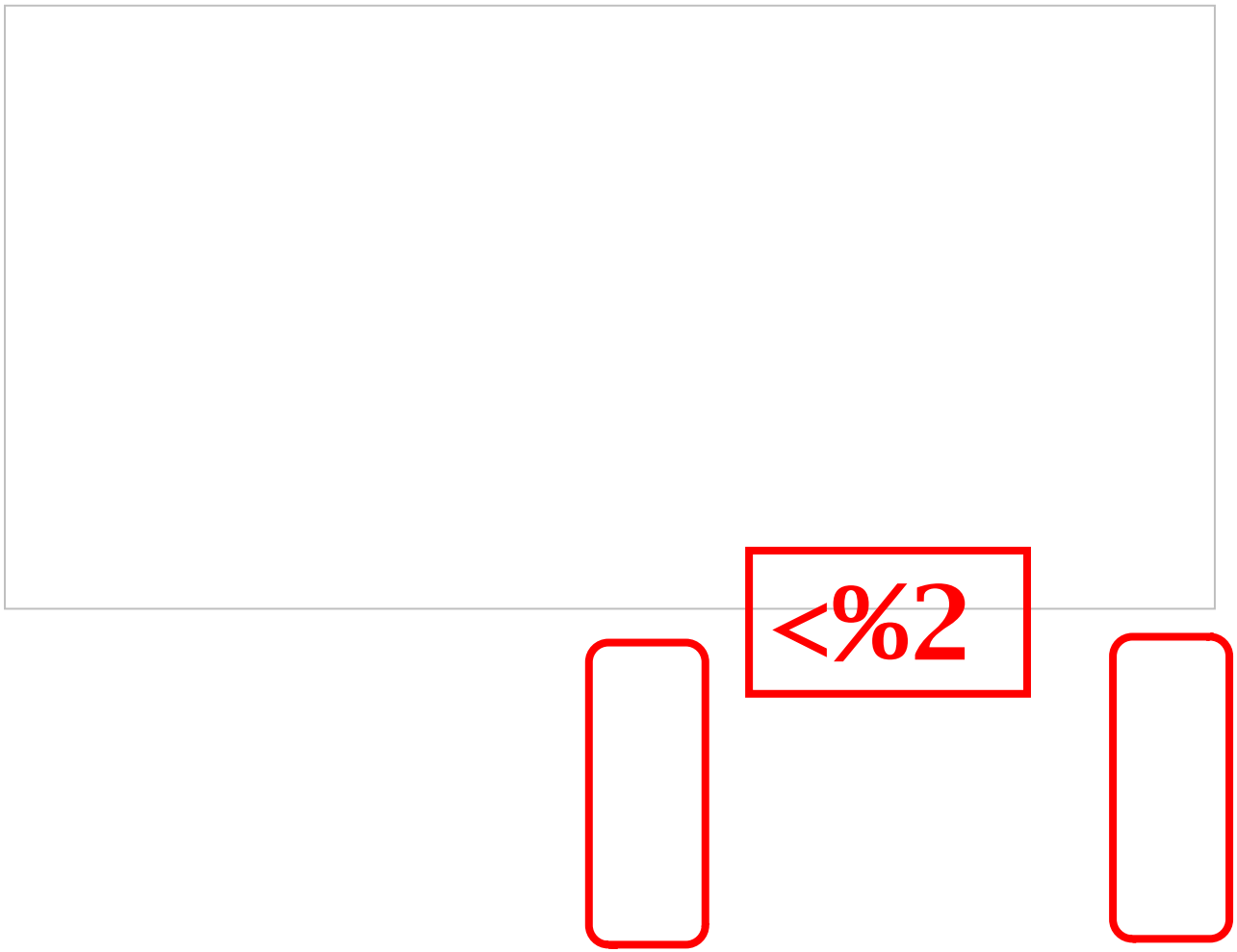
Müsteri Kabul Testleri (CAT) uygulandı.

- D20/D10,D20,D10,QI,Dmaks,Flatness/Symmetry



Foton Enerji Kalibrasyonu ve Testleri

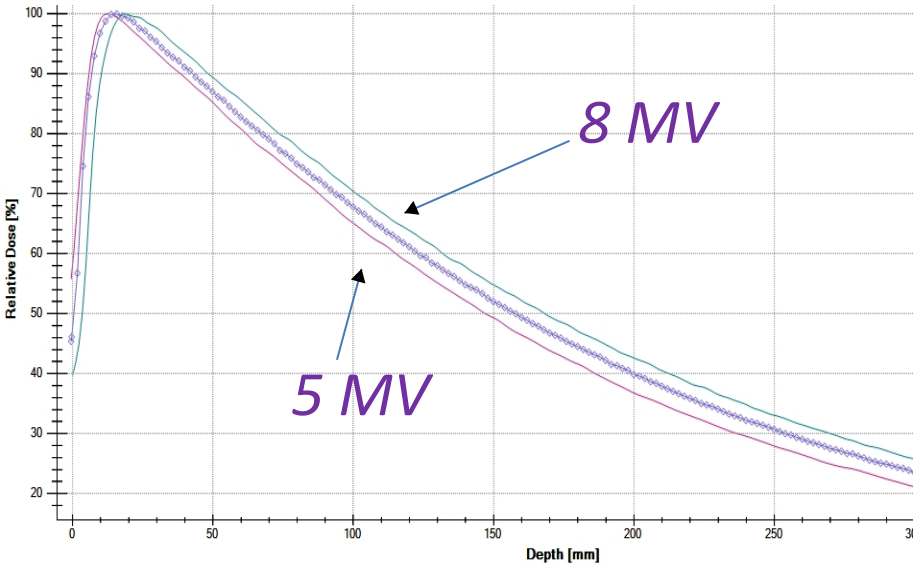
Enerji Kalibrasyonu
5MV / 6MV / 8MV



TPS

Beam Data Collection

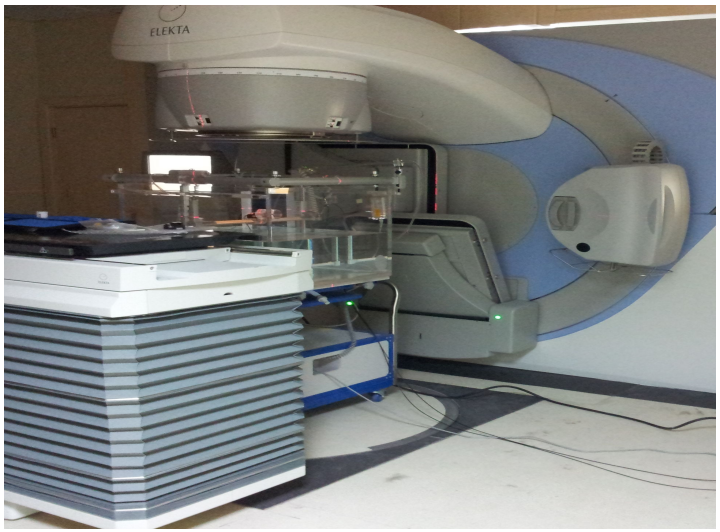
TG-106 önerileri referans alındı.
XiO CMS planlama sistemi (TPS) için
IBA Dozimetre Sistemleri ile toplandı.



TPS QA; TRS-430

TABLE 17. SAMPLE CRITERIA OF ACCEPTABILITY FOR EXTERNAL DOSE CALCULATIONS
(Adapted, with permission, from Ref. [18].)

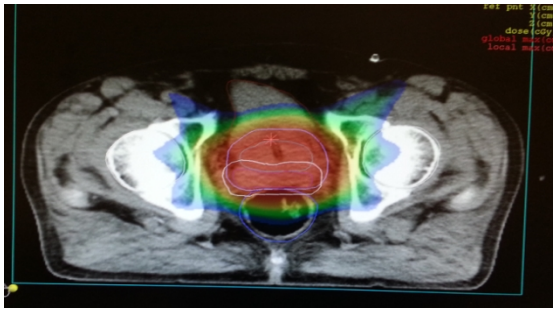
Situation	Absolute dose at normalization point (%)[a]	Central ray (%)	Inner beam (%)	Penumbra (mm)	Outer beam (%)	Buildup region (%)
Homogeneous phantoms						
Square fields	0.5	1	1.5	2	2	20
Rectangular fields	0.5	1.5	2	2	2	20
Asymmetric fields	1	2	3	2	3	20
Blocked fields	1	2	3	2	5	50
MLC shaped fields	1	2	3	3	5	20
Wedged fields	2	2	5	3	5	50
External surface variations	0.5	1	3	2	5	20
SSD variations	1	1	1.5	2	2	40
Inhomogeneous phantoms[b]						
Slab inhomogeneities	3	3	5	5	5	—
3-D inhomogeneities	5	5	7	7	7	—

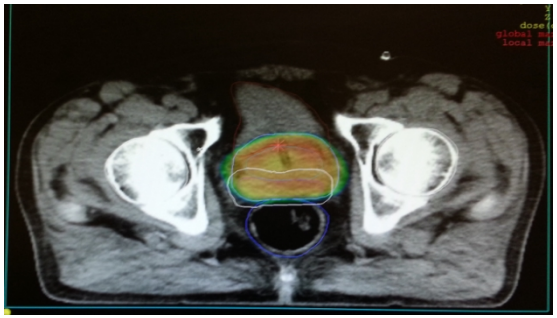


İyon odası: cc13 ve cc04

Tedavi Planlama

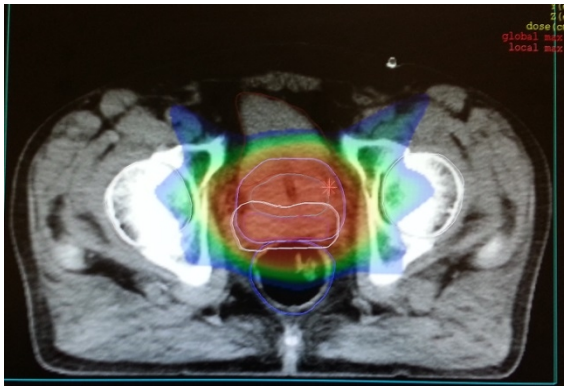
5 MV





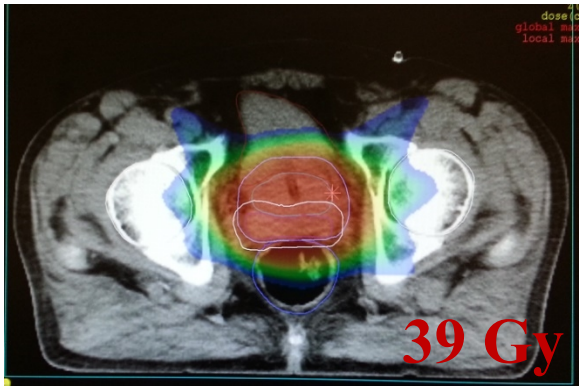
RTOG 0415
Rektum:V50, V60, V70, V75
Mesane: V65, V70, V75
Femur: V45, V50
Perifer doz hacmi (cc): D50

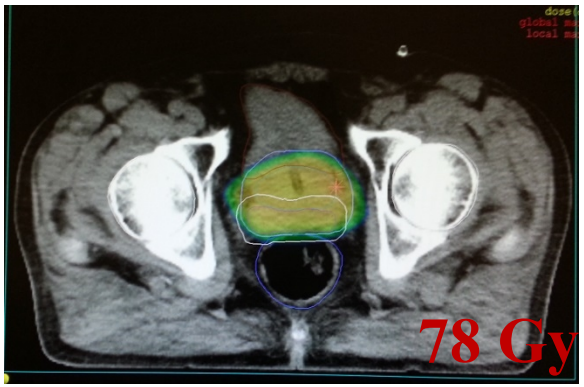
6 MV



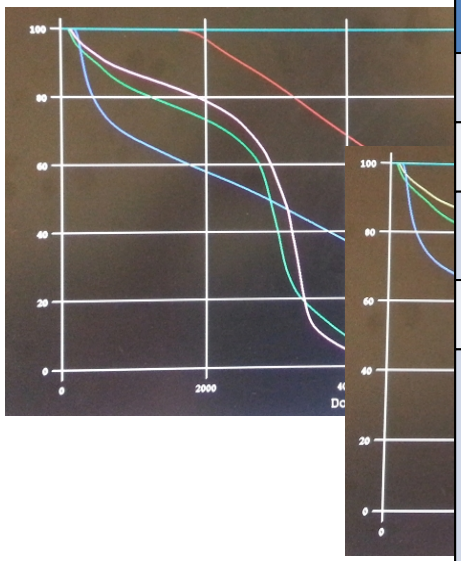
Total Dose: 78Gy

8 MV





Fiziksel İnceleme



CI: Referans Doz Hacmi/Hede

HI: (D2-D98)/D50

Amaç: PTV' nin %

Enerji	5 MV	6 MV	8 MV
CI	0.98	0.99	1.0
HI	0.04	0.06	0.06
Sıcak Nokta(cGy)	8127	8095	8073
Perifer Doz Hacmi(cc)	969	949	908
Rektum:			
V50	%28.0	%28.6	%27.4
V60	%20.6	%21.3	%19.3
V70	%12.2	%13.3	%10.6
V75	%6.1	%7.2	%5.0
Mesane:			
V65	%35.9	%32.9	%32.6
V70	%28.2	%25.5	%25.2
V75	%18.8	%15.8	%16.0
Femur:			
V45	%2.4	%5.1	%3.8
V50	%0.4	%1.7	%1.0
# segment	106	93	93
MU ort	725	642	601

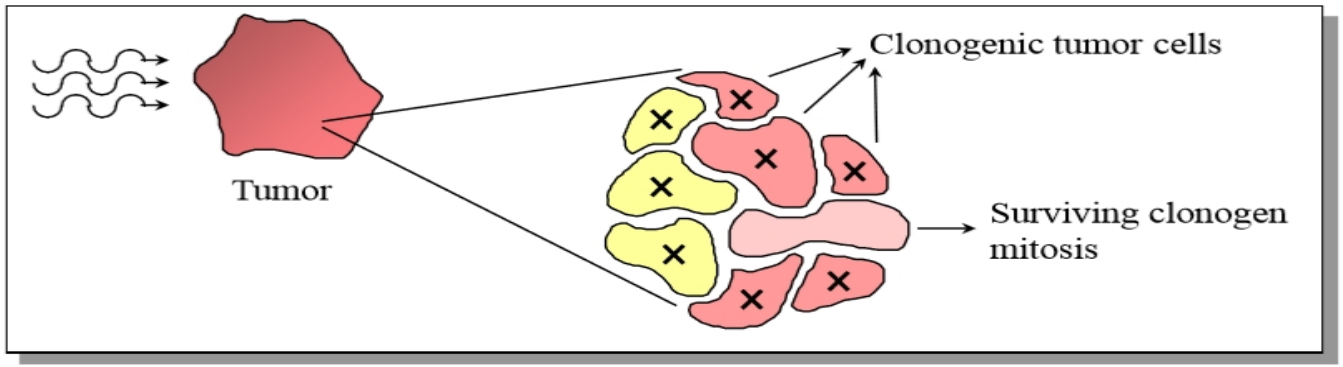
TCP

Fowler, J.F. (1989). The linear-quadratic formula and progress in fractionated radiation therapy. *The British Journal of Radiology* 62(740): 679-694.

The number of surviving cells is modified by the time factor to incorporate clonogen proliferation:

$$N_s = N_0 \cdot e^{\left[-n\left(\alpha d+\beta d^2\right)+\lambda T'\right]}$$

Radiation cell kill — Clonogen proliferation



Ignoring the β term, the equation for TCP becomes:

$$TCP = \sum_{j=1}^{K} f_{\alpha_j} \cdot e^{-\sum_{i=1}^{n} N_{0,i} \cdot e^{\left[-\left(\alpha_j \cdot D_i\right)+\frac{\ln 2}{T_{eff}}\left(T-T_k\right)\right]}}$$

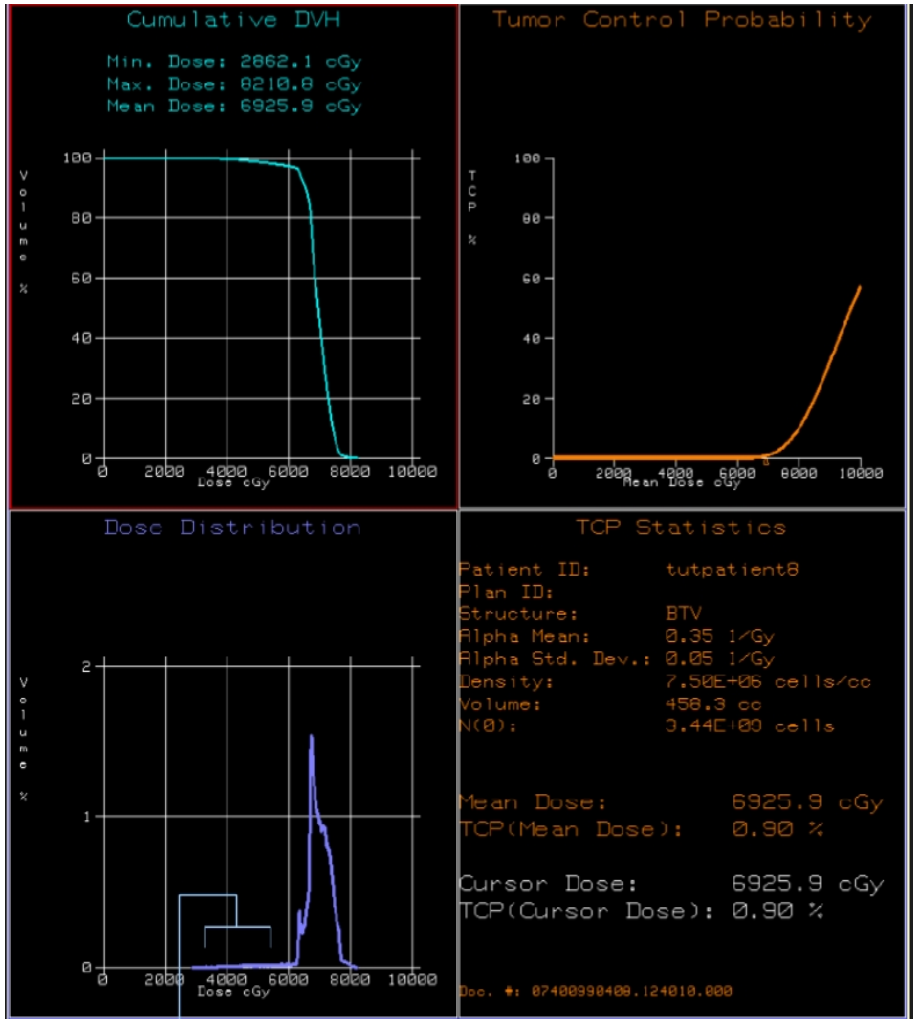
Time factor parameters:

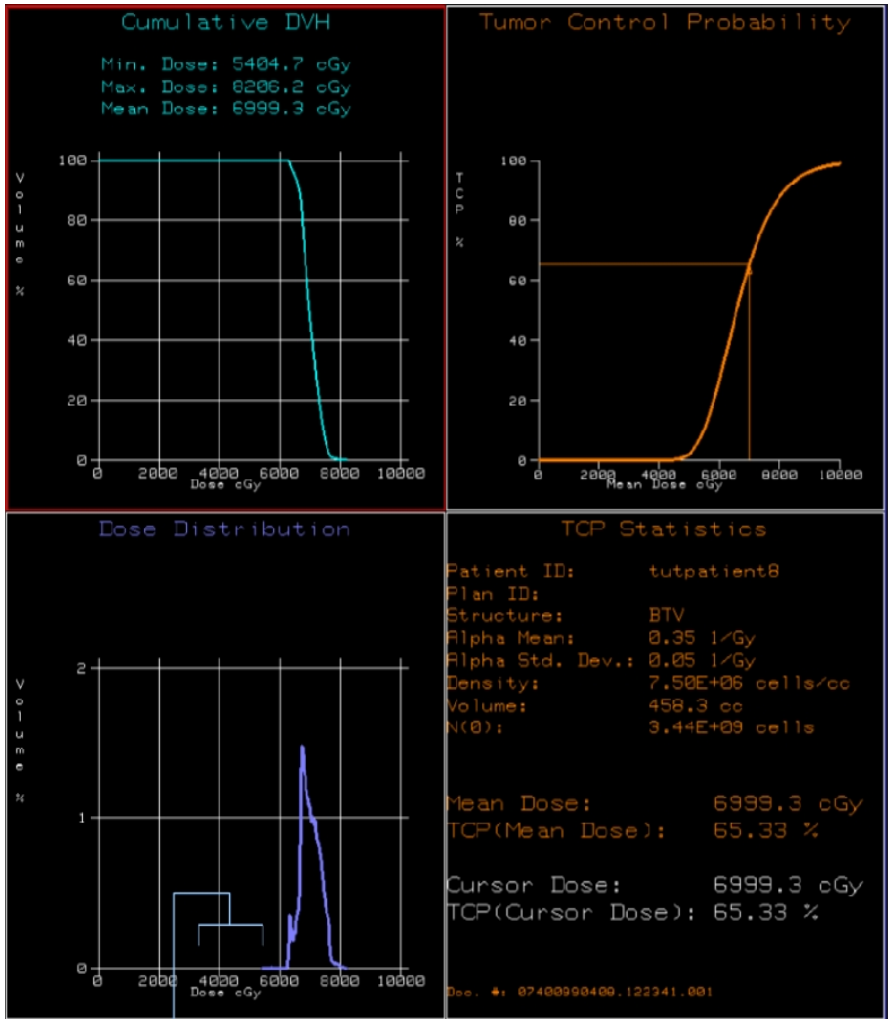
$$\lambda = \frac{\ln 2}{T_{eff}}$$ → Effective doubling time of tumor clonogen

$$T' = T - T_k$$ → "Kick-off" time

T → Total time to deliver total dose, all fractions

TCP


Cumulative DVH
Min. Dose: 2862.1 cGy
Max. Dose: 8210.8 cGy
Mean Dose: 6925.9 cGy
Volume %
Dose cGy
Tumor Control Probability
TCP %
Mean Dose cGy
Dose Distribution
Volume %
Dose cGy
TCP Statistics
Patient ID: tutpatient8
Plan ID:
Structure: BTV
Alpha Mean: 0.35 1/Gy
Alpha Std. Dev.: 0.05 1/Gy
Density: 7.50E+06 cells/cc
Volume: 458.3 cc
N(0): 3.44E+09 cells
Mean Dose: 6925.9 cGy
TCP(Mean Dose): 0.90 %
Cursor Dose: 6925.9 cGy
TCP(Cursor Dose): 0.90 %
Doc. #: 07400990400.124010.000

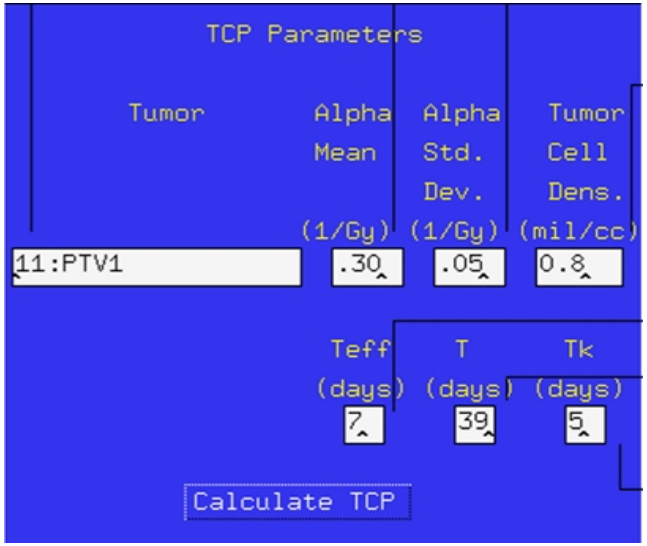

Cumulative DVH
Min. Dose: 5404.7 cGy
Max. Dose: 8206.2 cGy
Mean Dose: 6999.3 cGy
Volume %
Dose cGy
Tumor Control Probability
TCP %
Mean Dose cGy
Dose Distribution
Volume %
Dose cGy
TCP Statistics
Patient ID: tutpatient8
Plan ID:
Structure: BTV
Alpha Mean: 0.35 1/Gy
Alpha Std. Dev.: 0.05 1/Gy
Density: 7.50E+06 cells/cc
Volume: 458.3 cc
N(0): 3.44E+09 cells
Mean Dose: 6999.3 cGy
TCP(Mean Dose): 65.33 %
Cursor Dose: 6999.3 cGy
TCP(Cursor Dose): 65.33 %
Doc. #: 07400990400.122341.001

TCP

	$TCP_{prostat}$	$TCP_{Baş\text{-}Boyun}$
T_{eff}	27	45
T	39	33
Tk	34	28
α(mean)	0.3 Gy^{-1}	0.3 Gy^{-1}
ρ	$6x10^5$	$5x10^6$

Gao *et.al.2010*

Tepper *et.al.1992,* Wyatt *et.al.2003*



	5 MV	6 MV	8 MV
$TCP_{prostat}$	%87.1	%87.2	%87.5
$TCP_{Baş\text{-}Boyun}$	%75.3	%75.1	%75.0

NTCP

Equations 16-19: Lyman's Model of the NTCP for Uniform Irradiation of a Fractional Organ Volume

$$NTCP = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{\left(\frac{-t^2}{2}\right)} dt$$

$$v = \frac{V}{V_{ref}}$$

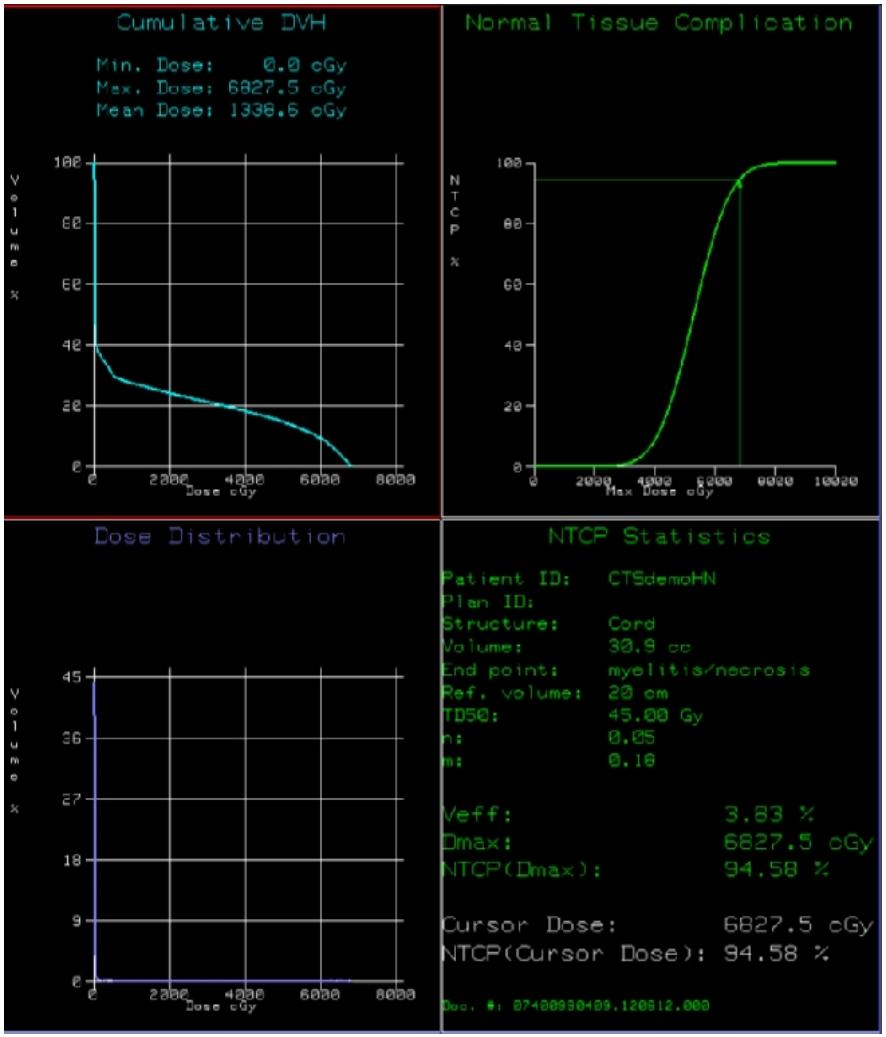
$$t = \frac{D - TD_{50}(v)}{m * TD_{50}(v)}$$

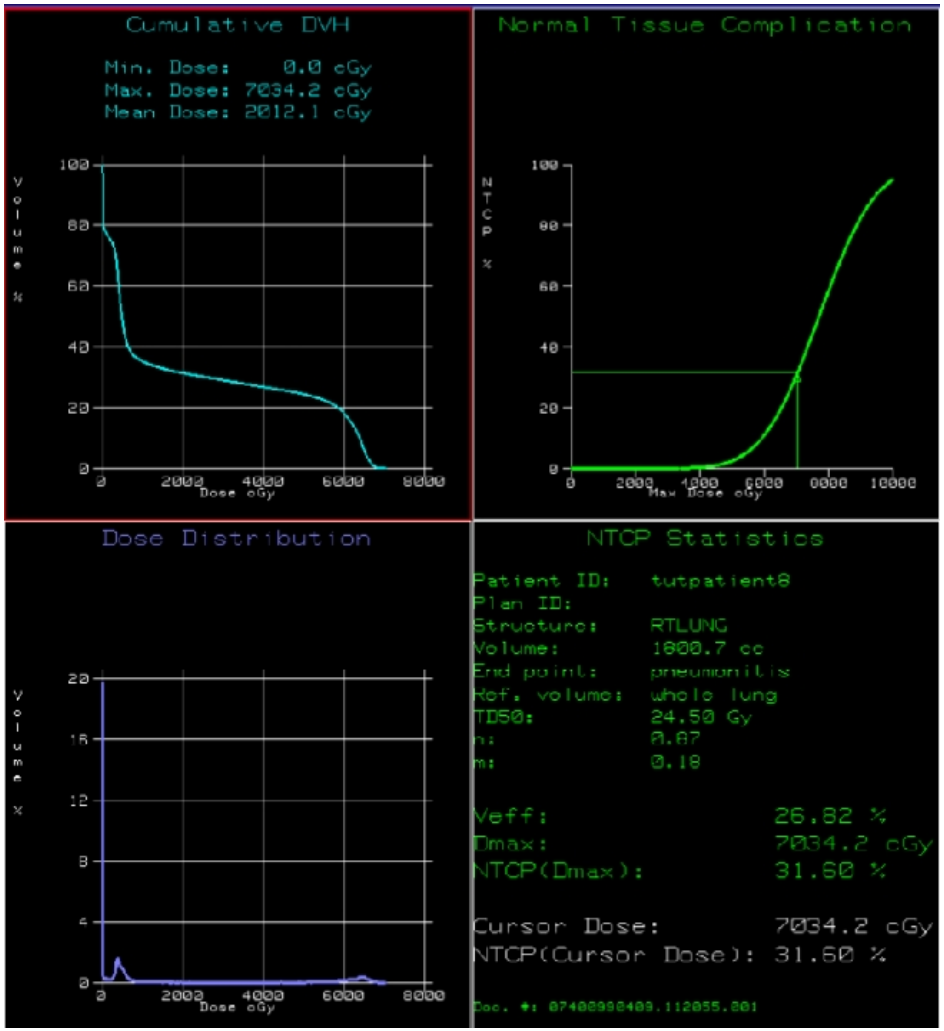
$$TD(v) = TD(1) * v^{-n}$$

where

V	Volume of organ irradiation to a uniform dose D
V_{ref}	Fraction of reference volume irradiated
$TD_{50}(1)$	Dose to reference volume leading to 50% complication probability
$TD_{50}(v)$	Dose to partial volume leading to 50% complication probability
n	Parameter describing the volume dependence of the organ
m	Parameter describing the slope of NTCP vs. dose

NTCP


Cumulative DVH
Min. Dose: 0.0 cGy
Max. Dose: 6827.5 cGy
Mean Dose: 1338.6 cGy
Volume %
Dose cGy
Normal Tissue Complication
NTCP %
Max Dose cGy
Dose Distribution
Volume %
Dose cGy
NTCP Statistics
Patient ID: CTSdemoHN
Plan ID:
Structure: Cord
Volume: 30.9 cc
End point: myelitis/necrosis
Ref. volume: 20 cm
TD50: 45.00 Gy
n: 0.05
m: 0.18
Veff: 3.83 %
Dmax: 6827.5 cGy
NTCP(Dmax): 94.58 %
Cursor Dose: 6827.5 cGy
NTCP(Cursor Dose): 94.58 %
Doc. #: 07408030409.120512.000


Cumulative DVH
Min. Dose: 0.0 cGy
Max. Dose: 7034.2 cGy
Mean Dose: 2012.1 cGy
Volume %
Dose cGy
Normal Tissue Complication
NTCP %
Max Dose cGy
Dose Distribution
Volume %
Dose cGy
NTCP Statistics
Patient ID: tutpatient8
Plan ID:
Structure: RTLUNG
Volume: 1800.7 cc
End point: pneumonitis
Ref. volume: whole lung
TD50: 24.50 Gy
n: 0.87
m: 0.18
Veff: 26.82 %
Dmax: 7034.2 cGy
NTCP(Dmax): 31.60 %
Cursor Dose: 7034.2 cGy
NTCP(Cursor Dose): 31.60 %
Doc. #: 07408030409.112055.001

NTCP

	n	m	TD50	EndPoint
Mesane	0.5	0.11	80	semptomatik mesane kontraktürü ve hacim kaybı
Rektum	0.12	0.15	80	şiddetli proktit, nekroz ve darlık
Parotis	0.7	0.18	46	Ağız kuruluğu
Spinal Cord	0.05	0.175	66.5	Miyelit

Lyman Model

NTCP		5 MV	6 MV	8 MV
Mesane	Veff Dmax	%48.3 %0.4	%46.3 %0.2	%46.2 %0.2
Rektum	Veff Dmax	%10.3 %4.9	%11.6 %5.3	%9.1 %4.3
Parotis	Veff Dmax	%29.7 %0.8	%32.6 %1.2	%34.7 %1.7
Spinal Cord	Veff	%9.2	%15.3	%17.1

Plan-QA

SONUÇ

- Lineer hızlandırıcılarda mekanik aksam değiştirilmeden belirli enerji aralıklarında tüm enerjiler oluşturulabilir
- Farklı enerjilerin tedavideki avantajlarını Biyolojik modeller daha net göstermektedir.
- Nitelik artırımı ekstra maliyet getirmemektedir.

Teşekkürler

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(1) ONCOTECH Medikal Sistemler

XV. ULUSAL MEDİKAL FİZİK KONGRESİ