

APPLICAZIONE IN AMBITO GINECOLOGICO DELLA BRACHITERAPIA

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S.C. Fisica
Sanitaria**



Fondazione IRCCS
San Gerardo dei Tintori

Sistema Socio Sanitario

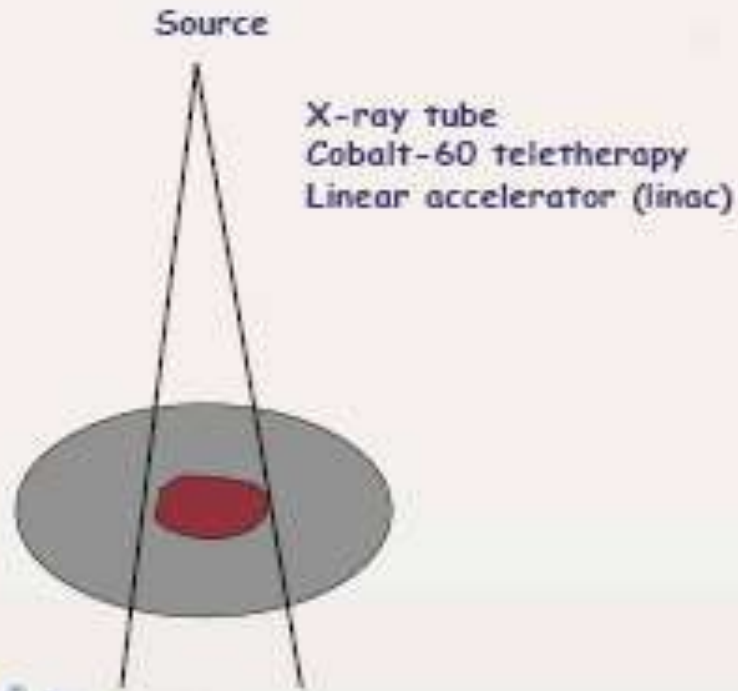


Regione
Lombardia

LA BRACHITERAPIA

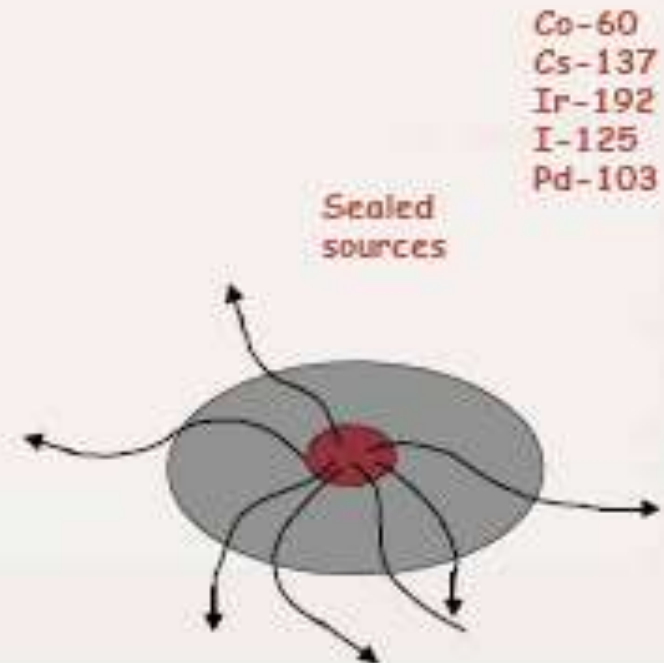
External beam radiotherapy

(external source of radiation)



Brachytherapy

(internal source of radiation)



CHE COSA E' LA BRACHITERAPIA

IN BRACHITERAPIA LE SORGENTI SONO
NEI PRESSI O ALL'INTERNO DEL VOLUME
BERSAGLIO

LO SCOPO E' AUMENTARE IL RAPPORTO
TRA LA DOSE AL VOLUME BERSAGLIO E
QUELLA AGLI ORGANI A RISCHIO
CIRCOSTANTI

LA BRACHITERAPIA

VANTAGGI

- ALTA DOSE LOCALIZZATA AL TARGET
- RIPIDA CADUTA DI DOSE AL DI FUORI DEL VOLUME BERSAGLIO
- MIGLIORE CONFORMAZIONE DI DOSE

SVANTAGGI

- VOLUMI PICCOLI
- VOLUMI BEN LOCALIZZATI
- TECNICA COMPLESSA E LABORIOSA

CARATTERISTICHE DELLA BRACHITERAPIA

SORGENTE IMPIANTATA

- TEMPORANEAMENTE
- PERMANENTEMENTE

CARATTERISTICHE DELLA BRACHITERAPIA

IMPIANTO
TEMPORANEO

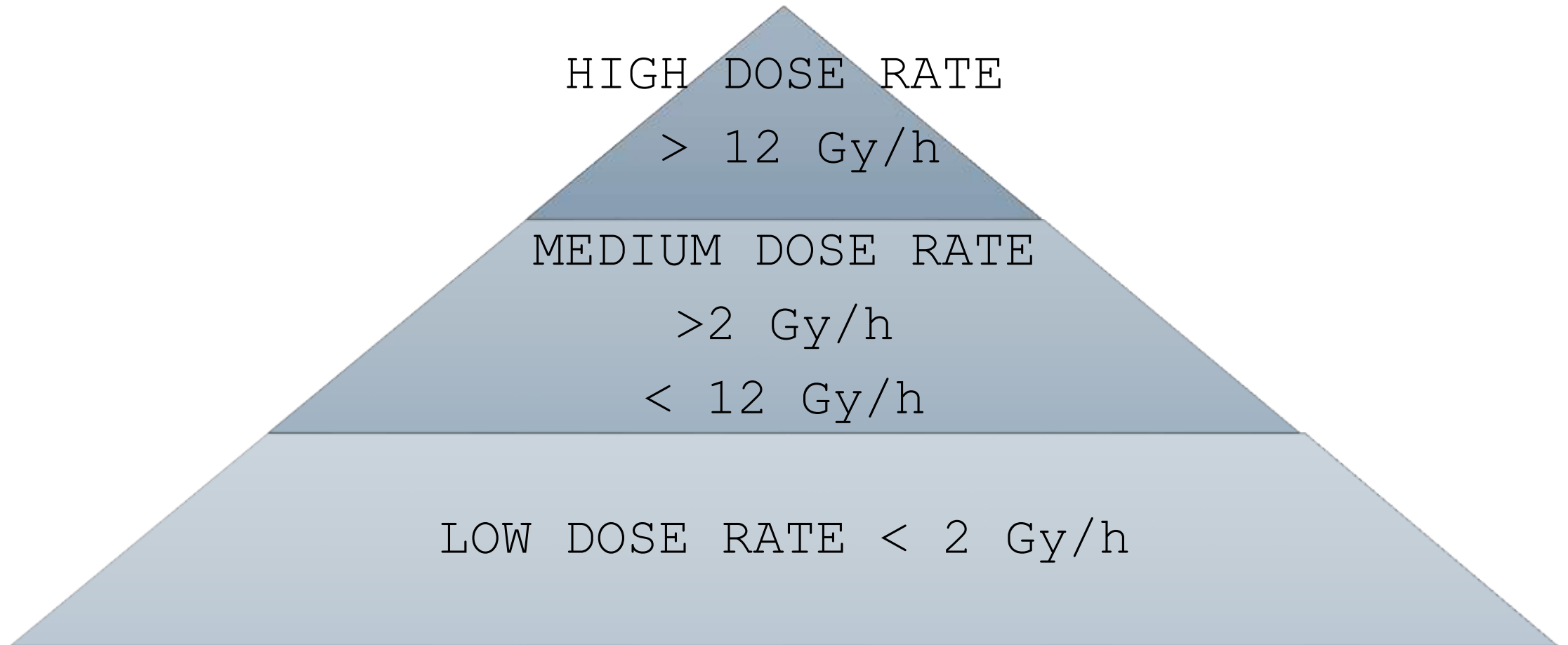
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graph TD; A[IMPIANTO TEMPORANEO] --> B[LOW DOSE RATE]; A --> C[MEDIUM DOSE RATE]; A --> D[HIGH DOSE RATE];
```

LOW DOSE
RATE

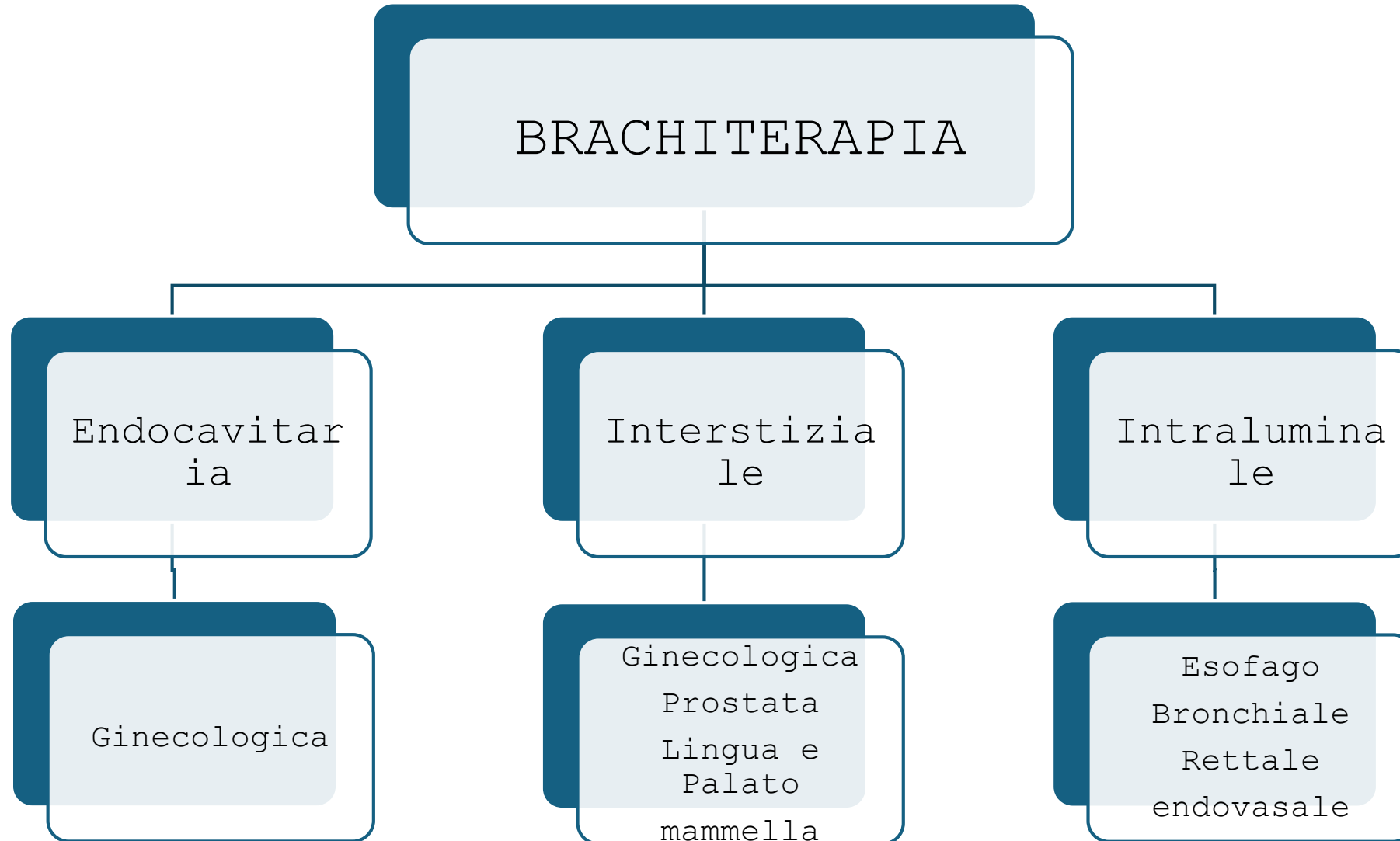
MEDIUM
DOSE RATE

HIGH DOSE
RATE

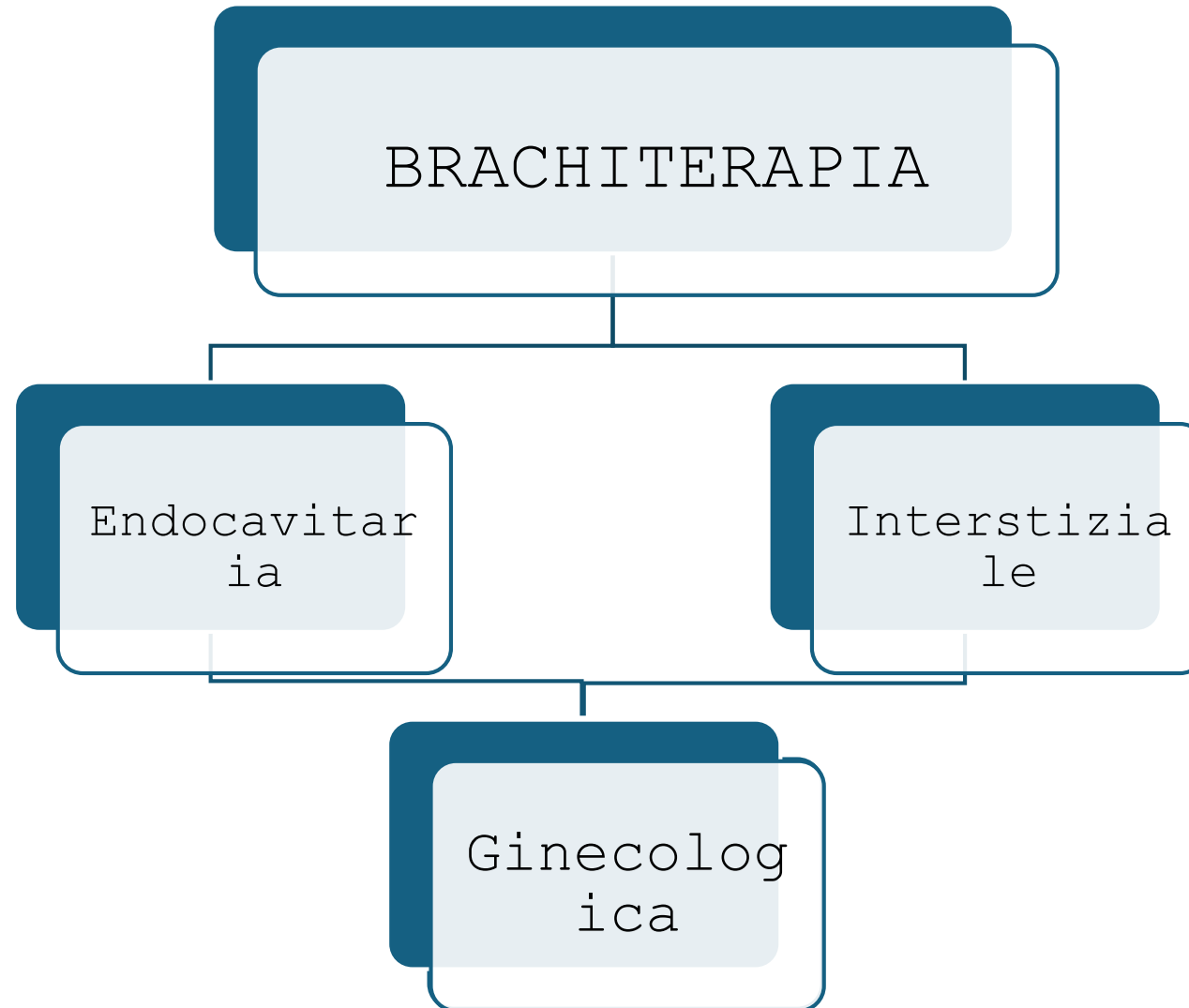
CARATTERISTICHE DELLA BRACHITERAPIA



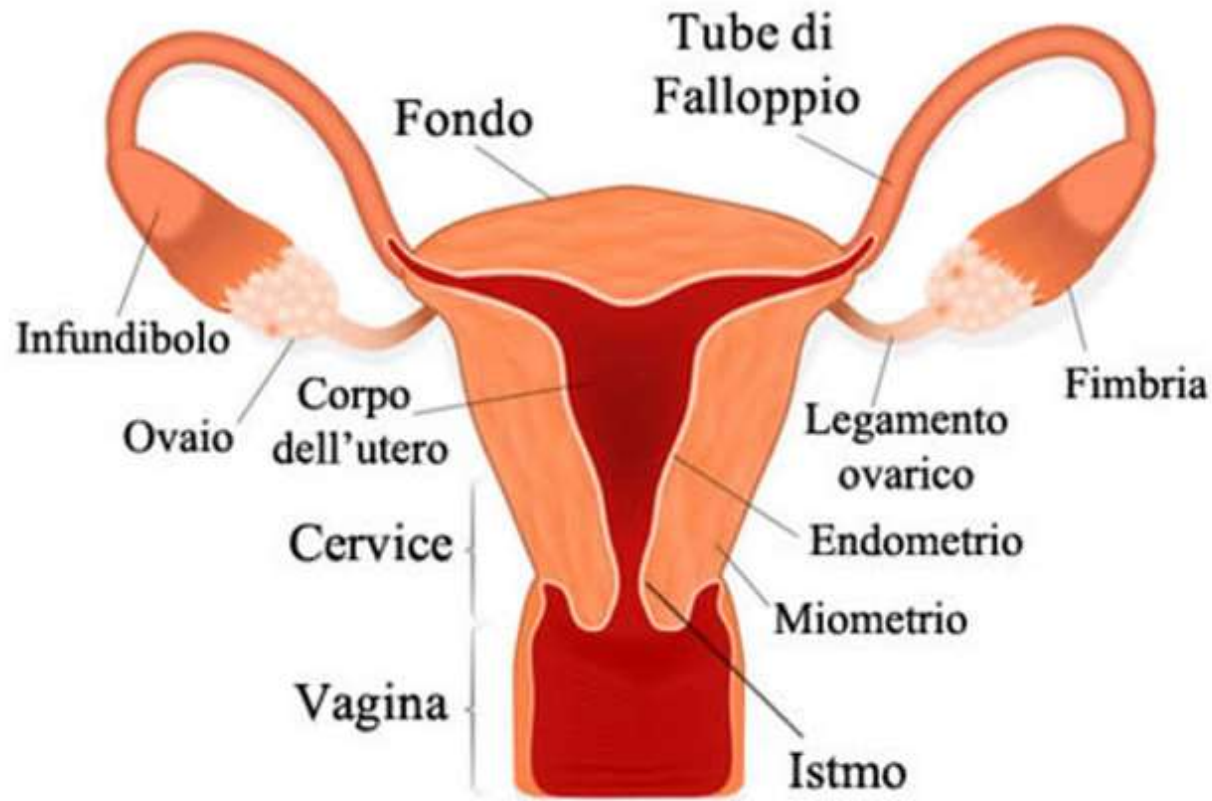
CARATTERISTICHE DELLA BRACHITERAPIA



CARATTERISTICHE DELLA BRACHITERAPIA



ANATOMIA



- tumori della cervice uterina,
- tumori dell'endometrio,
- tumori della vagina,
- alcune recidive ginecologiche

LA BRACHITERAPIA GINECOLOGICA ENDOCAVITARIA E' LA PRATICA PIU' UTILIZZATA DI BRACHITERAPIA (ICRU 89)

Colson-Fearon D, Han K, Roumeliotis M **Updated Trends in Cervical Cancer Brachytherapy Utilization and Disparities in the United States From 2004 to 2020**
International Journal of Radiation Oncology, Biology, Physics, 2023; 119, 154-162

LA SOPRAVVIVENZA A 4 ANNI DELLE PAZIENTI CON CARCINOMA DELLA CERVICE UTERINA LOCALMENTE AVANZATO E' DEL 67,7% CON BRACHITERAPIA CONTRO UN 45,7% SENZA BRACHITERAPIA

LE PAZIENTI CON TUMORE DELLA CERVICE UTERINA LOCALMENTE AVANZATO CHE NON RICEVONO LA BRACHITERAPIA MA SOLO CHEMIO E RADIO A FASCI ESTERNI HANNO UNA SOPRAVVIVENZA GLOBALE PEGGIORE

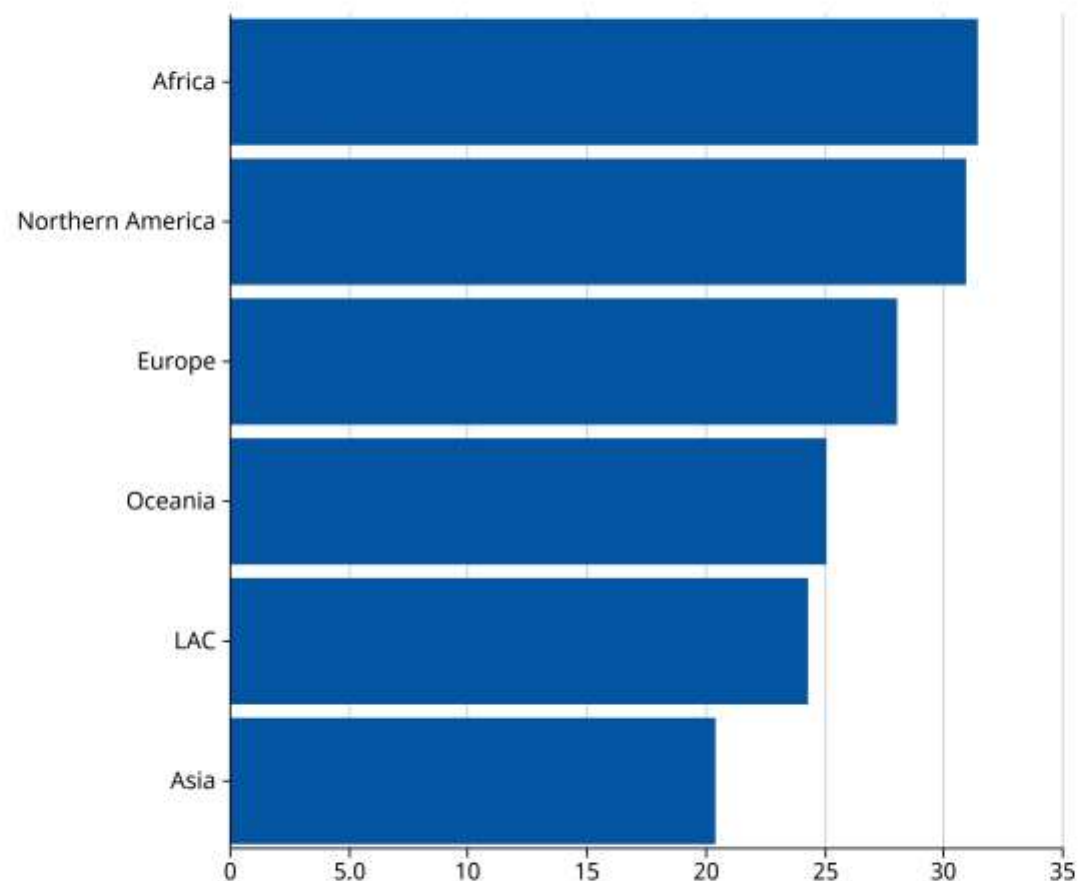
LA BRACHITERAPIA E' INDISPENSABILE NEL TRATTAMENTO DEL CARCINOMA DELLA CERVICE UTERINA LOCALMENTE AVANZATO

Age-Standardized Rate (World) per 100 000, Incidence, Females, in 2022

Vulva + Vagina + Cervix uteri + Corpus uteri

Continents

INCIDENZA TUMORI GINECOLOGICI CI MONDO



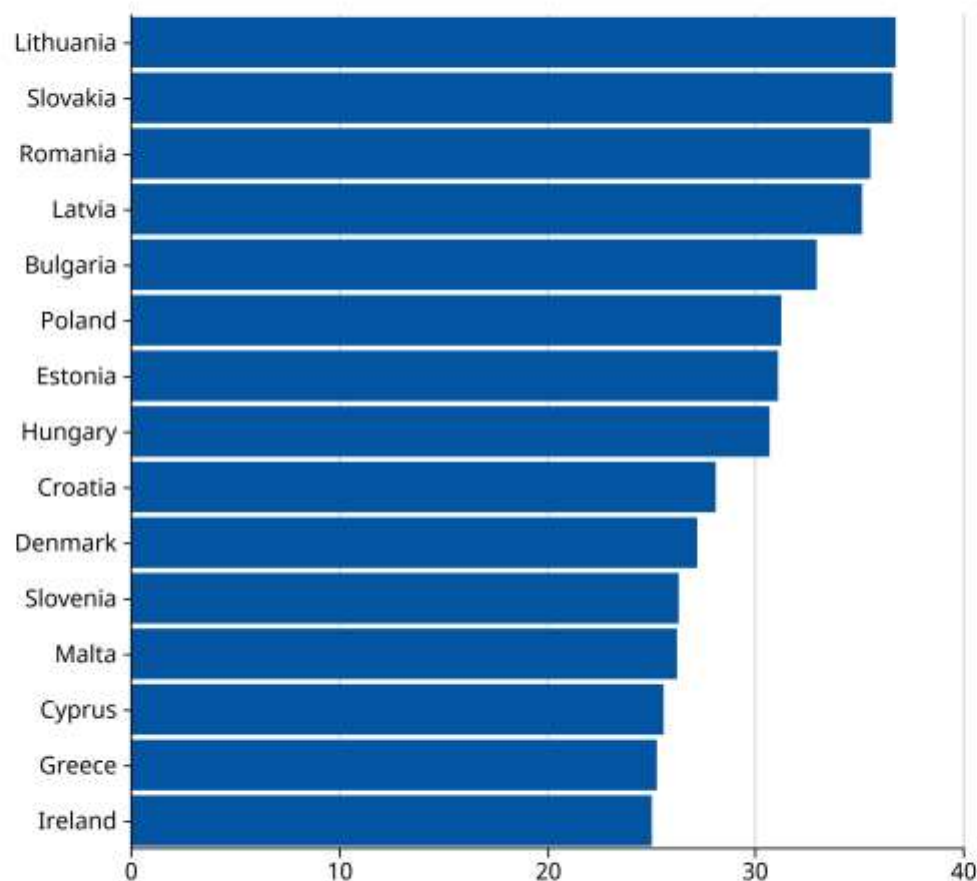
ASR (World) per 100 000

Age-Standardized Rate (World) per 100 000, Incidence, Females, in 2022

Vulva + Vagina + Cervix uteri + Corpus uteri

European Union (27) (Top 15)

INCIDENZA TUMORI GINECOLOGICI I EUROPA



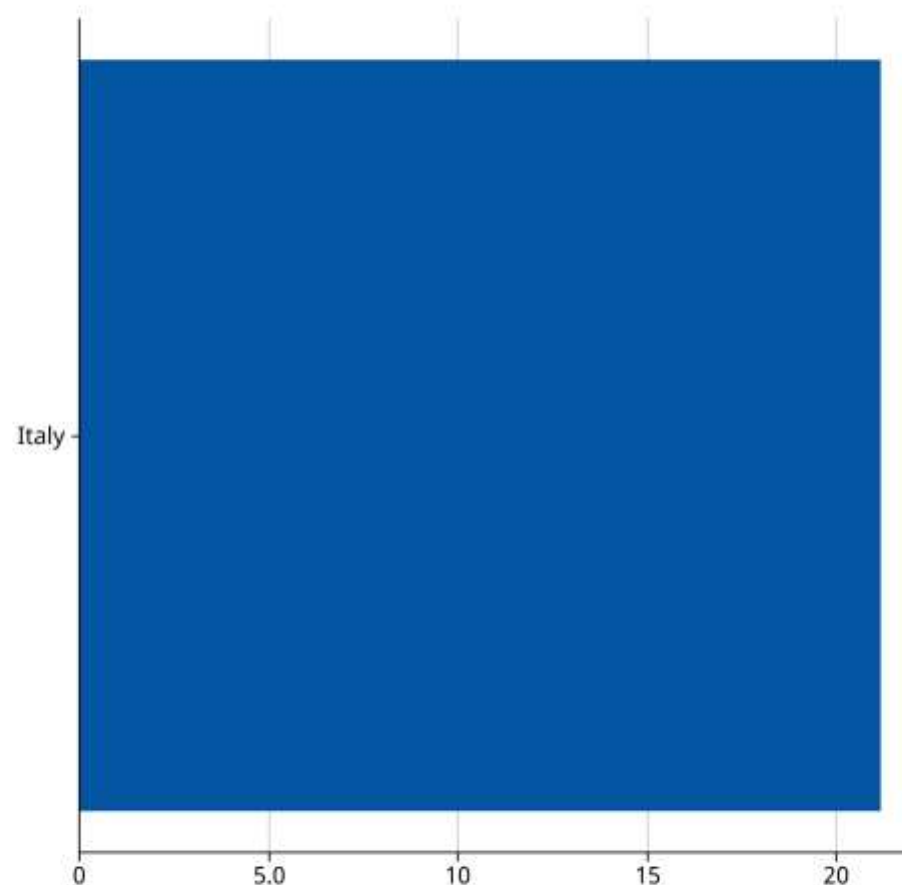
ASR (World) per 100 000

Age-Standardized Rate (World) per 100 000, Incidence, Females, in 2022

Vulva + Vagina + Cervix uteri + Corpus uteri

Italy

INCIDENZA TUMORI GINECOLOGICI CI ITALIA



ASR (World) per 100 000

LE ORIGINI

LA BRACHITERAPIA GINECOLOGICA E' STATA LA PRIMA APPLICAZIONE DELLA BRACHITERAPIA CON USO DI TUBI E AGHI DI Ra-226 GIÀ DAGLI INIZI DEL '900

L'INSERZIONE MANUALE DI TUBI E AGHI HA COMPORTATO L'ESPOSIZIONE DEGLI OPERATORI (MEDICI E FISICI) A IMPORTANTI ESPOSIZIONE DI DOSI

SISTEMI

Sistema di Stoccolma

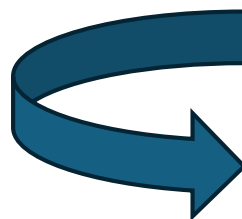
30 a 90 mgRa utero
60 a 80 mg Ra vagina
X 3 sedute da 30 h
10000 mg x h

Sistema di Parigi

mg x h fissi per un
dato volume
120 h minima durata del
trattamento per dare
8000 mg x h

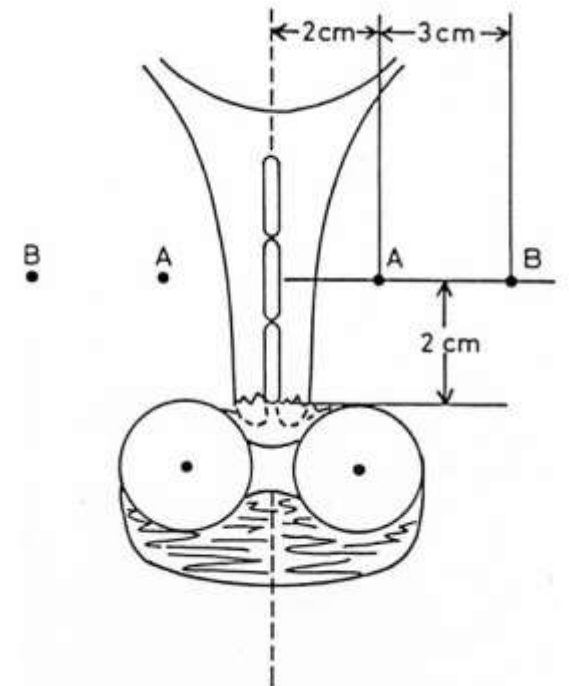
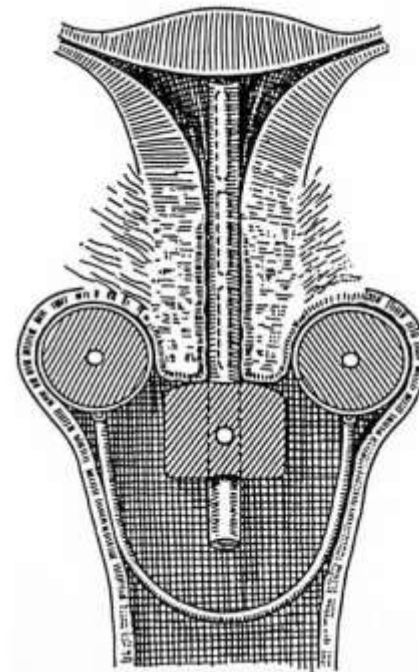
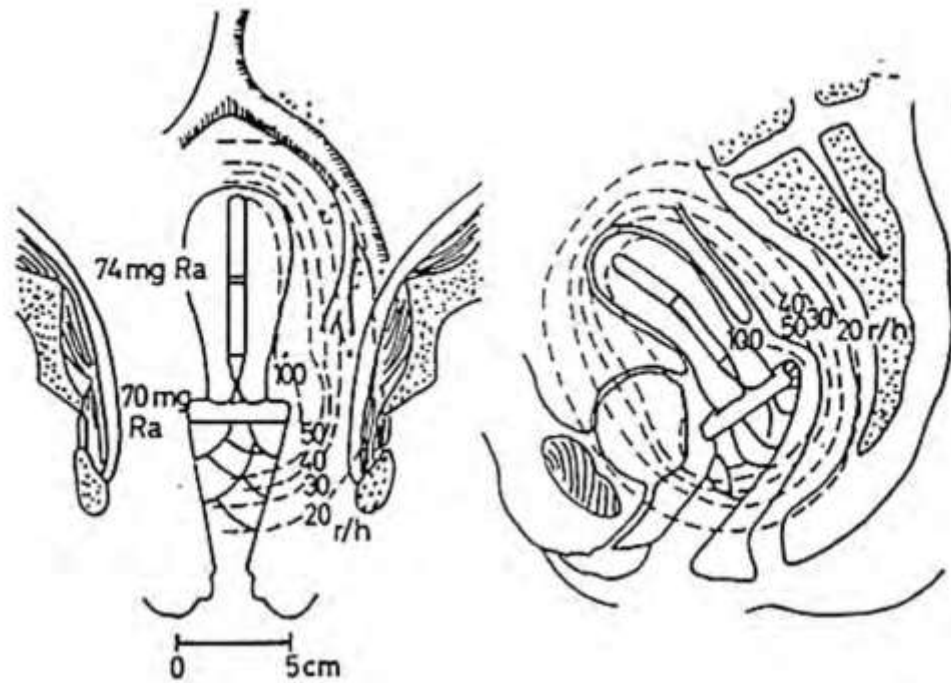
Sistema di Manchester

dosi fisse per punti A
72 h x 2 applicazioni
x dare 8000R al punto
A



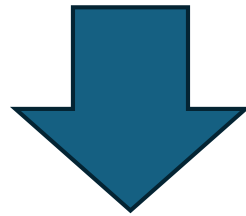
Ra-226 mg x h

SISTEMI



SISTEMI

Sistema di
Manchester



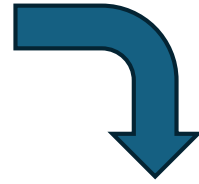
Ra-226 mg
x h



Dose ai
punti A

SISTEMI

Sistema
di
Fletcher



Ra-226 mg

x h



Tempo massimo
di

irradiazione



Dose a retto vescica
e vagina

Afterload
ers



Sorgenti
artifici
ali



Nuova era della
brachiterapia

REMOTE AFTERLOADERS

NEGLI ANNI 60 VENGONO REALIZZATI I PRIMI PROIETTORI DI SORGENTI CON COMANDO A DISTANZA.

SORGENTI ARTIFICIALI (^{137}Cs , ^{60}Co , ^{192}Ir)

SISTEMA PNEUMATICO DI TRENI DI SORGENTI ^{137}Cs DI FORMA SFERICA

SISTEMA CON CAVO DI TRENI DI SORGENTI ^{137}Cs SOTTO FORMA DI SEMI O DI FILI DI ^{192}Ir

REMOTE AFTERLOADERS

LA SORGENTE RADIOATTIVA

IL CONTENITORE SCHERMATO

SISTEMA DI GUIDA E CONTROLLO DELLA SORGENTE

TUBI CHE COLLEGANO IL CONTENITORE E GLI APPLICATORI

CONSOLLE DI TRATTAMENTO

REMOTE AFTERLOADERS

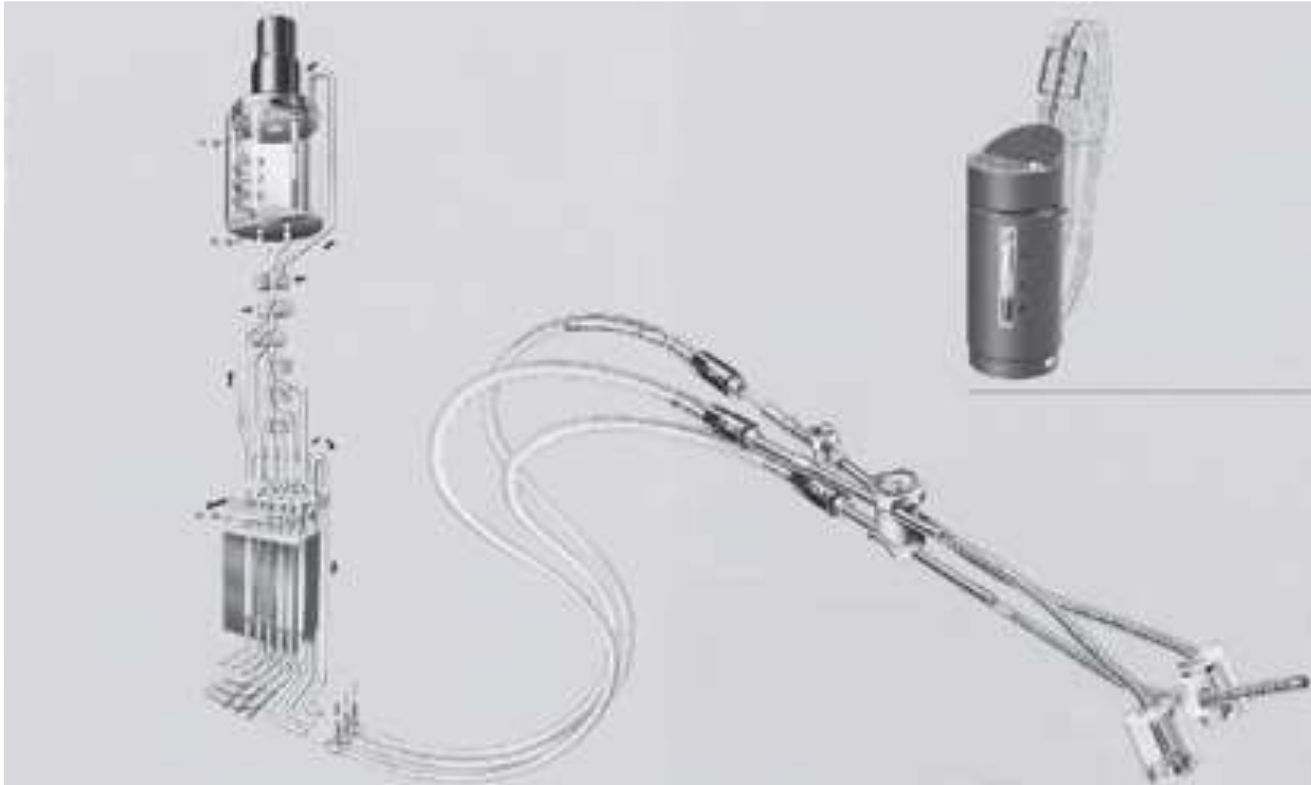
TRE MODALITA' PRINCIPALI DI FUNZIONAMENTO:

TRENI DI SORGENTI FISSE

TRENI DI SORGENTI PROGRAMMABILI

SINGOLA SORGENTE COLLEGATA VIA CAVO A MOTORE PASSO-PASSO

REMOTE AFTERLOADERS



Selectron LDR



CURIETRON

REMOTE AFTERLOADERS

NEGLI ANNI 90 VENGONO REALIZZATI I PRIMI PROIETTORI DI SORGENTI CON UNICA SORGENTE.

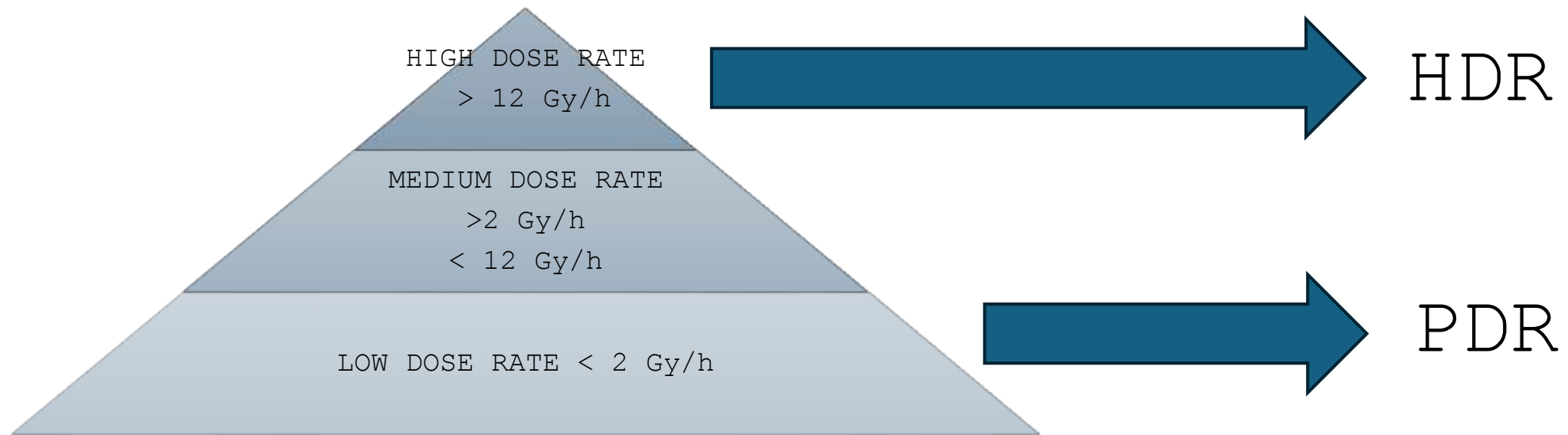
SISTEMA CON CAVO COLLEGATO AD UN UNICA SORGENTE (^{137}Cs , ^{60}Co , ^{192}Ir) COMANDATA DA MOTORE PASSO-PASSO

REMOTE AFTERLOADERS



Figure 4.1. Image of the flagship HDR afterloaders from the three manufacturers (a) Bravos™ (Varian Medical Systems Inc.), (b) Flexitron® (Elekta AB), (c) SagiNova® (Bebig Medical GmbH). Images are used with permission from the respective manufacturer.

AFTERLOADERS A SINGOLA SORGENTE



**L' ^{192}Ir È L' ISOTOPO MAGGIORMENTE UTILIZZATO IN ENTRAMBI LE
MODALITÀ**

REMOTE AFTERLOADERS

NEI REMOTE AFTERLOADERS CON SISTEMA DI MOVIMENTAZIONE AD ARIA COMPRESSA VIENE TESTATA LA TENUTA DEL SISTEMA TUBI-APPLIATORI PRIMA DI INIZIARE IL TRATTAMENTO.

NEI REMOTE AFTERLOADERS CON SISTEMA DI MOVIMENTAZIONE VIA CAVO CON MOTORE PASSO-PASSO UNA SORGENTE FANTOCIO, PRIMA DEL TRATTAMENTO, VIENE FATTA PASSARE LUNGO IL PERCORSO CHE DOVRA' FARE LA SORGENTE REALE PER VERIFICARE CHE NON CI SIANO OSTRUZIONI

REMOTE AFTERLOADERS



Dose Calculation for Photon-Emitting Brachytherapy Sources with Average Energy Higher than 50 keV: Full Report of the AAPM and ESTRO

**Report of the
High Energy Brachytherapy Source Dosimetry (HEBD)
Working Group**

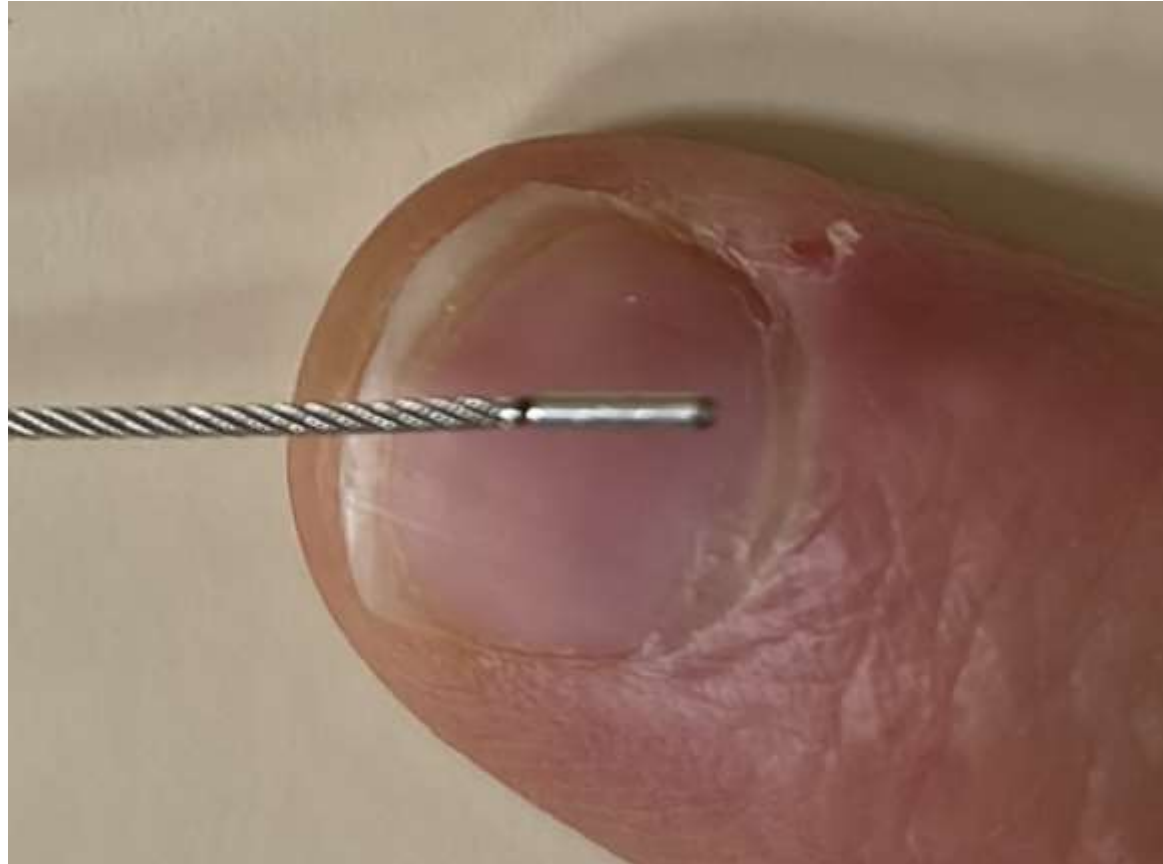
August 2012

REMOTE AFTERLOADERS

Table I. Physical properties of radionuclides considered in this report. Data have been taken from the NNDC.^[20] Mean photon energy values are calculated with a cutoff of $\delta = 10$ keV. Data on Auger and internal conversion (IC) electrons are not included.

	¹⁹² Ir	¹³⁷ Cs	⁶⁰ Co
Half-life	73.81 days	30.07 years	5.27 years
Type of disintegration	β^- (95.1%), EC (4.9%)	β^- (100%)	β^- (100%)
Maximum x-ray energy (keV)	78.6	37.5	8.3
Gamma energy-range (keV)	110.4 to 1378.2	661.6	1173.2 to 1332.5
Mean x-ray and gamma energy (keV)	350.0	613.0	1252.9
Maximum β^- ray energies (keV)	81.7 (0.103%) 258.7 (5.6%) 538.8 (41.43%) 675.1 (48.0%)	514.0 (94.4%) 1175.6 (5.6%)	318.2 (99.88%) 1491.4 (0.12%)
Mean β^- ray energy (keV)	180.7	188.4	96.5
Air kerma rate constant, $\Gamma_{\delta=10 \text{ keV}}$ ($\mu\text{Gy m}^2 \text{ h}^{-1} \text{ MBq}^{-1}$)	0.1091	0.0771	0.3059
Specific activity (GBq mg^{-1})	341.0	3.202	41.91

REMOTE AFTERLOADERS



AFTERLOADERS A SINGOLA SORGENTE

HDR singola sorgente da 370 GBq (RAKR
40mGy/h a 1m)

PDR singola sorgente da 37 GBq

Trattamento PDR 0.5 Gy per impulso con
pulsate da 1h



Moltiplicato per il numero di ore per concorrere alla dose
è già un trattamento in EQD2 (es. 40h sono 20Gy in EQD2
sia per $\alpha/\beta=10$ che per $\alpha/\beta=3$)

brachiterapia ginecologica

nuovi applicatori

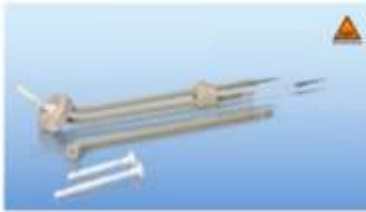
Differenti schemi
temporali di
erogazione del
trattamento

Nuove modalità di
imaging TC, RM, US

Personalizzazione
dei trattamenti

Nuovi sistemi di
calcolo

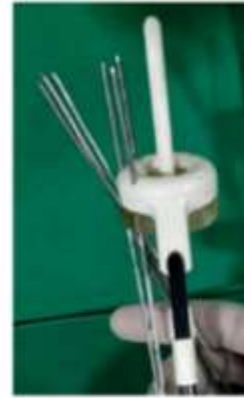
APPLICATORS



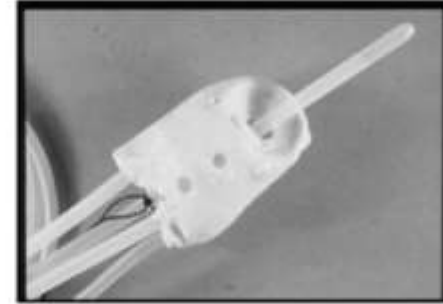
Ring applicator with
cervical sleeve (Varian)



Vienna applicator (Elekta)



Vienna II applicator



Vaginal mould



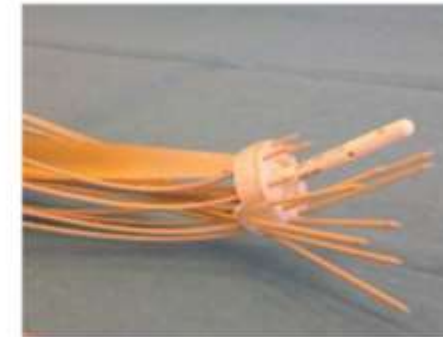
Fletcher-type ovoid
applicator with rectal
retractor (Bebig)



Utrecht applicator
(Elekta)



Venezia universal
applicator (Elekta)



Aarhus individualised 3D printed
tandem-needle template

Figure 13. Examples of applicators (Reprinted from Semin. Radiat. Oncol., 29/3, Tan LT, Tanderup K, Kirisits C, et al, Image-guided Adaptive Radiotherapy in Cervical Cancer, 284-298, 2019, with permission from Elsevier).

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Journal of the ICRU

ICRU REPORT 89

Prescribing, Recording, and Reporting
Brachytherapy for Cancer of the Cervix

OXFORD
UNIVERSITY PRESS



OXFORD UNIVERSITY PRESS

INTERNATIONAL COMMISSION ON
RADIATION UNITS AND
MEASUREMENTS

2013

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ICRU 89

Imaging 2D



Imaging 3D

Dose
puntuale



Dose volumi

EBRT +BT



Dose EQD2

ICRU 89

Volumi
Target
 $CTV_{HR, IR, LR}$



$D_{90\%}$ e $D_{98\%}$

OAR



D_{2cc} e $D_{0.1cc}$

ICRU 89

EQD2

Volumi
Target
CTV_{HR, IR, LR}
OAR

Modello LQ $\alpha/\beta=10$

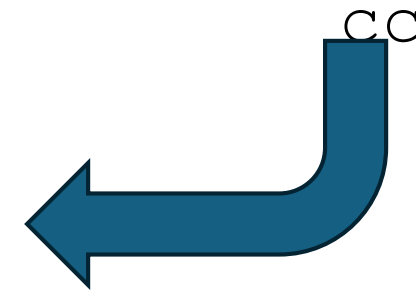
$D_{90\%}$ e $D_{98\%}$

Modello LQ $\alpha/\beta=3$

D_{2cc} e $D_{0.1}$

EBRT + BRT

cc



A.2.5.3 Treatment Planning Aim

Table A.2.3. Treatment planning aim and prescribed dose

				Planning aim (Gy)	Prescribed dose (Gy)
CTV _{HR}	D_{90}	EQD2 ₁₀	≥ 85		86.3
Bladder	$D_{2\text{cm}^3}$	EQD2 ₃	≤ 90		79.2
Rectum	$D_{2\text{cm}^3}$	EQD2 ₃	≤ 70		56.4
Sigmoid	$D_{2\text{cm}^3}$	EQD2 ₃	≤ 75		70.1

Doses are given in EQD2 using $\alpha/\beta = 10$ Gy for target and $\alpha/\beta = 3$ Gy for organs at risk.

TABLE 3 RISK-ADAPTED BRACHYTHERAPY DOSE PRESCRIPTION PROTOCOL FOR EMBRACE-II

Target	$D_{90} \text{ CTV}_{\text{HR}}$ EQD2 ₁₀	$D_{98} \text{ CTV}_{\text{HR}}$ EQD2 ₁₀	$D_{98} \text{ GTV}_{\text{res}}$ EQD2 ₁₀	$D_{98} \text{ CTVI}_{\text{R}}$ EQD2 ₁₀	Point A
Planning aims	>90 Gy <95 Gy	>75 Gy	> 95 Gy	> 60 Gy	>65 Gy
Limits for prescribed dose	>85 Gy		> 90 Gy	-	

OAR	Bladder D2cm ³ EQD2 ₃	Rectum D2cm ³ EQD2 ₃	ICRU recto- vaginal point EQD2 ₃	Sigmoid D2cm ³ EQD2 ₃	Bowel D2cm ³ EQD2 ₃
Planning aims	<80 Gy	<65 Gy	<65 Gy	<70 Gy	<70 Gy
Limits for prescribed dose	<90 Gy	<75 Gy	<75 Gy	<75 Gy	<75 Gy

CALCOLO DELLA DOSE

TG-43 (1995)

Formalismo calcolo
della dose in BT
in acqua

Dw in mezzo
omogeneo di acqua

TG-186 (2012)

Formalismo basato
su modello per il
calcolo della dose
in BT

Dose in
tessuto nel mezzo
in mezzo
disomogeneo

Calcolo della Dose TG 43

RAKR (reference air kerma rate)

Costante di dose rate $\dot{D}_w/\text{RAKR}$

Funzione geometrica (dose nel punto rispetto alla sorgente)

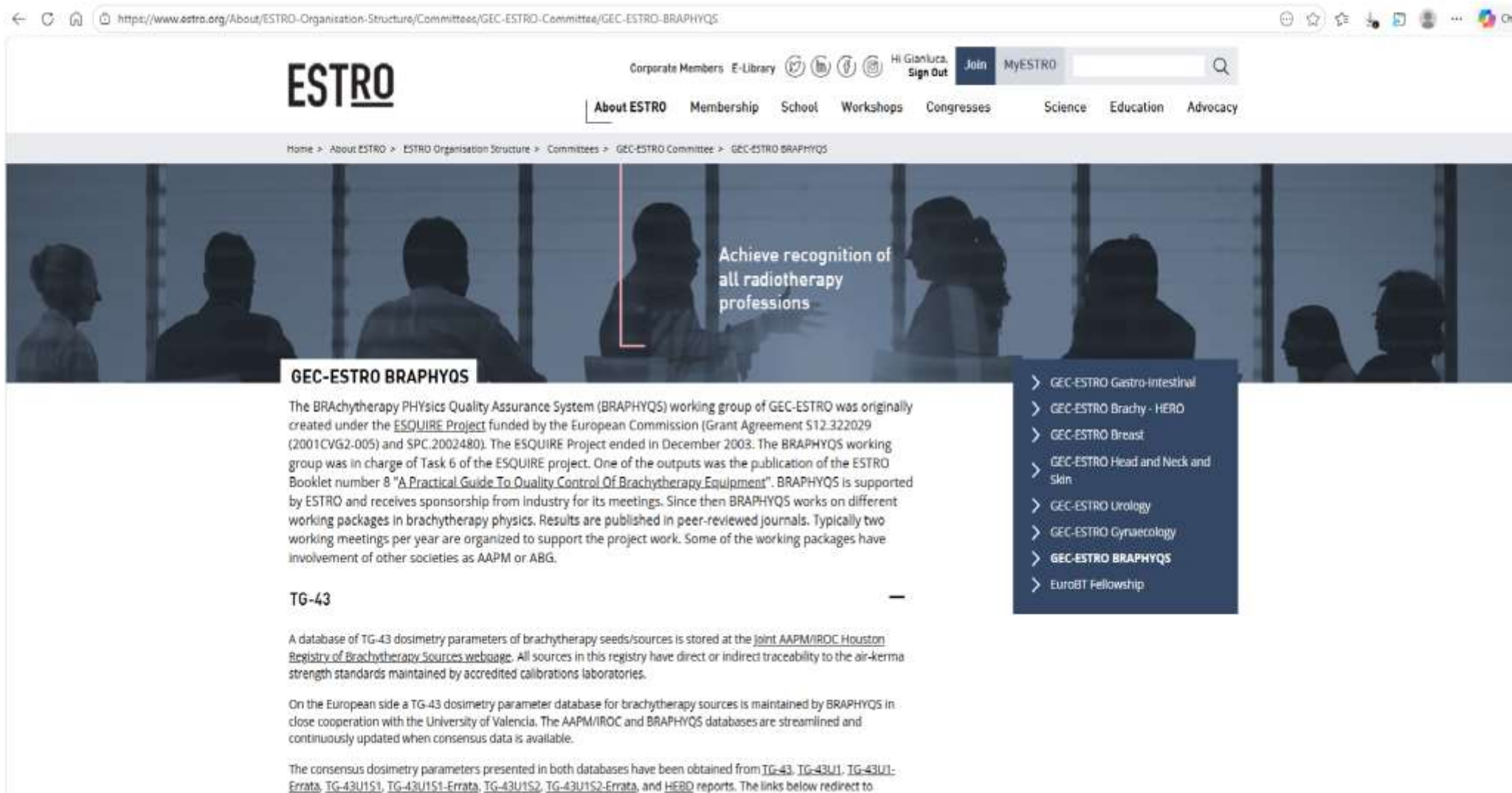
Funzione di dose radiale (assorbimento e scattering $\perp$)

Funzione di anisotropia

CALCOLO DELLA DOSE

QA Along-away												
z / cm	0	0.25	0.5	0.75	1	1.5	2	3	4	5	6	7
7	0.01642	0.01672	0.01701	0.01730	0.01758	0.01788	0.01786	0.01705	0.01559	0.0138	0.01204	0.01042
6	0.0221	0.0226	0.0231	0.0236	0.0241	0.0244	0.0242	0.0225	0.0200	0.01713	0.01451	0.01226
5	0.0312	0.0322	0.0332	0.0342	0.0348	0.0351	0.0343	0.0305	0.0258	0.0213	0.01750	0.01432
4	0.0474	0.0496	0.0518	0.0537	0.0545	0.0541	0.0511	0.0426	0.0338	0.0265	0.0208	0.01654
3	0.0815	0.0870	0.0927	0.0957	0.0961	0.0907	0.0812	0.0605	0.0441	0.0324	0.0244	0.01875
2	0.1778	0.197	0.212	0.213	0.203	0.1702	0.1361	0.0854	0.0558	0.0384	0.0277	0.0207
1.5	0.315	0.359	0.379	0.360	0.323	0.241	0.1765	0.0995	0.0615	0.0410	0.0290	0.0215
1	0.715	0.848	0.812	0.680	0.542	0.340	0.223	0.1125	0.0662	0.0431	0.0301	0.0221
0.5	3.34	3.45	2.20	1.354	0.886	0.447	0.264	0.1219	0.0694	0.0445	0.0307	0.0224
0	<u>3.85E+08</u>	15.55	4.31	1.959	1.113	0.498	0.281	0.1254	0.0704	0.0449	0.0309	0.0225
-0.5	2.31	3.45	2.20	1.357	0.885	0.446	0.264	0.1220	0.0696	0.0445	0.0308	0.0224
								0.112	0.066	0.043	0.030	

CALCOLO DELLA DOSE



SCHEMI DI TRATTAMENTO

CA cervice uterina

- Trattamento radicale EBRT (radioterapia fasci esterni) sulla pelvi + CT (chemioterapia) + Boost BRT (brachiterapia) completa
- Se operata con margini positivi EBRT pelvi + CT + Boost BRT su cupola vaginale

CA endometrio

- Chirurgia + EBRT pelvi e CT (se alto rischio) o BRT su cupola vaginale se rischio intermedio

CA vagina

- EBRT pelvi + CT + Boost BRT su regione vaginale

Handbook of Brachytherapy

ESTRO

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Chapter 7: Principles of brachytherapy planning systems - new

Chapter 8: Treatment planning, evaluation and reporting in brachytherapy - new

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Chapter 12: Head and Neck: oral tongue and floor of mouth - 1st edition 2002

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Chapter 20: Prostate cancer - 2nd edition 2014

Chapter 21: Urinary bladder cancer - 2nd edition 2015

Chapter 22: Penis cancer - 2nd edition 2022

Chapter 23: Anal cancer - 2nd edition 2023

Chapter 24: Rectal cancer - 2nd edition 2014

Chapter 25: Oesophageal cancer - 2nd edition 2019

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Chapter 28: Primary and secondary liver malignancies - 2nd edition 2022

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Chapter 16: Cervix cancer - 2nd edition 2023

Chapter 17: Endometrial cancer - 2nd edition 2016

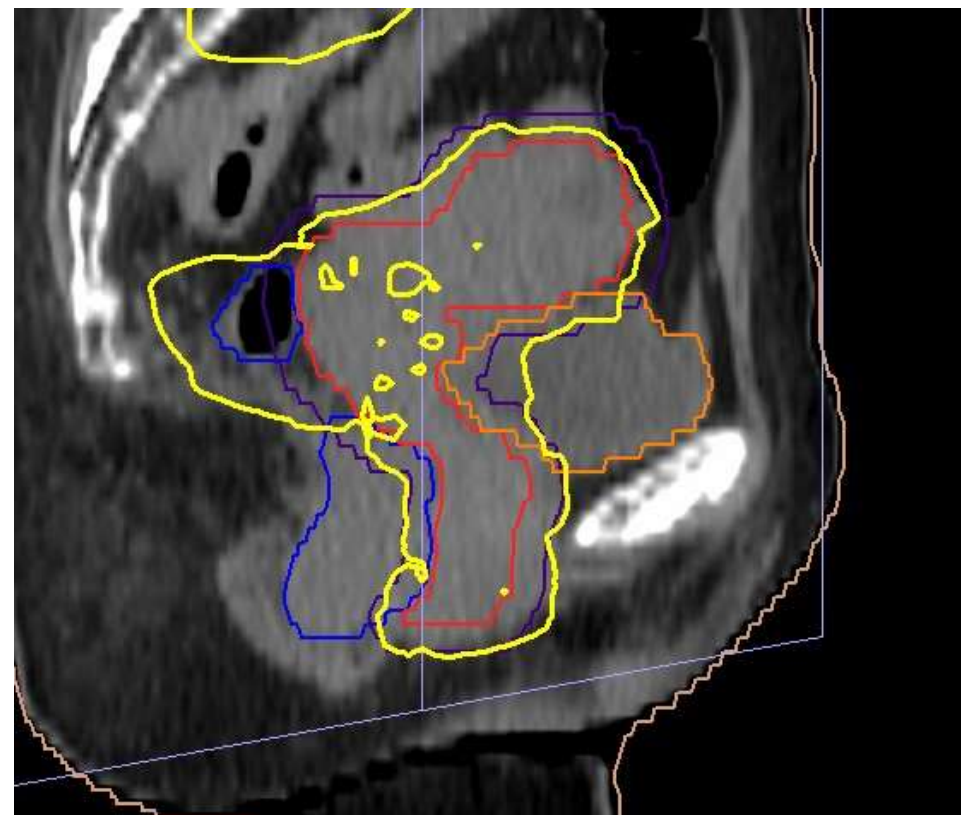
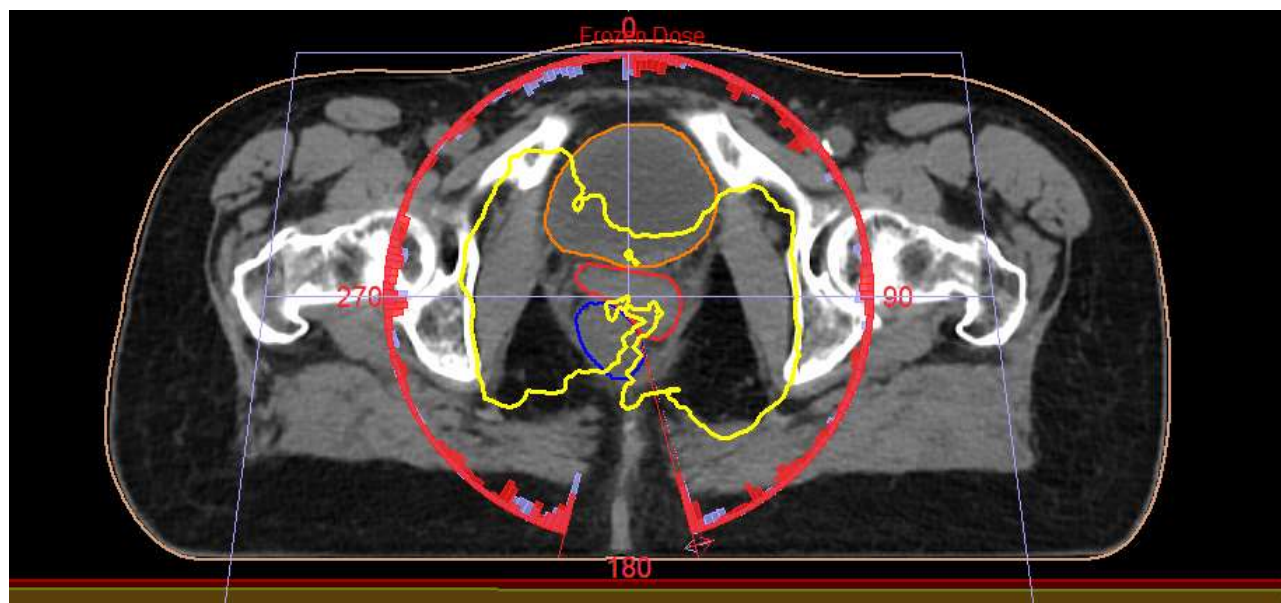
Chapter 18: Primary vaginal cancer and vaginal recurrences - 2nd edition 2023

Chapter 19: Vulva - new

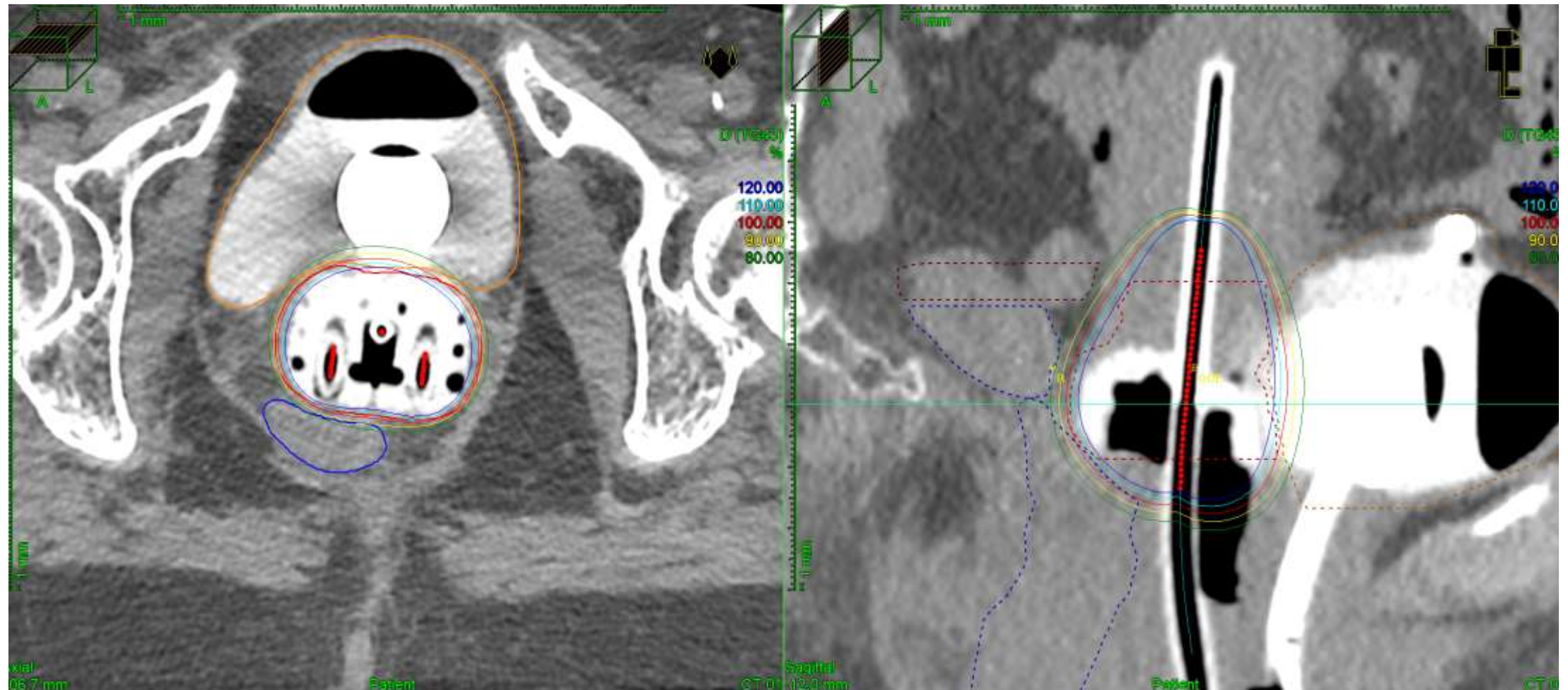
DOSI DI TRATTAMENTO

	EBRT	BT	EBRT+BT
CA CERVIC UTERINA	45 Gy (1.8Gy/fr x 25)	7 Gy x 4 (EQD2 40 Gy)	EQD2 85 Gy
CA VAGINA	45 Gy (1.8Gy/fr x 25)	7 Gy x 2 (EQD2 20 Gy)	EQD2 65 Gy

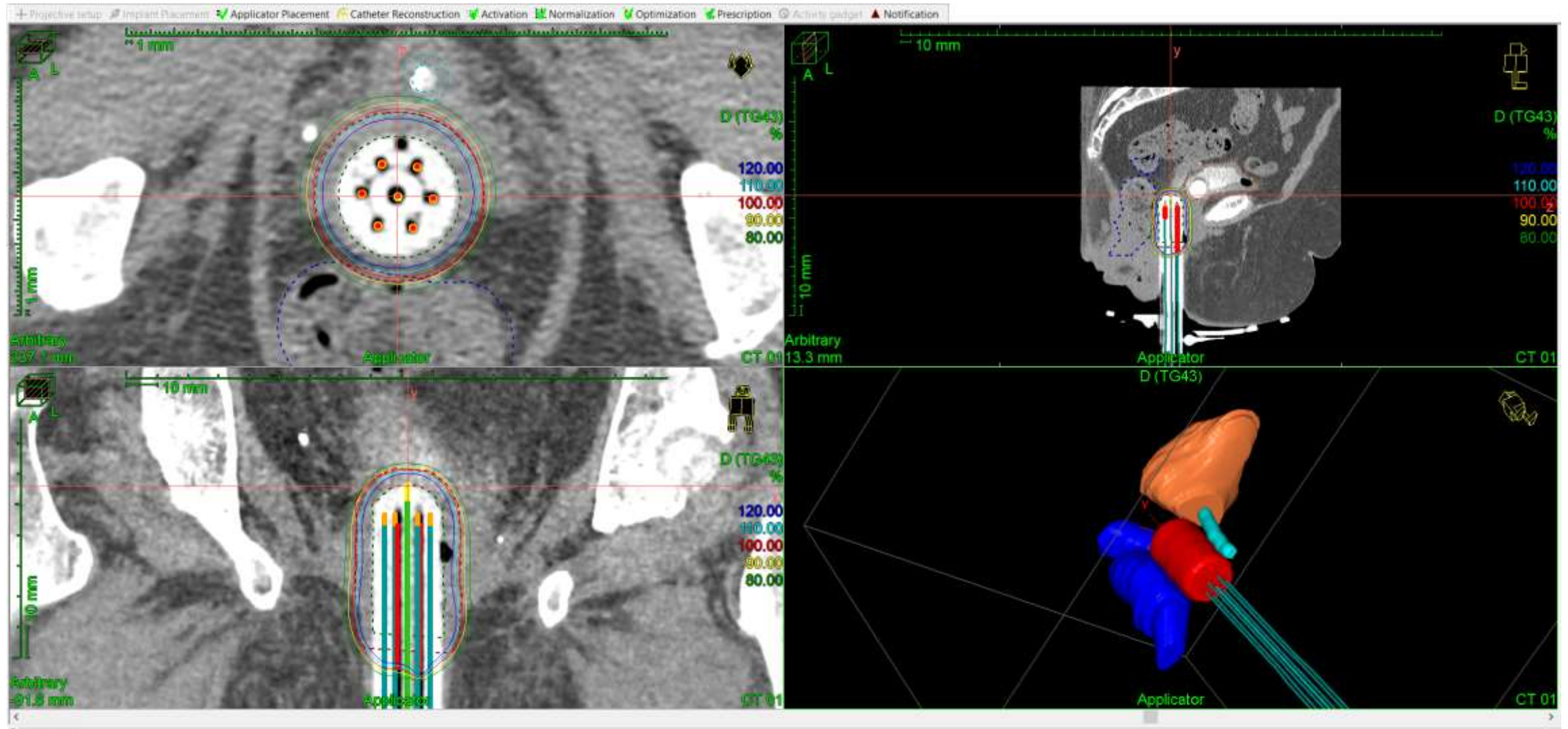
EBRT



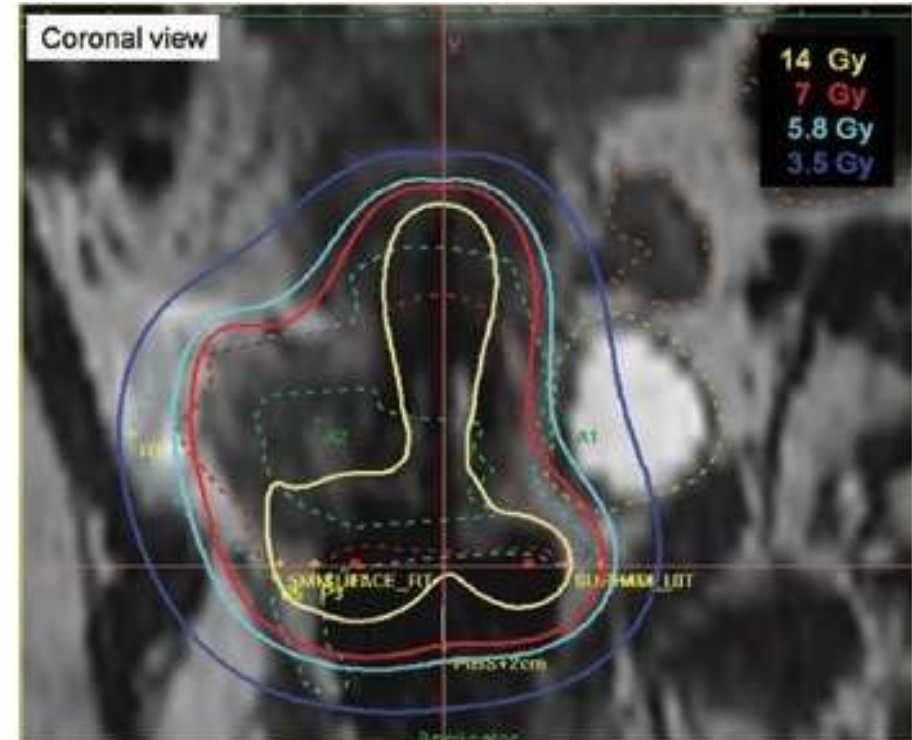
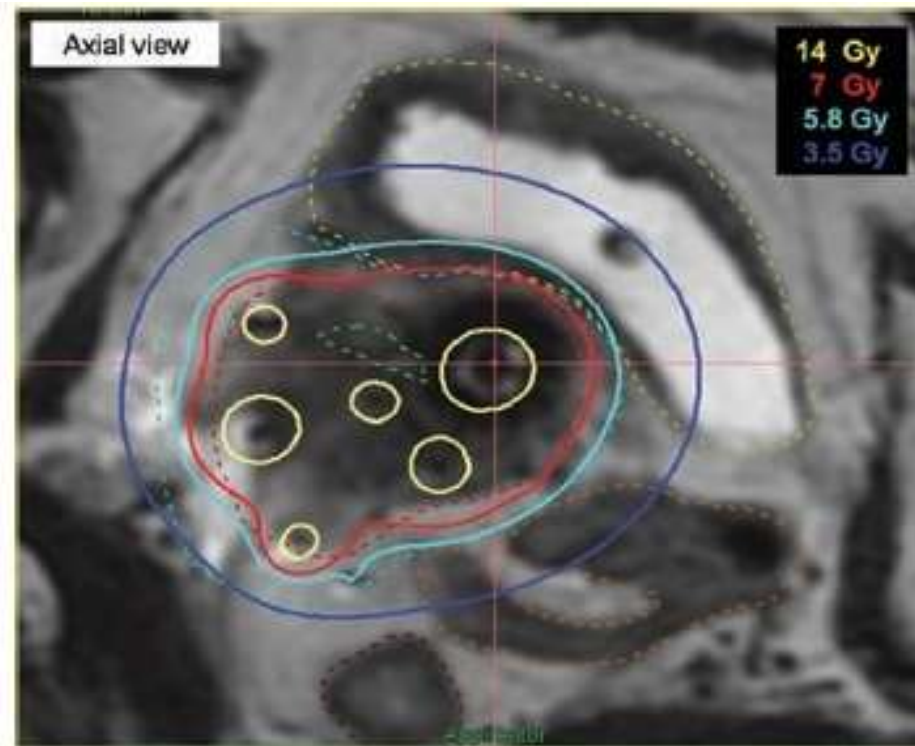
BT CERVIX UTERINA



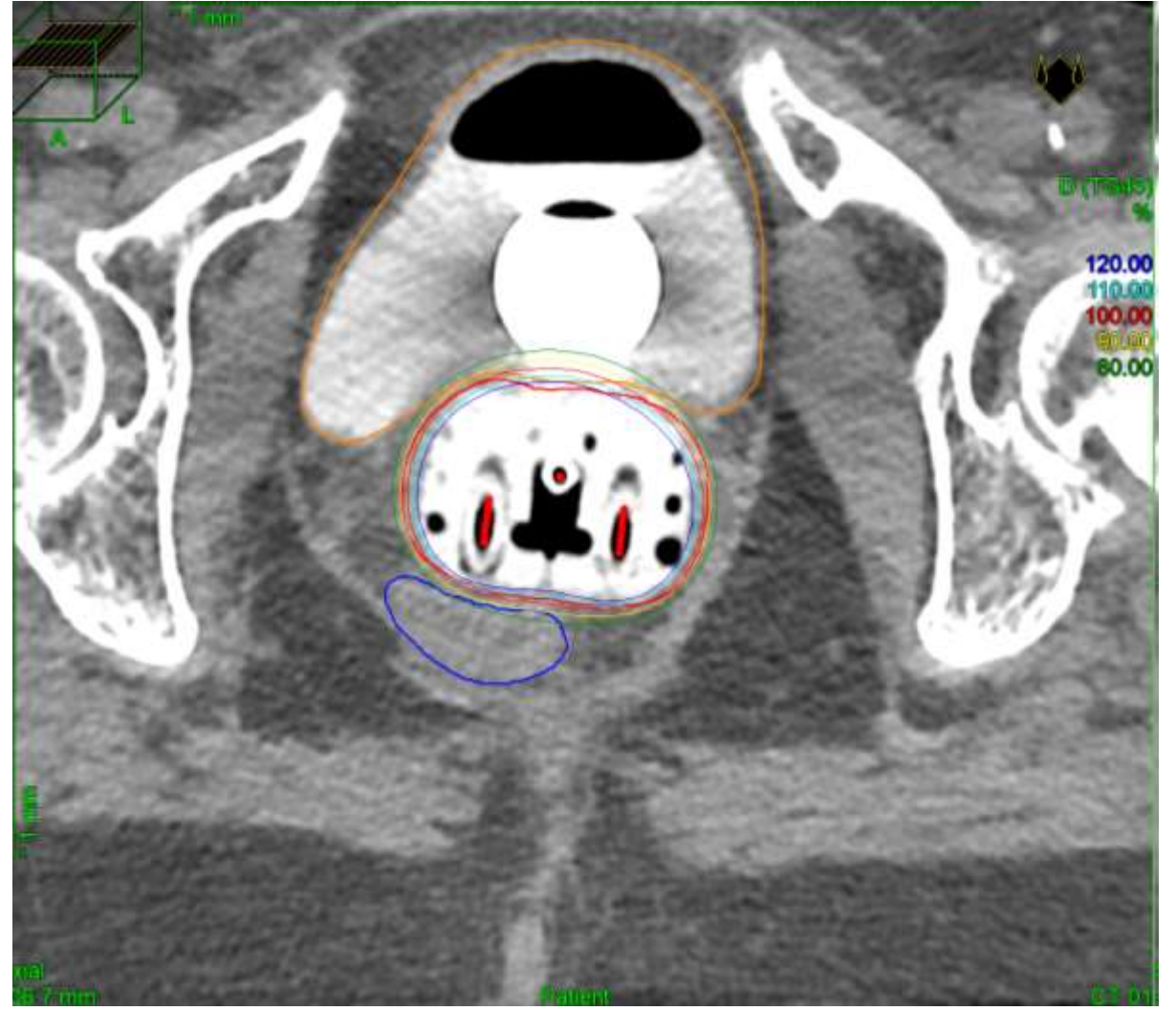
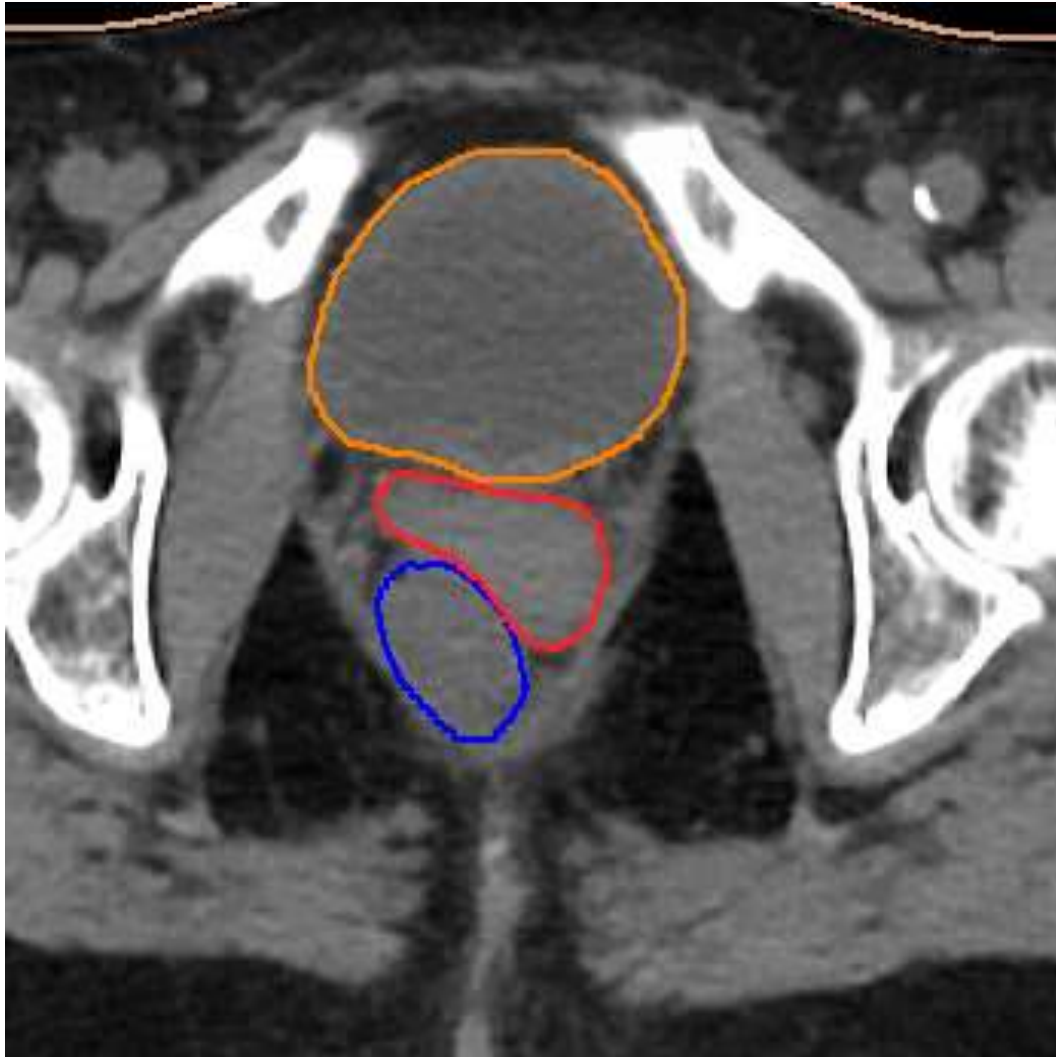
BT VAGINALE



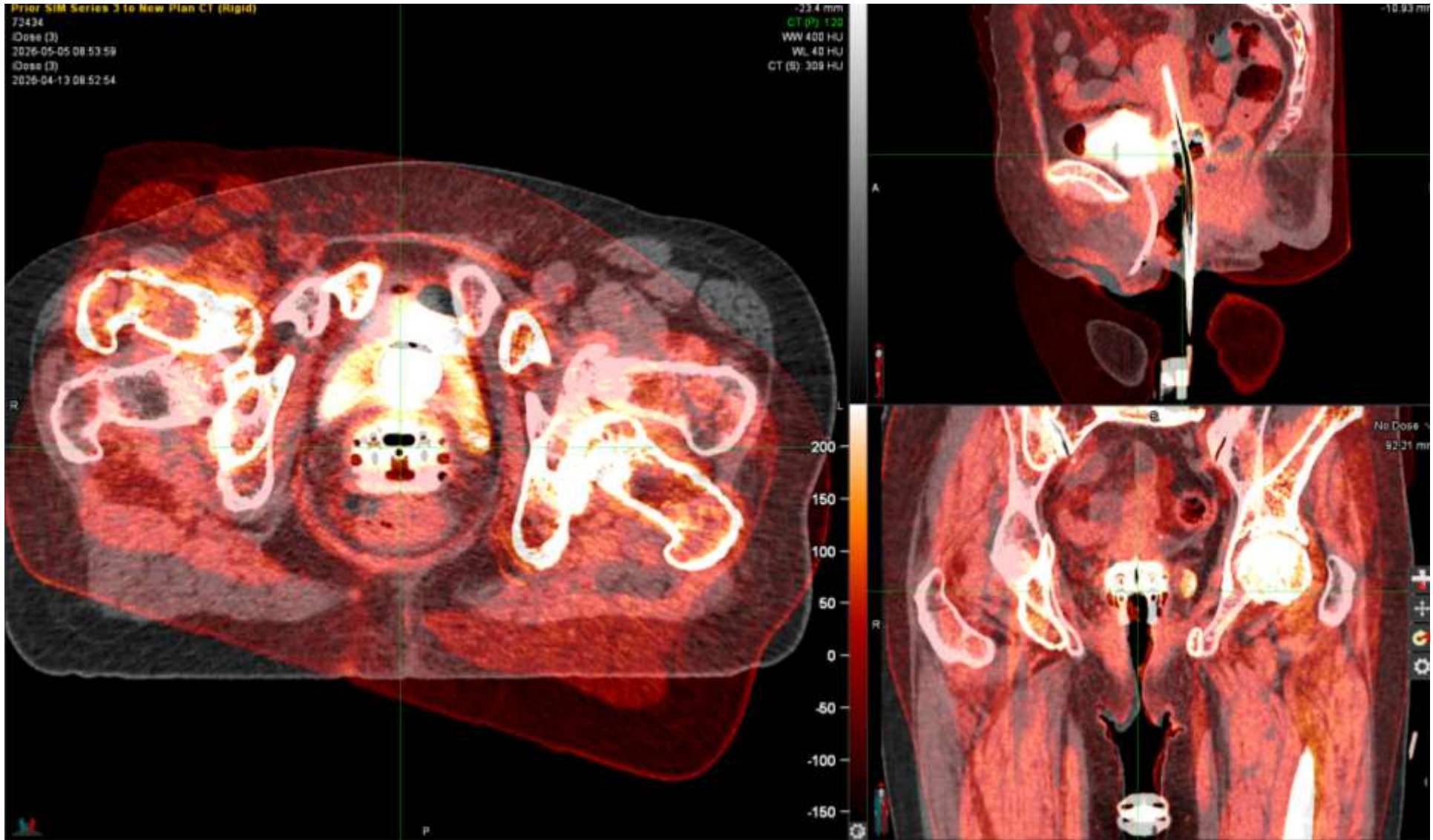
BT INTERSTIZIALE + ENDOCAVITARIA



FUSIONE?



FUSIONE



FUSIONE



D_{2cc} VESCICA 80Gy
EQD2
 D_{2cc} VESCICA 85Gy
EQD2

D_{2cc} RETTO 70Gy EQD2
 D_{2cc} RETTO 78Gy EQD2

DA FUSIONE

DA Σ SUI SINGOLI
TRATTAMENTI

GRAZIE PER
L'ATTENZIONE

