La radioterapia adaptiva

Tarek Hijal

McGill University

Transformation • Innovation • Excellence

sur trois sites | on three sites

Centre universitaire de santé McGill

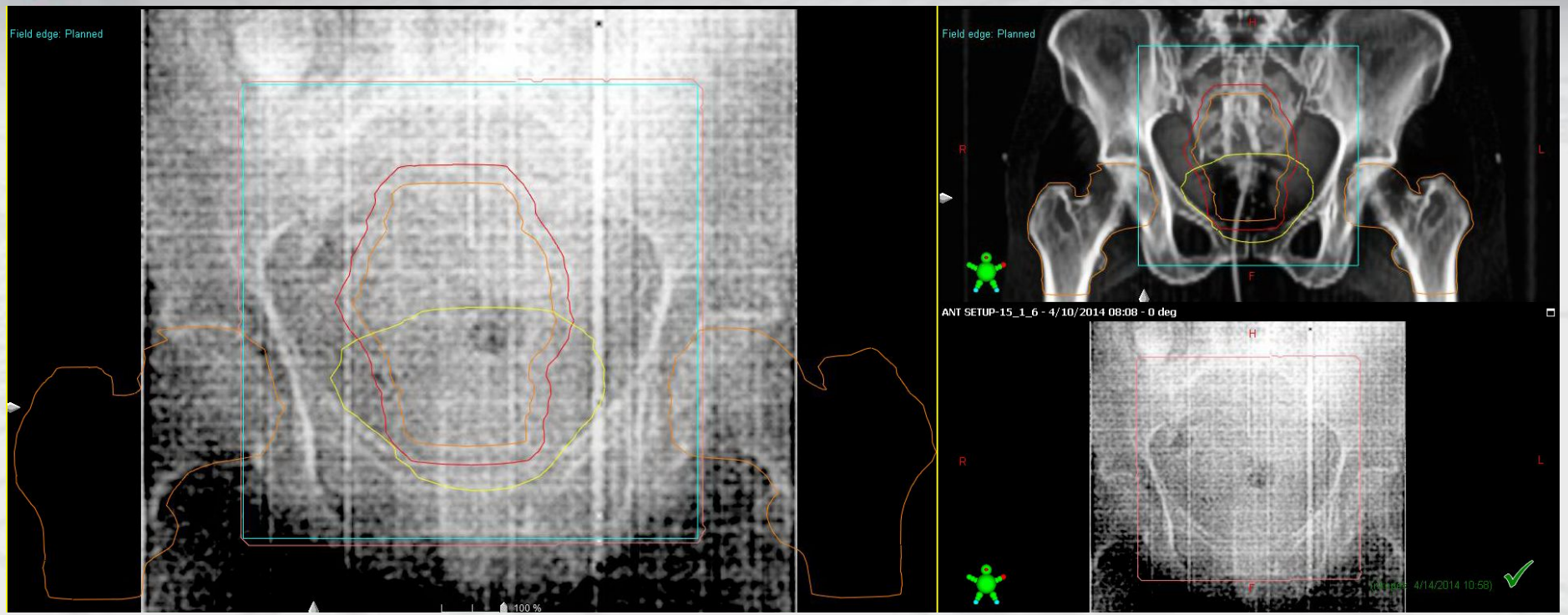
McGill University Health Centre

¿Qué es el IGRT?

IGRT: La radioterapia guiada por imágenes

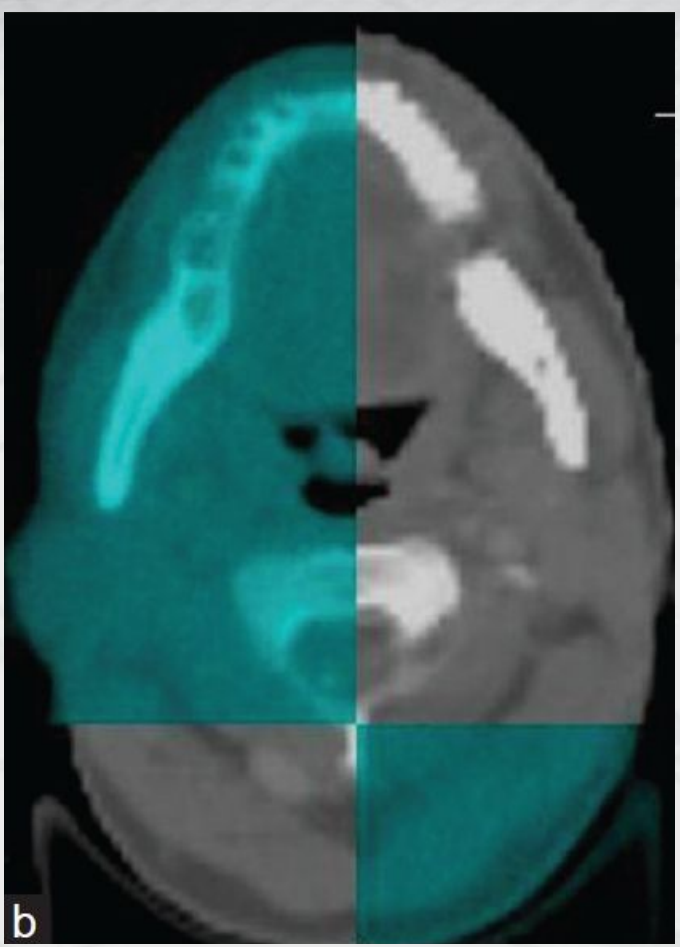
IGRT es el uso de imágenes durante la radioterapia para mejorar la precisión y exactitud de la administración del tratamiento.

Era Pre-IGRT



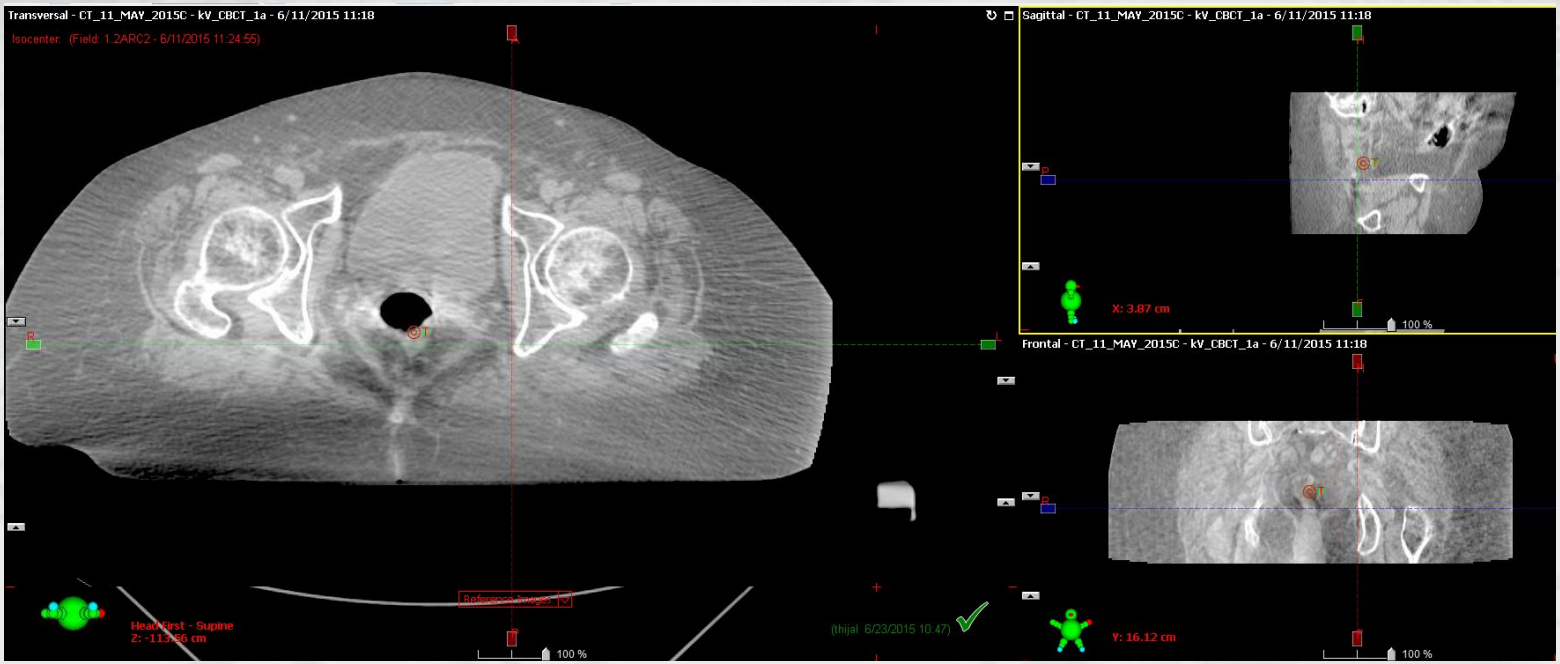
Dos peliculas ortogonales

TomoTherapy: Un sistema temprano de IGRT



TomoTherapy: Un TC antes de cada tratamiento

Cone beam CT: Otro técnico de IGRT



IGRT con un acelerador lineal con RMN

IGRT puede reducir los errores de posicionamiento geométrico

- Interpretación errónea de las instrucciones de configuración
- Posicionamiento de marca de piel inválido
- Alineación inadecuada

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Radiotherapy incidents

Trend analysis of radiation therapy incidents over seven years

Jean-Pierre Bissonnette*, Gaylene Medlam

Radiation Medicine Program, Princess Margaret Hospital, Toronto, Ontario, Canada

Another major change that occurred during the course of this study was the implementation of IGRT, which has been rolled out gradually from 2004 to half of our treatment units in 2006. Trend analysis has shown a statistically significant (two-tailed t-test, $p < 0.002$) decrease in the rate of actual incidents caused by location errors between the periods before (2001–2005; 0.27 per 100 courses) and after (2006–2007; 0.13 per 100 courses) implementation of IGRT using cone-beam CT. Therefore, wide-spread introduction of IGRT on six of our 16 linear accelerators appears to have helped reduce the rate of actual (i.e., non-near miss) incidents caused by location errors by 50%; we therefore anticipate actual location error rates to further decrease as IGRT is deployed to the remaining treatment units.

4 componentes de IGRT segura

1. Puesta en marcha y garantía de calidad continua (QA) de los sistemas
2. Protocolos para la adquisición e interpretación de imágenes
3. El vínculo entre las prácticas de orientación de imágenes y el margen PTV
4. Educación, formación y recursos humanos.

Guias de IGRT: Por qué tenerles?

Asegúrese de que el uso clínico de las modalidades de IG sea coherente con el proceso y la puesta en marcha del sistema.

Guías específicas del sitio del cáncer contienen:

1. Resumen del protocolo de tratamiento
2. Tamaño del margen de PTV para un método particular de inmovilización y configuración
3. Métodos de alineación de imagen
4. Límites de acción

Agilizar el proceso de toma de decisiones

Importancia des la guias de IGRT

1) Consistencia entre oncólogos radioterapeutas

2) Consistencia entre tecnólogos

3) Usar el material de imagen más actualizado

4) Disminución de ineficiencias
   Esperar que los médicos aprueben las películas.
   Deja los expertos (tecnólogos) hagan lo que mejor saben hacer

5) Mantenerse con la literatura más actualizada sobre imágenes

Gastrointestinal – Lower GI – Pelvic irradiation, long or short course

The institutional standard PTV margin ranges from 7 mm for the involved nodes to 10 mm for the primary. Two fractionation schemes are generally used: 45 Gy in 25 fractions or 25 Gy in 5 fractions to the PTV. Generally, no immobilization devices are necessary.

Prior to first fraction, orthogonal pair imaging will be used for patient setup, based on stable bony structures in the proximity of the treatment region. Any visible disease must fall within the contoured PTV region.

For lower GI targets, particular care must be paid to the shifts of the target with respect to the external body contour. The coordinators will be informed of separation changes of 10 mm or more. In addition, the coordinators will be informed of any changes in bladder / rectum volume and position that may compromise the treatment.

Imaging with the orthogonal pair will be followed by applying couch corrections daily. The verification with CBCT will follow daily for the first five fractions. For the remainder of the treatment, the setup will be based on kV/kV orthogonal images and verified with CBCT once per week.

On days when orthogonal pair indicates a shift of 10mm or more in any direction, the shift will be verified with a CBCT.

Additional imaging requests are to be prescribed by the coordinators.

Cómo hacer el aseguramiento de la calidad del proceso IGRT?

PLANNING PHASE: Margins consistent with IGRT site-specific protocol
Patient specific setup instructions and alerts included in patient's chart (if needed)
Guidance structures sent from dosimetry

PRIOR TO FIRST TREATMENT: Review of DRRs
Confirmation of isocenter and guidance structures

DURING EACH TREATMENT: Visual inspection of images
Evaluate shifts against action levels
Evaluate anatomical changes
Confirm correction using repeat imaging (larger shifts)
Record IGRT corrections in the patient's

WEEKLY: Image review by physician

DURING WEEK 1 OF TREATMENT: Audit of image registrations by coordinator

AS NEEDED: Dosimetric analysis by physicist and re-planning by dosimetry

Table 2: Recommendations to establish a foundation for safe and effective IGRT practices

Recommendation	Comments	Refs.
1. Establish a multi-professional team responsible for IGRT activities.	MP, DP, RTT, and RO membership; responsible for leading IGRT initiatives. Collectively, this team has deep expertise on IGRT. The program should make educational investments in this team.	37
2. Establish and monitor a program of daily, monthly, and annual QA for all new or existing IGRT sub-systems.	Led by MPs with participation by RTTs. Reporting and results should be transparent to other professions and administrators. See AAPM Task Group reports for test frequency.	12,13
3. Provide device- and process-specific training for all staff operating IGRT systems or responsible for IGRT delivery.	Applications training needs to be augmented by internal process-specific training with competency testing for all professions and supported by the IGRT team (see Recommendation 1, above).	13
4. Perform end-to-end testing for all new IGRT procedures (from simulation to dose delivery) and document performance prior to clinical release.	The combination of various sub-systems is typically not certified by vendors and needs to be tested before use. Tests should be specific to the process and include staff that will be performing the procedure in the clinical setting.	13
5. Establish process-specific documentation and procedures for IGRT.	These guide internal training procedures and ensure consistent practices. Procedures include pre-IGRT QA checks, imaging technique, analysis methods, action levels, correction method, and patient-specific documentation.	5
6. Clearly identify who is responsible for approval of IGRT correction decision and the process whereby this decision is made and documented.	Requires oversight of responsible clinician(s) in action or delegation. Written procedures are critical to ensure the delegation of this important activity is robust. The frequency and response time for review also need to be specified in the protocol.	11
7. Establish and document site-specific planning procedures, specifically, the procedure for defining PTV margins. Link these planning procedures to IGRT procedures.	In general, PTV margins are strongly dependent on the IGRT procedures and IGRT system performance. Treatments with this strong dependence should have documented procedures for planning to ensure PTVs are properly constructed.	26,42,43
8. Multi-professional peer-review of PTV volumes. Peer-review of GTV/CTV volumes by ROs.	Confirm PTV margins being employed are consistent with the performance of the IGRT technique. GTV/CTV delineation errors represent a significant systematic error source not typically accommodated in the PTV.	29
9. Verify proper creation and transfer of IGRT reference data (PTV, OARs, DRRs, etc) to IGRT system.	DPs/RTTs/MPs should assure the correct structures for interpretation of the IGRT images have been transferred to the IGRT system. ROs confirm guidance structures are correct prior to treatment – this includes patient-specific guidance structures.	39
10. Establish a reporting mechanism for IGRT-related variances in the radiation treatment process.	IGRT is an important part of the process and recording variances and near-miss events provides a means to evaluate and improve performance.	5,44

Practical Radiation Oncology (2013)

pro

Assuring Safety and Quality in Image Guided Delivery Of Radiation Therapy

David A. Jaffray, Ph.D.[a], Katja M. Langen, Ph.D.[b], Gikas Mageras, Ph.D.[c], Laura A. Dawson, M.D. [d], Di Yan, D.Sc.[e], Robert Adams, Ed.D. [f], Arno J. Mundt, M.D.[g], Benedick Fraass, Ph.D.[h]

Diferencia entre IGRT y RTA

• Radioterapia guiada por imagen (IGRT): comúnmente referida a un proceso de reposicionamiento del paciente sin modificar el plan de tratamiento inicial

• Radioterapia adaptativa (ART): implica la modificación del plano inicial, incluido el cambio de las aberturas del haz o los patrones de intensidad

Bases de la RTA

Un plan único diseñado antes del tratamiento es insuficiente para describir la dosis real administrada, y a menudo conduce a un tratamiento subóptimo.

¿Por qué se necesita la ART?

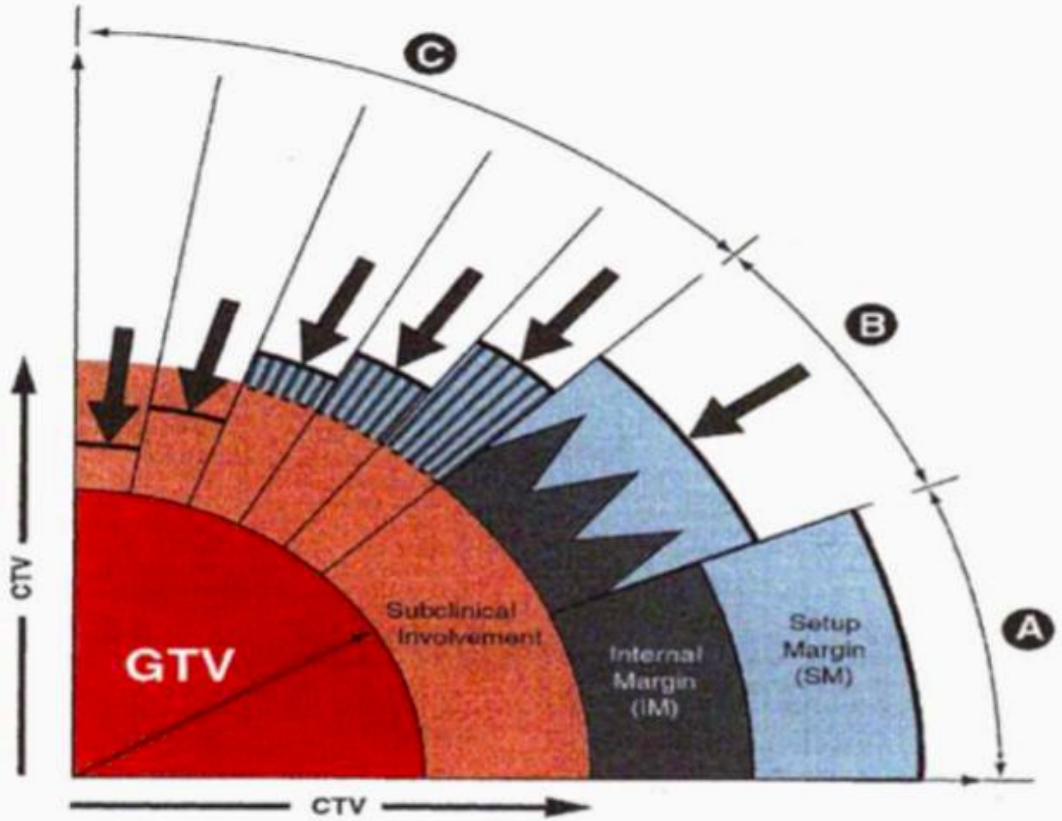
1. Tratamos a los pacientes asumiendo que la forma, el volumen y las posiciones relativas de la estructura serán las mismas durante todo el tratamiento.

2. Un paciente vivo es un problema de tratamiento dinámico.

3. Ninguno de los márgenes de ICRU explica estos cambios

1

ICRU 62



The arrow illustrates the influence of the organs at risk on delineation of the PTV (thick,full line).

- Gross Tumor Volume (GTV)
- Subclinical Involvement
- Internal Margin (IM)
- Set Up Margin (SM)

Ejemplos de cambios dentro de un curso de radioterapia

1. Cambios en el tamaño y la forma del tumor
   a. Cuello voluminoso que regresa con el tratamiento
   b. Regresión de masa retroperitoneal que hace que los riñones sean en el campo de tratamiento
   c. Globo ocular proptótico que retrocede con respuesta a la radioterapia
   d. Hinchazón del quiste de un craneofaringioma
2. Cambios en la geometría del paciente
   a. Pérdida de peso
   b. Cambios postoperatorios resolviendo / edema

Ejemplos de cambios dentro de un curso de radioterapia

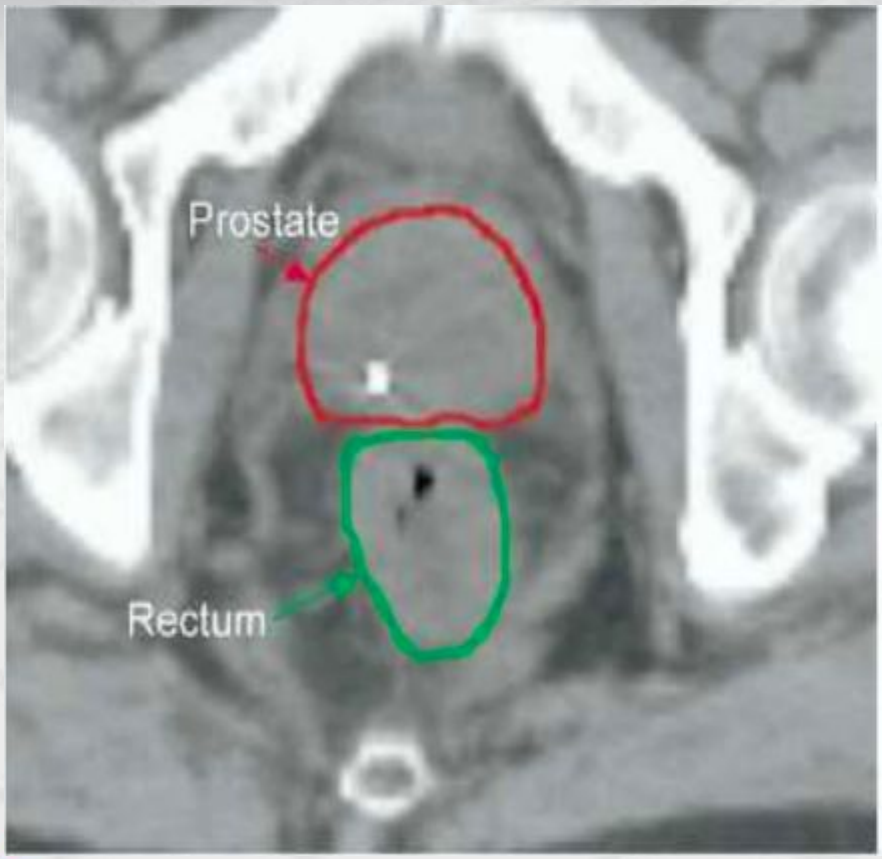
3. Cambios en el tamaño / forma y la relación de los OAR circundantes

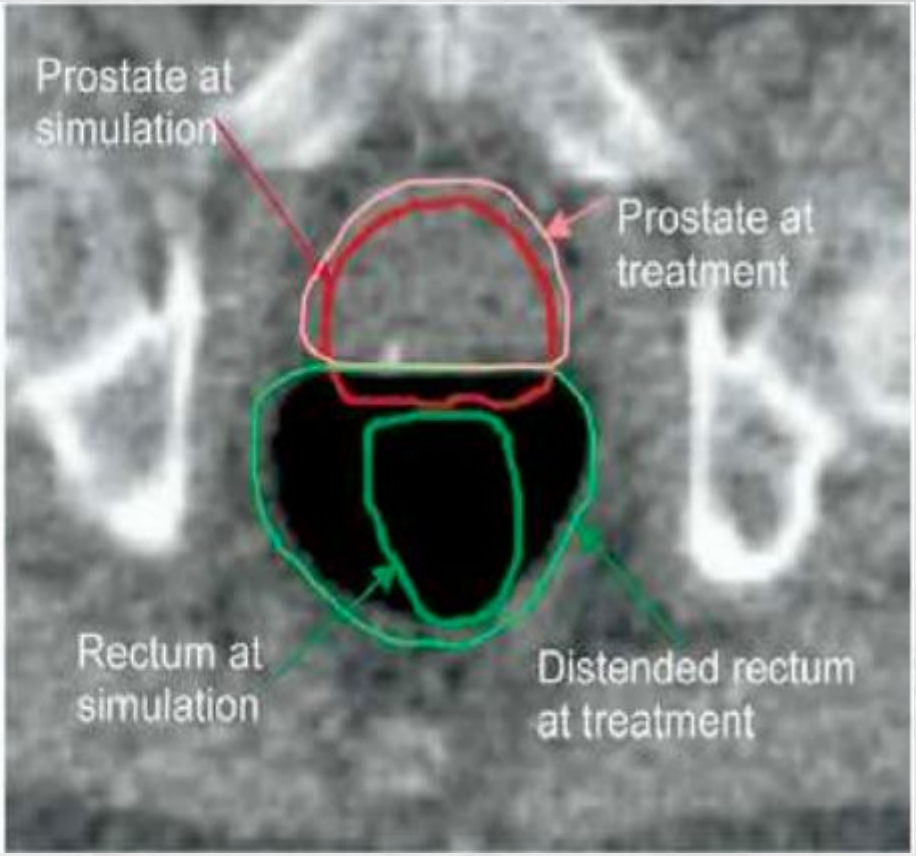
a. Distensión rectal que causa desplazamiento de próstata.
b. Alivio de la obstrucción esofágica
c. causando pulmón el movimiento del pulmón en el volumen objetivo
d. Pérdida de volumen de la parótida
e. Pérdida de grasa de la pared abdominal

Ejemplos de cambios dentro de un curso de radioterapia

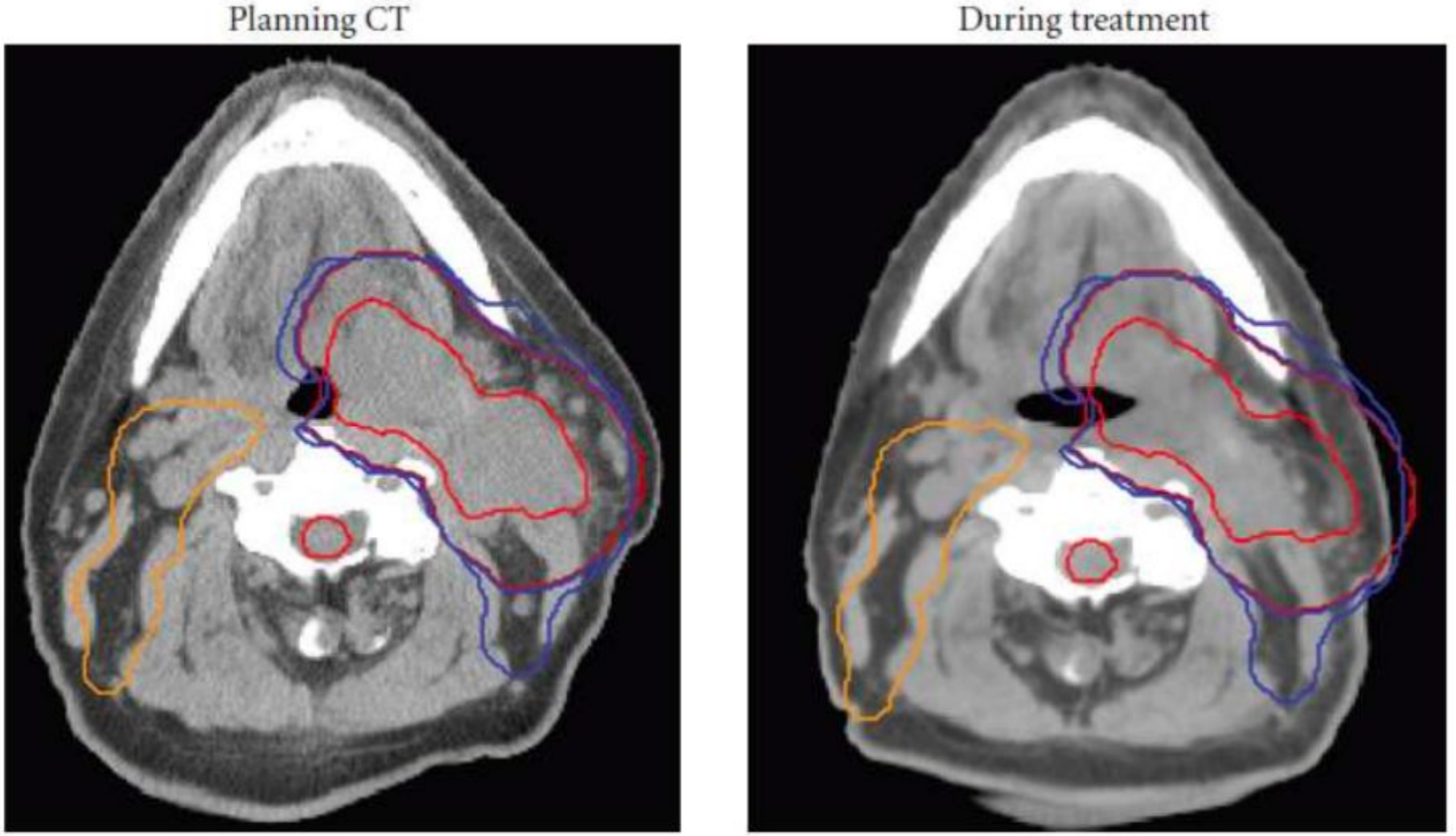
4. Cambios en los patrones de absorción en tumores
    a. Áreas hipóxicas que no responden a la RT
    b. Nuevas áreas de captación

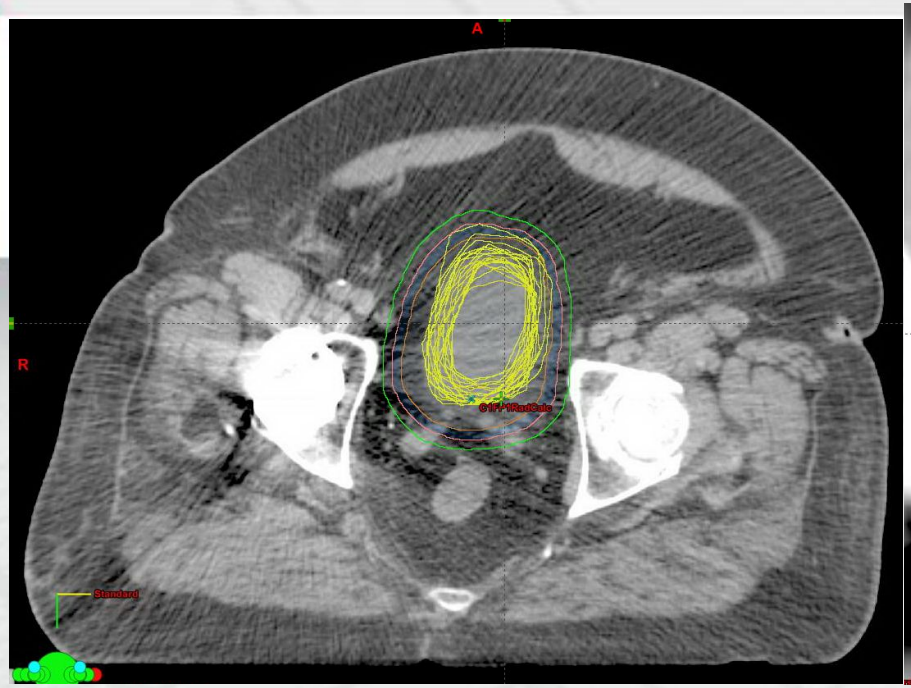
Ejemplo: Cáncer de prostata

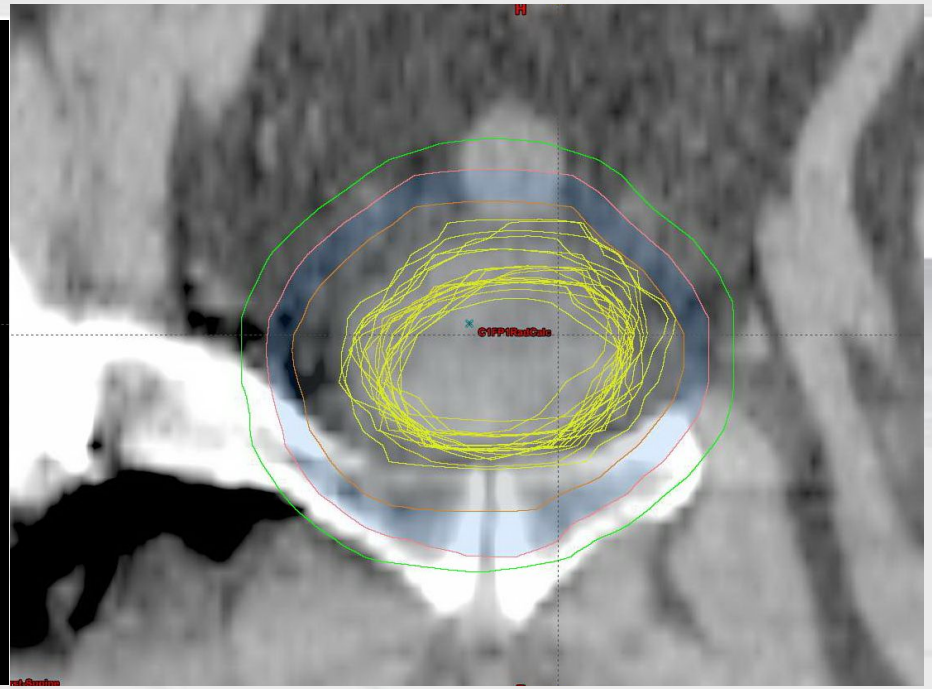




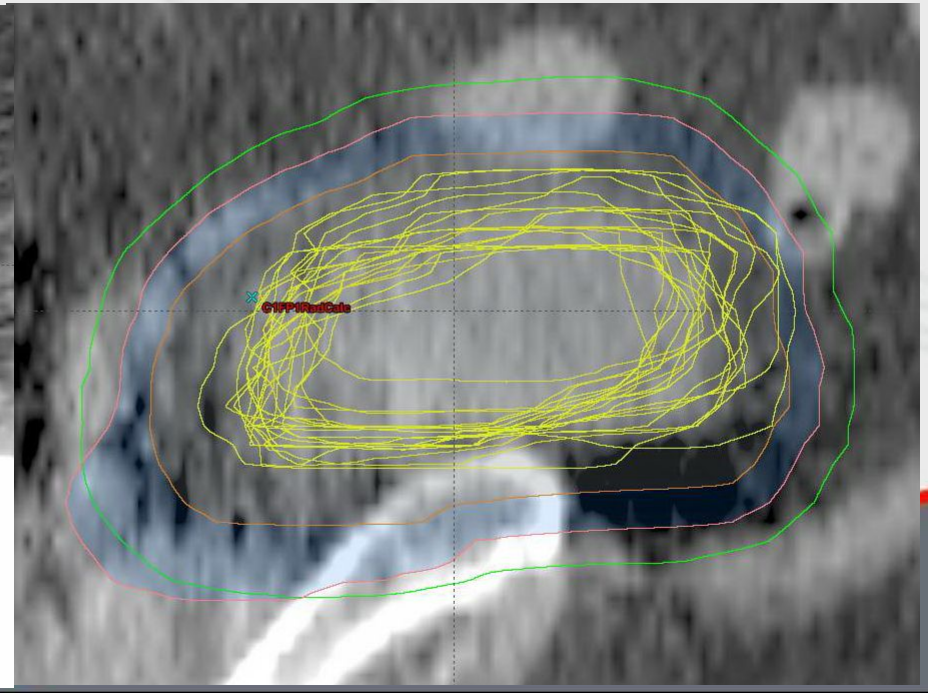
Ejemplo: Cáncer de cabeza y cuello

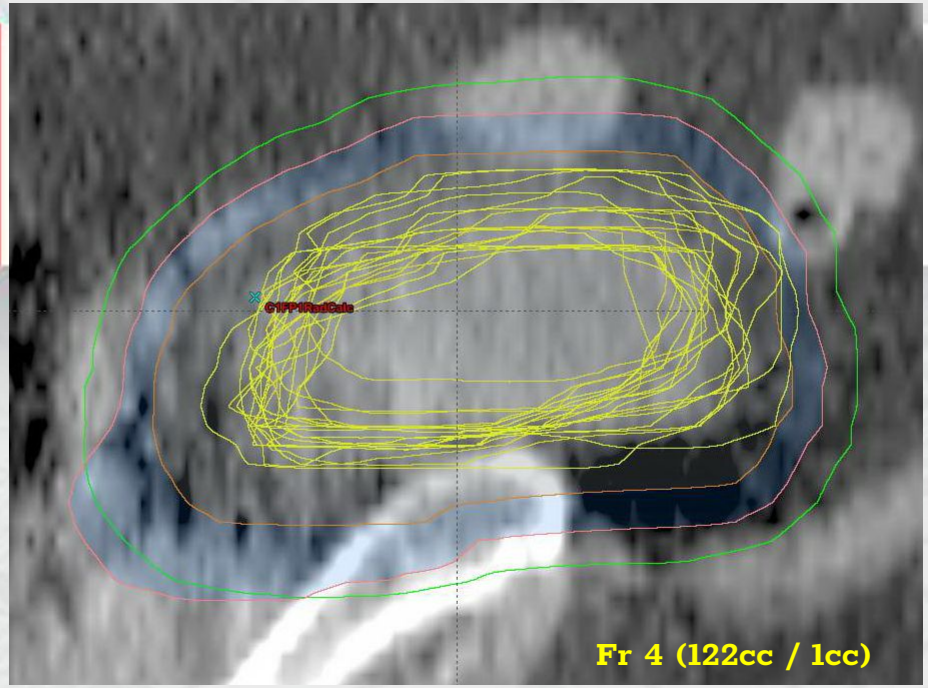


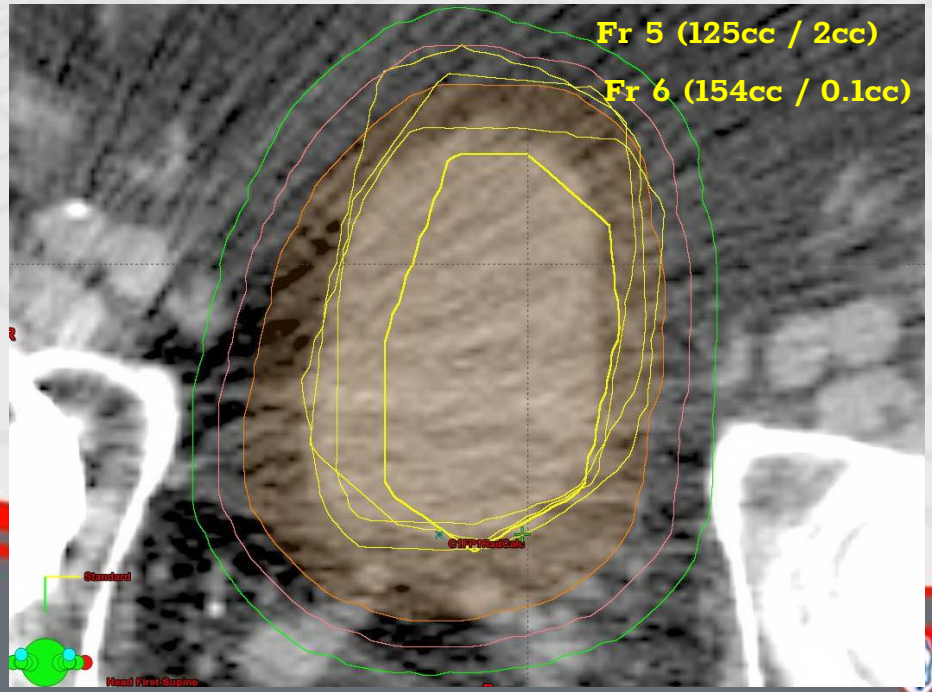





Bladder +1cm
Bl +1.5cm
Bl +1.5cm





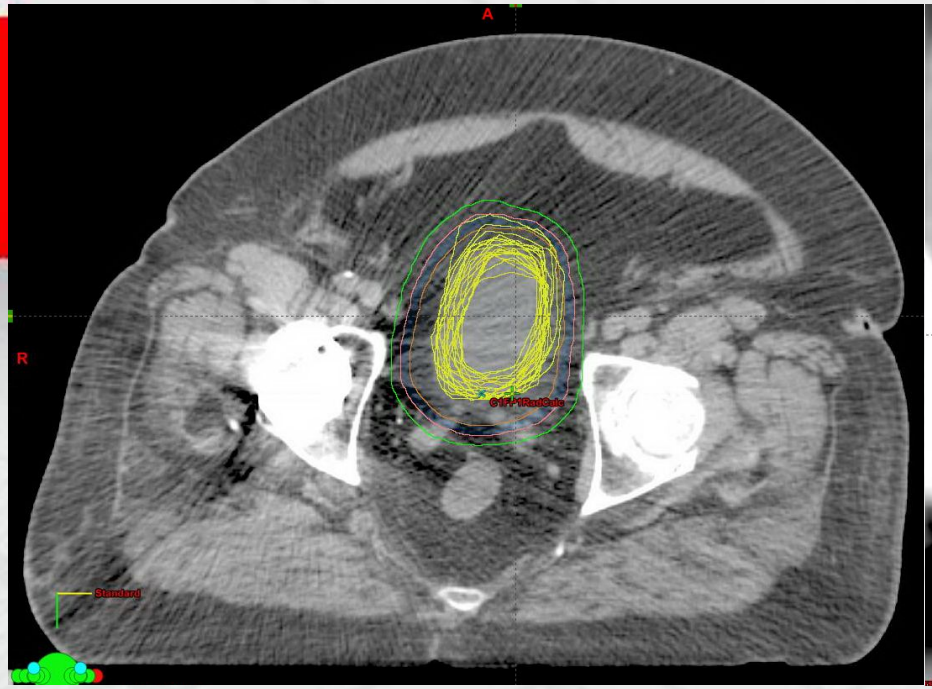


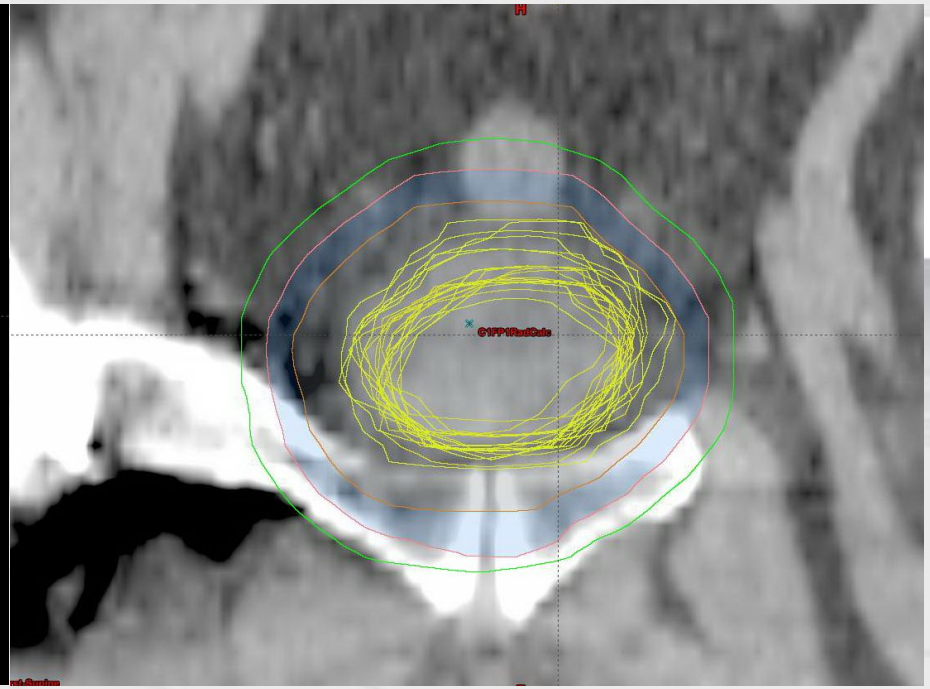
CT simulation	(cc)
bladder	103.2
bladder+1cm	273.0
bladder+2cm	566.1

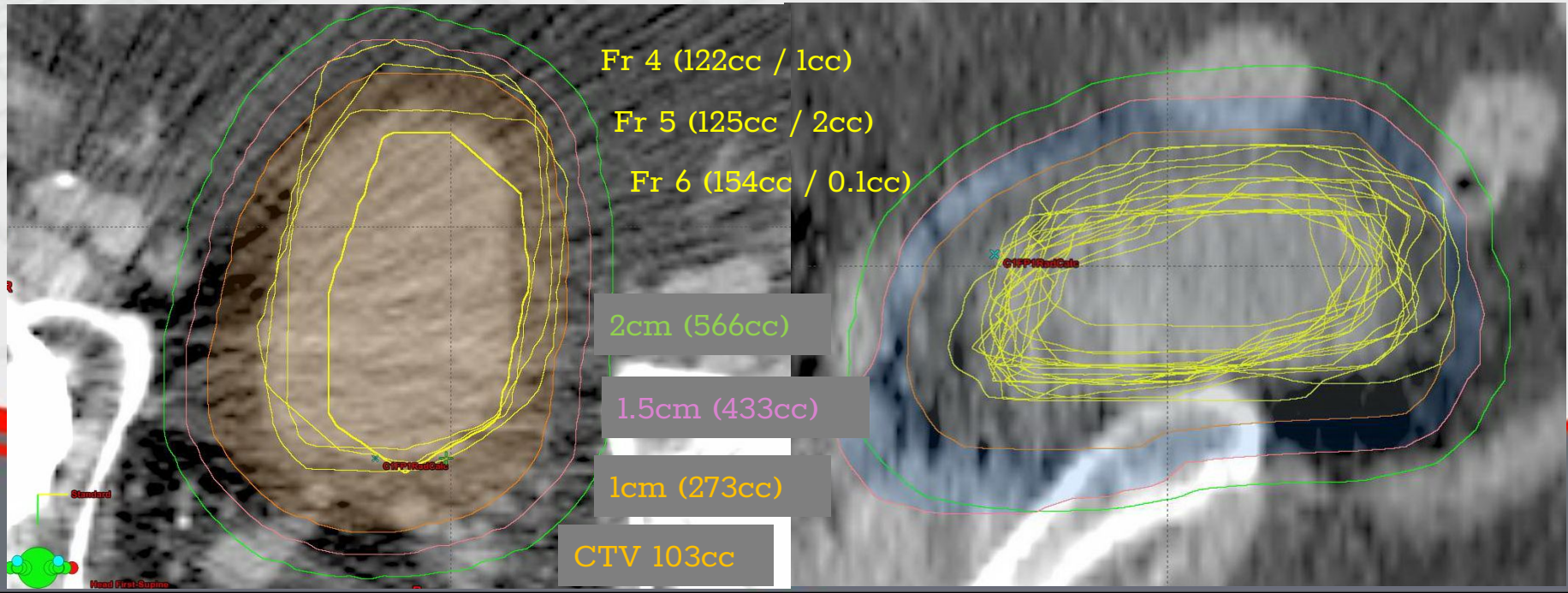
Fraction #	Volume (cc)	out of 1cm margin (cc)
1	55.8	0
2	99.9	0
3	53.86	0
4	121.68	0.83
5	124.93	1.98
6	153.8	0.11
7	62.91	0
8	68.44	0
9	102.73	0.01
10	83.6	0
11	78.74	0
12	60.06	0
13	71.23	0
14	59.43	0
15	63.1	0
16	87.89	0
17	58.4	0
18	48.63	0
19	70.4	0
20	63.89	0

McGill University Health Centre

K. Adil, M. Popovic, L. Souhami



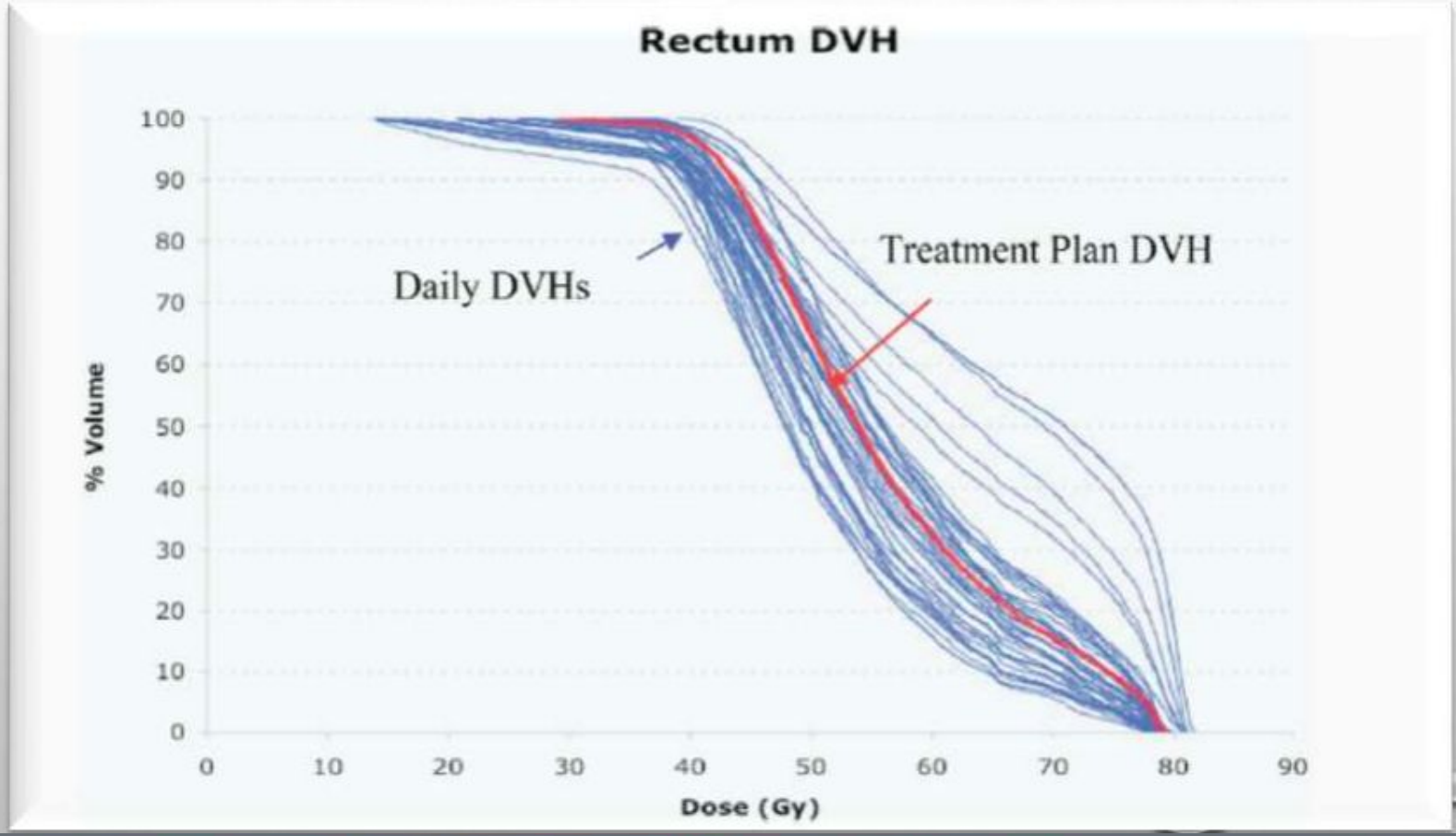



Fr 4 (122cc / 1cc)
Fr 5 (125cc / 2cc)
Fr 6 (154cc / 0.1cc)
2cm (566cc)
1.5cm (433cc)
1cm (273cc)
CTV 103cc

DAILY VARIATIONS IN DELIVERED DOSES IN PATIENTS TREATED WITH RADIOTHERAPY FOR LOCALIZED PROSTATE CANCER

PATRICK A. KUPELIAN, M.D.,* KATJA M. LANGEN, PH.D.,* OMAR A. ZEIDAN, PH.D.,* SANFORD L. MEEKS, PH.D.,* TWYLA R. WILLOUGHBY, M.S.,* THOMAS H. WAGNER, PH.D.,* SAM JESWANI, PH.D.,† KENNETH J. RUCHALA, PH.D.,† JASON HAIMERL, PH.D.,† AND GUSTAVO H. OLIVERA, PH.D.†‡

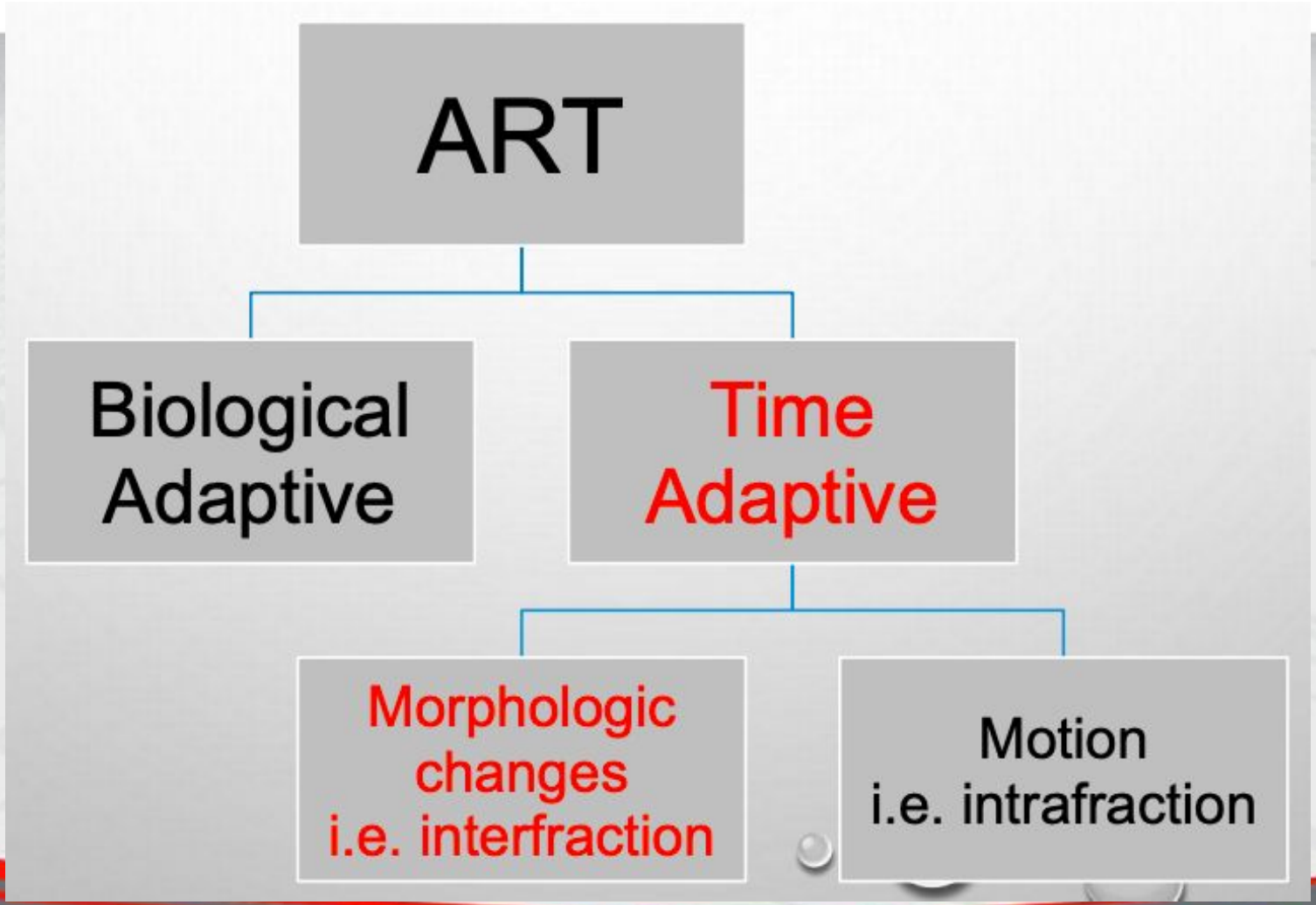
*Department of Radiation Oncology, The M. D. Anderson Cancer Center Orlando, Orlando, FL; †TomoTherapy Inc., Madison, WI; ‡University of Wisconsin-Madison, Madison, WI



¿Cómo reconocer la necesidad de la RTA?

1. Valoración clínica
2. Dispositivos de inmovilización mal ajustados
3. Imagenes de guía
4. Quejas de los pacientes

Tipos de RTA

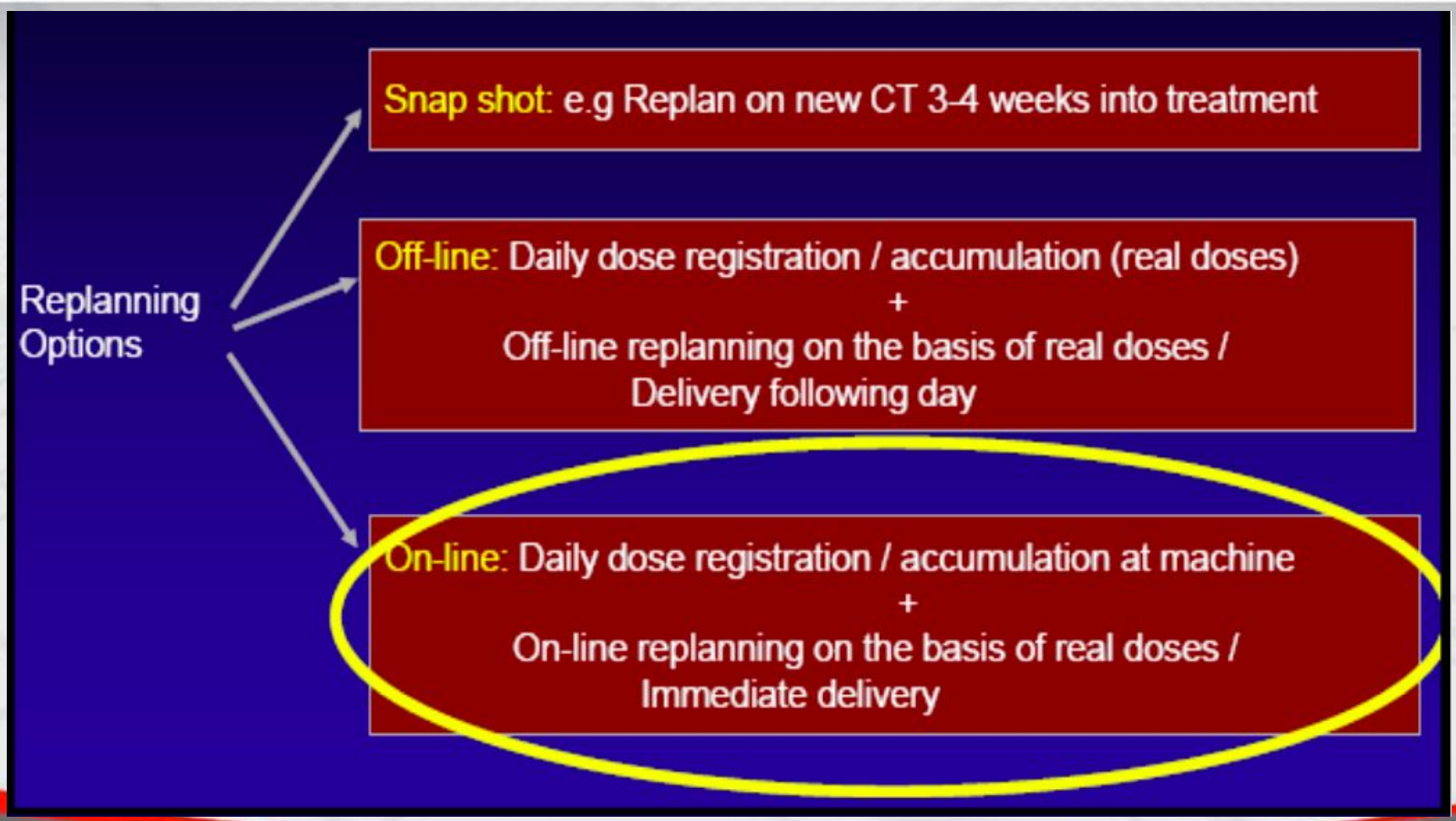

ART
Biological Adaptive
Time Adaptive
Morphologic changes i.e. interfraction
Motion i.e. intrafraction

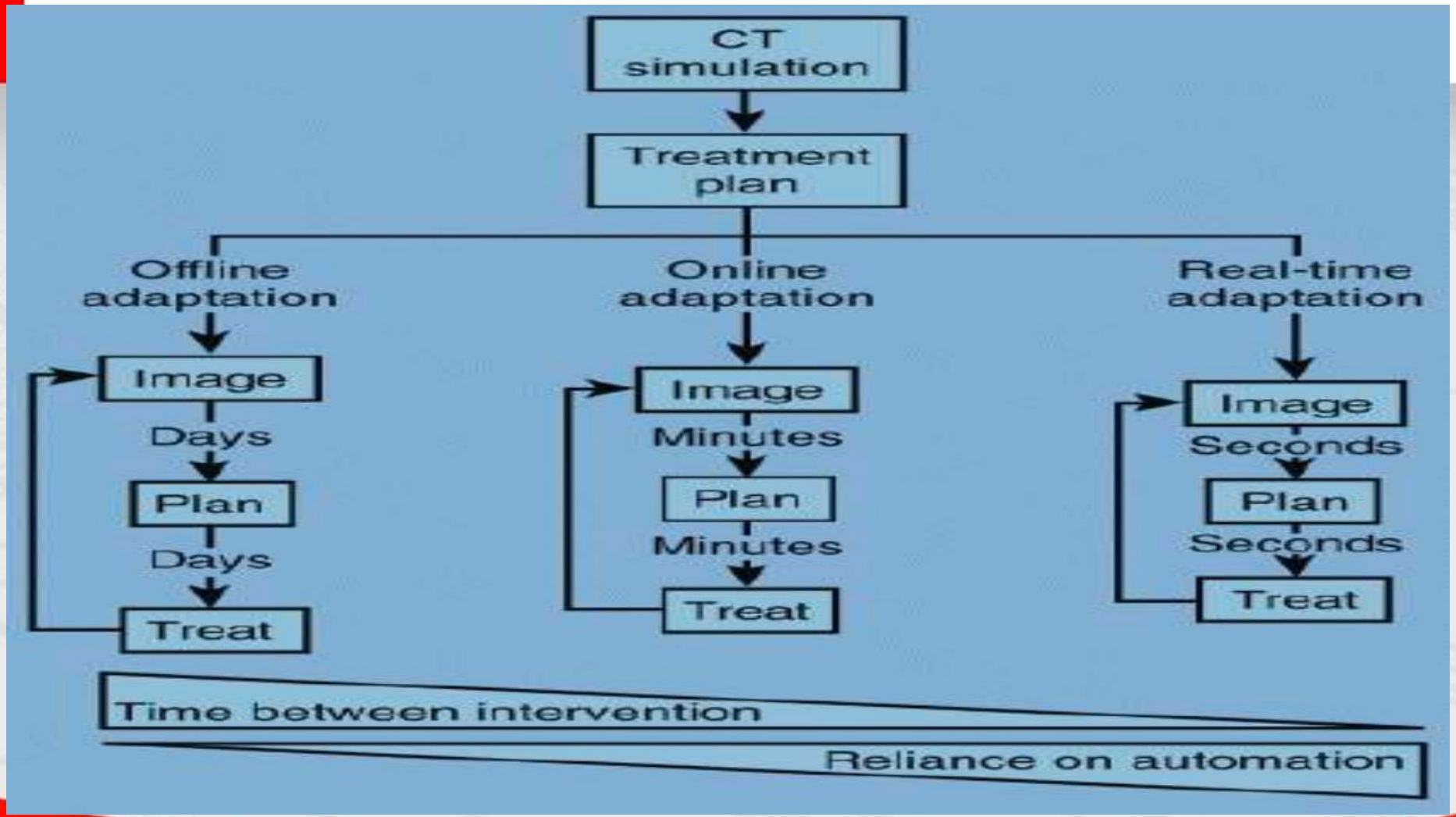
Los basicos de la RTA

La radioterapia adaptativa requiere que se haga un nuevo plan de radiación para el paciente

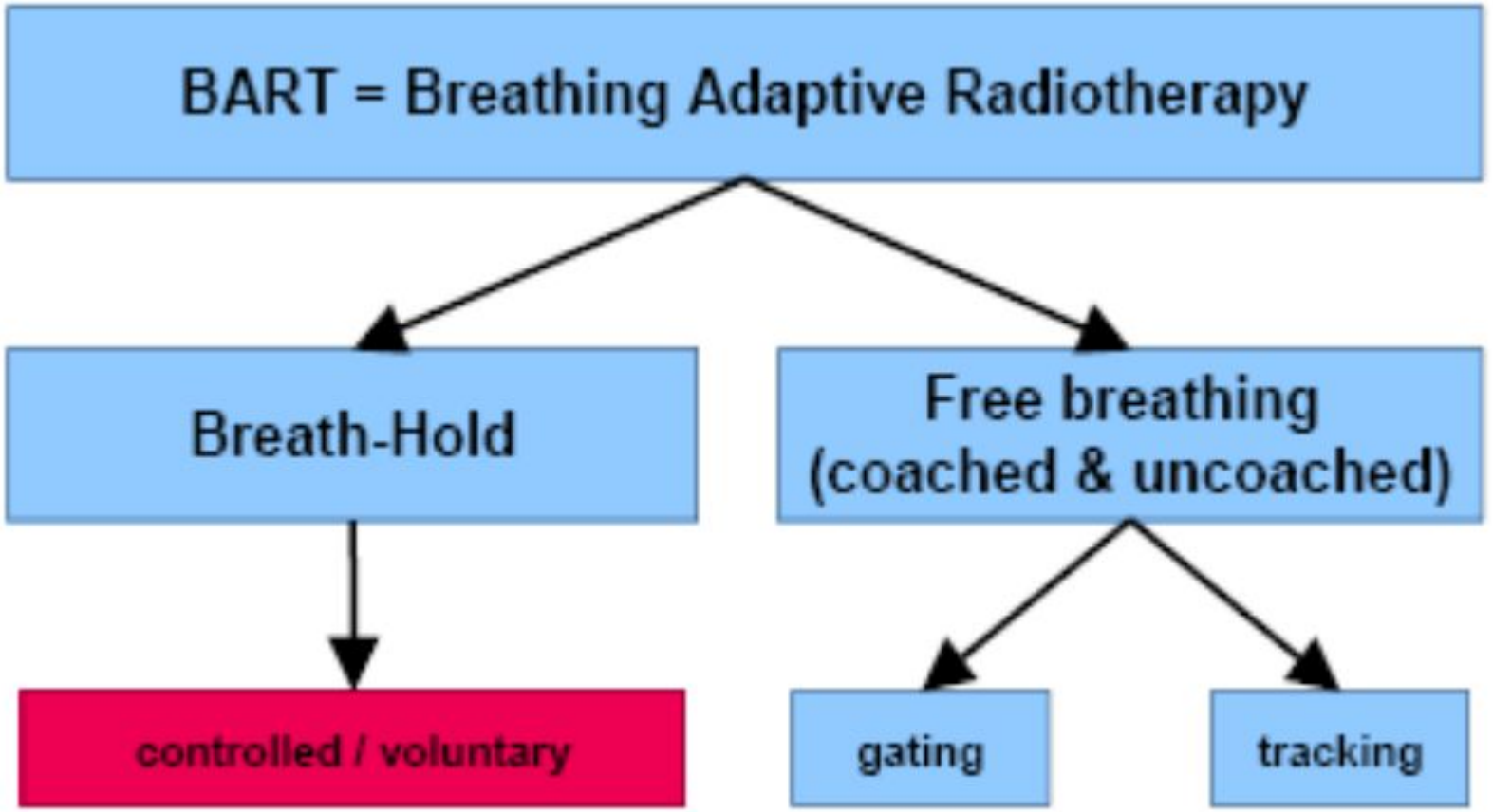
Puede ocurrir en diferentes escalas de tiempo:

- En cualquier momento dado
- Fuera de línea entre fracciones (Offline)
- En línea inmediatamente antes de una fracción (Online)
- En tiempo real durante una fracción (real-time)

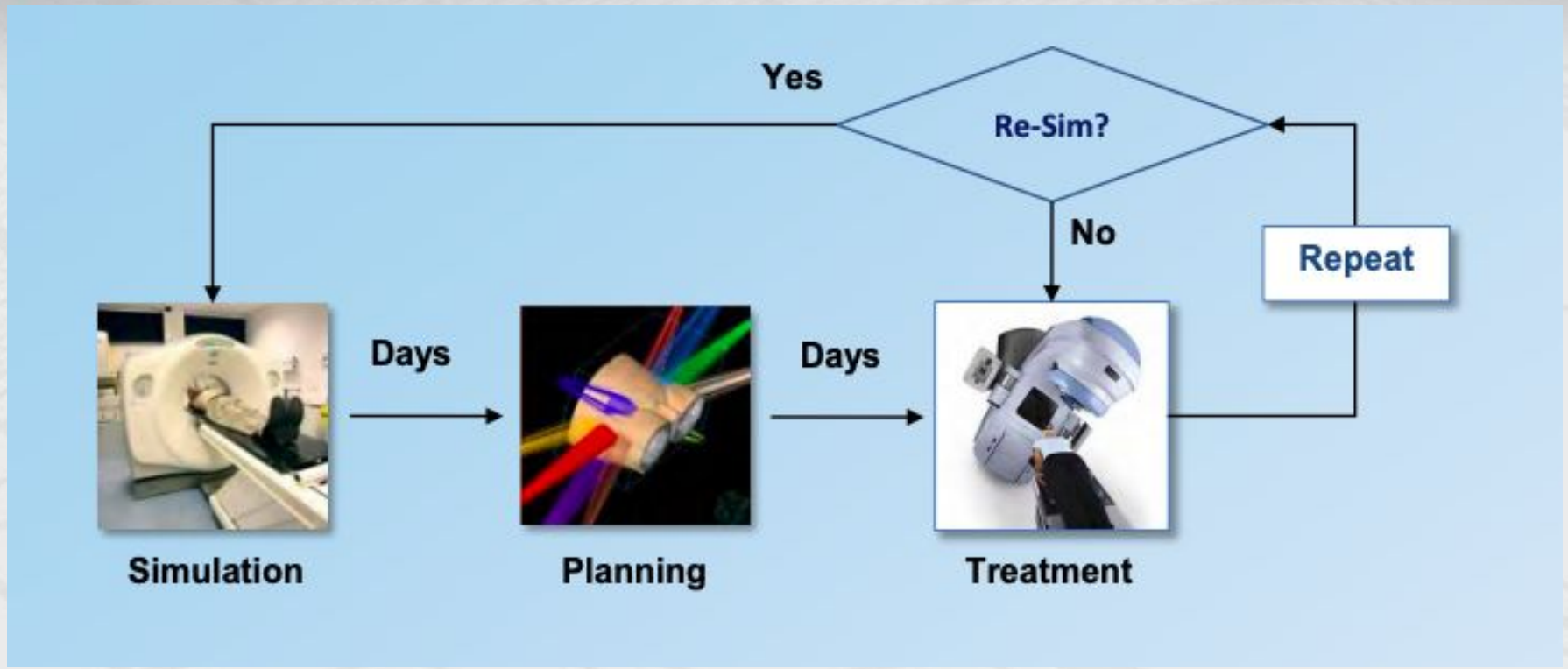

Replanning Options
Snap shot: e.g Replan on new CT 3-4 weeks into treatment
Off-line: Daily dose registration / accumulation (real doses)
+
Off-line replanning on the basis of real doses /
Delivery following day
On-line: Daily dose registration / accumulation at machine
+
On-line replanning on the basis of real doses /
Immediate delivery


CT simulation
Treatment plan
Offline adaptation
Online adaptation
Real-time adaptation
Image
Days
Plan
Days
Treat
Image
Minutes
Plan
Minutes
Treat
Image
Seconds
Plan
Seconds
Treat
Time between intervention
Reliance on automation

Tipos de RTA


BART = Breathing Adaptive Radiotherapy
Breath-Hold
Free breathing
(coached & uncoached)
controlled / voluntary
gating
tracking

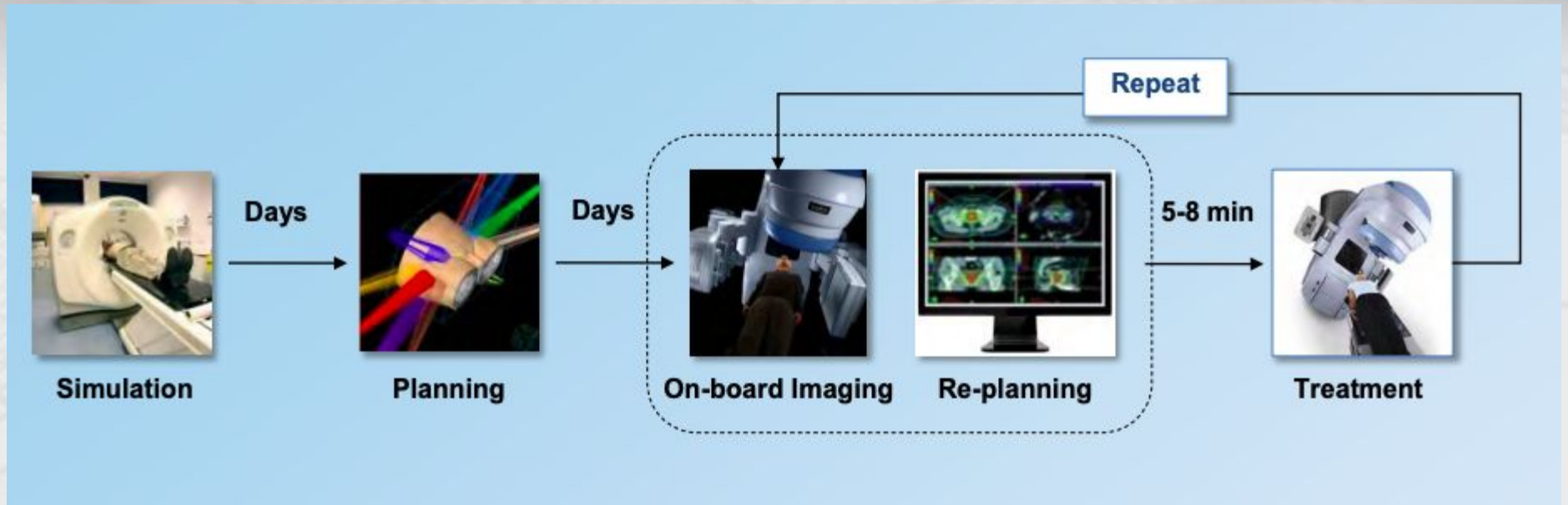
RTA Offline


Yes
Re-Sim?
No
Repeat
Days
Days
Simulation
Planning
Treatment

RTA Offline

1. Respuesta tumoral significativa y / o pérdida de peso significativa → Modificación del plan en medio del tratamiento
2. Baja eficiencia → Limitado a 1 modificación por paciente y muy pocos pacientes
3. Solo funciona para el cambio gradual de la anatomía del paciente.

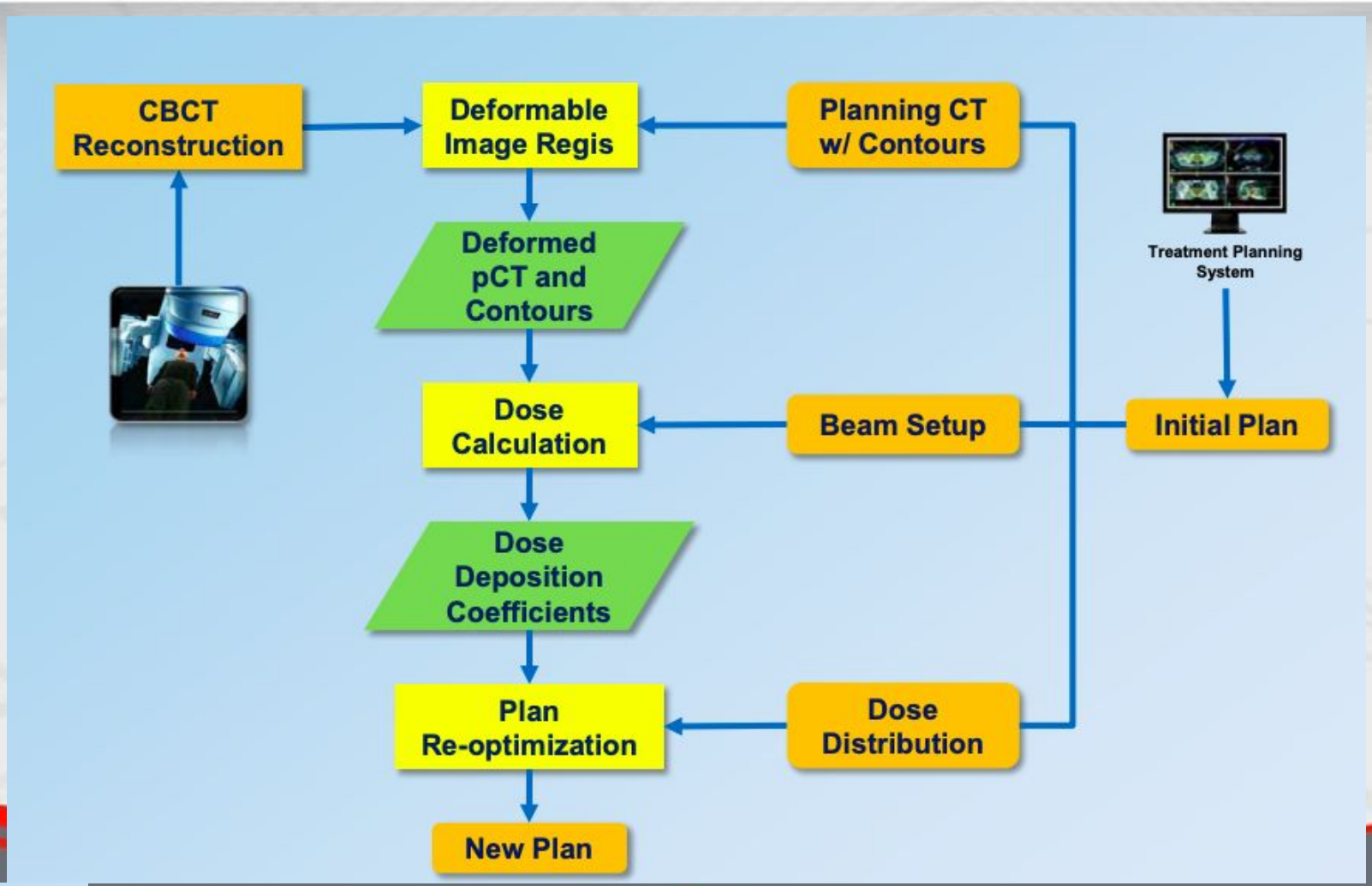
RTA Online


Repeat
Days
Days
5-8 min
Simulation
Planning
On-board Imaging
Re-planning
Treatment

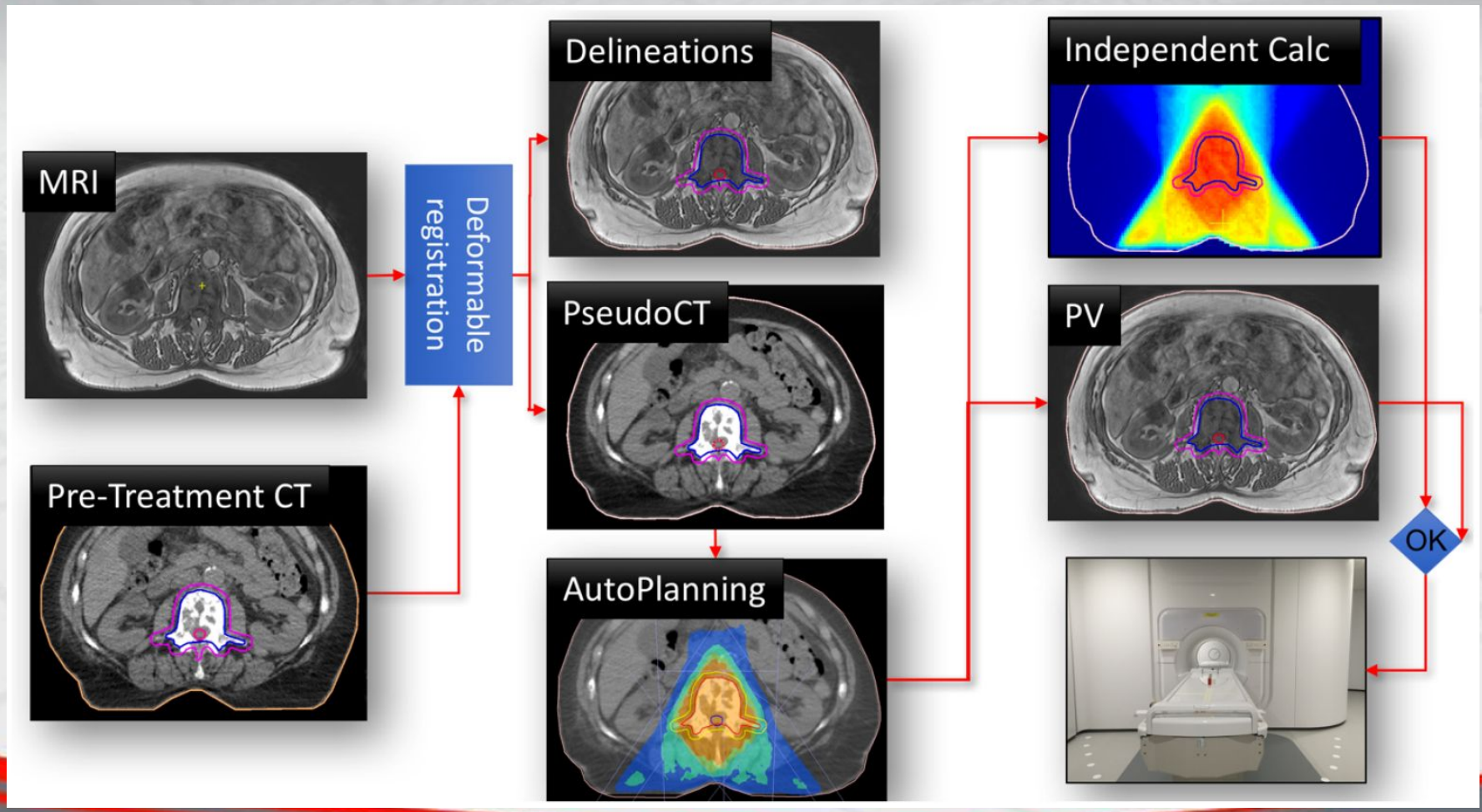
RTA Online

1. Tecnologías de tomas de imágenes volumétricas permiten de obtener imágenes antes y durante el tratamiento
2. Obstáculos técnicos importante para la realización clínica de la RTA en línea
   a. Re-planificación en tiempo real
   b. Cálculo y integración de dosis de imagen
   c. Flujo de trabajo clínico es complicado

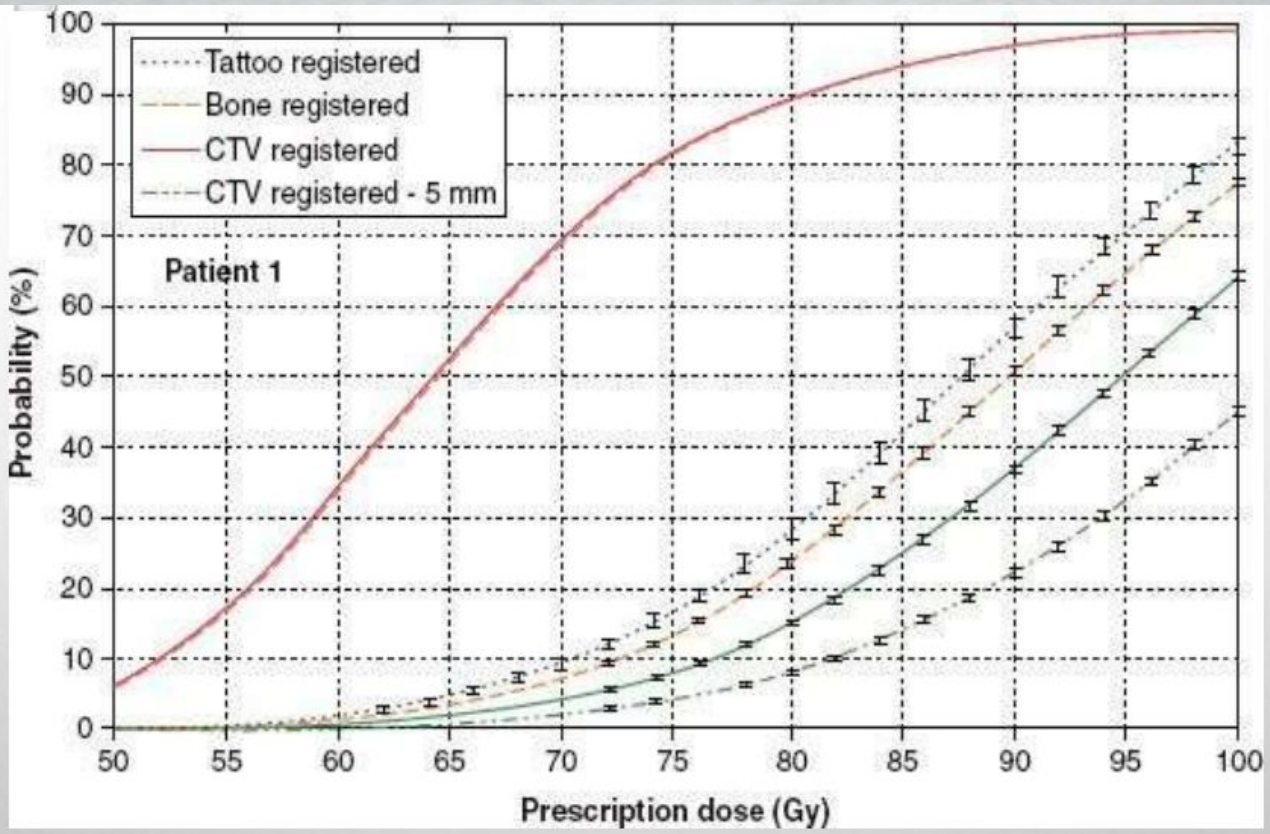
Proceso de planificación de la RTA Online



Proceso de planificación de la RTA Online



Ejemplo clínico: RTA en cáncer de próstata



Tumor control probability (TCP) and rectum normal tissue complication probability (NTCP) curves for prostate cancer patients, from 50 to 100 Gy in 2-Gy per-fraction increments, for the three image-guided adaptive registration techniques: tattoo, bone, clinical target volume (CTV) registered, and CTV-registered with margin reduced to 5 mm

Ejemplo clínico: RTA en cáncer de próstata

A DOSE-ESCALATION TRIAL WITH THE ADAPTIVE RADIOTHERAPY PROCESS AS A DELIVERY SYSTEM IN LOCALIZED PROSTATE CANCER: ANALYSIS OF CHRONIC TOXICITY

DONALD BRABBINS, M.D., ALVARO MARTINEZ, M.D., F.A.C.R., DI YAN, D.SC., DAVID LOCKMAN, D.SC., MICHELL WALLACE, R.N., GARY GUSTAFSON, M.D., PETER CHEN, M.D., FRANK VICINI, M.D., AND JOHN WONG, PH.D.

Department of Radiation Oncology, William Beaumont Hospital, Royal Oak, MI

Ejemplo clínico: RTA en cáncer de próstata

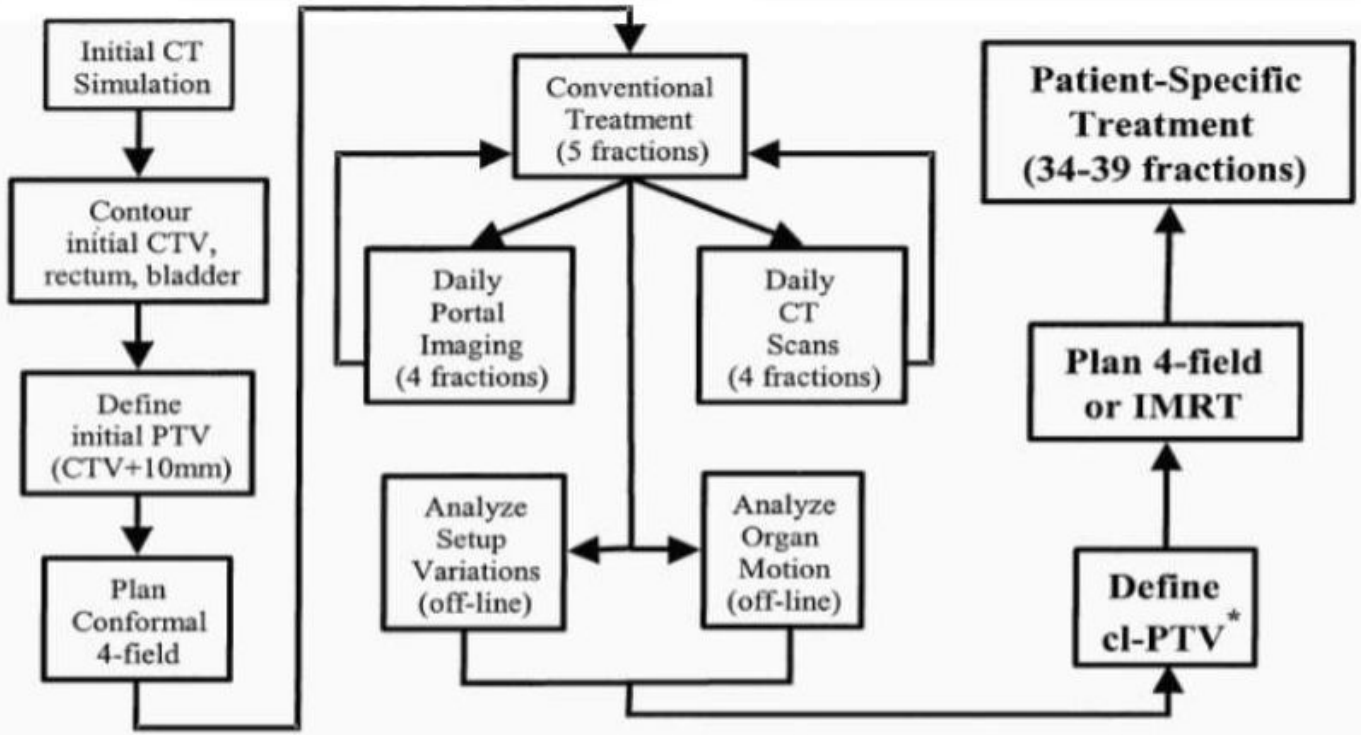


Fig. 2. Flowchart depicting the adaptive radiation therapy (ART) process. The process performs off-line analysis of the setup error and organ motion occurring during the first 5 days of treatment. These characterizations are used to predict variation over the remaining fractions, and the c1-PTV is designed to provide dosimetric coverage of the nonsystematic components of these variations. Systematic components are removed with commensurate block aperture shifts during replanning. Cl-PTV = confidence limited PTV; CT = computed tomography; CTV = clinical target volume; IMRT = intensity-modulated radiation therapy; PTV = planning target volume.

Ejemplo clínico: RTA en cáncer de próstata

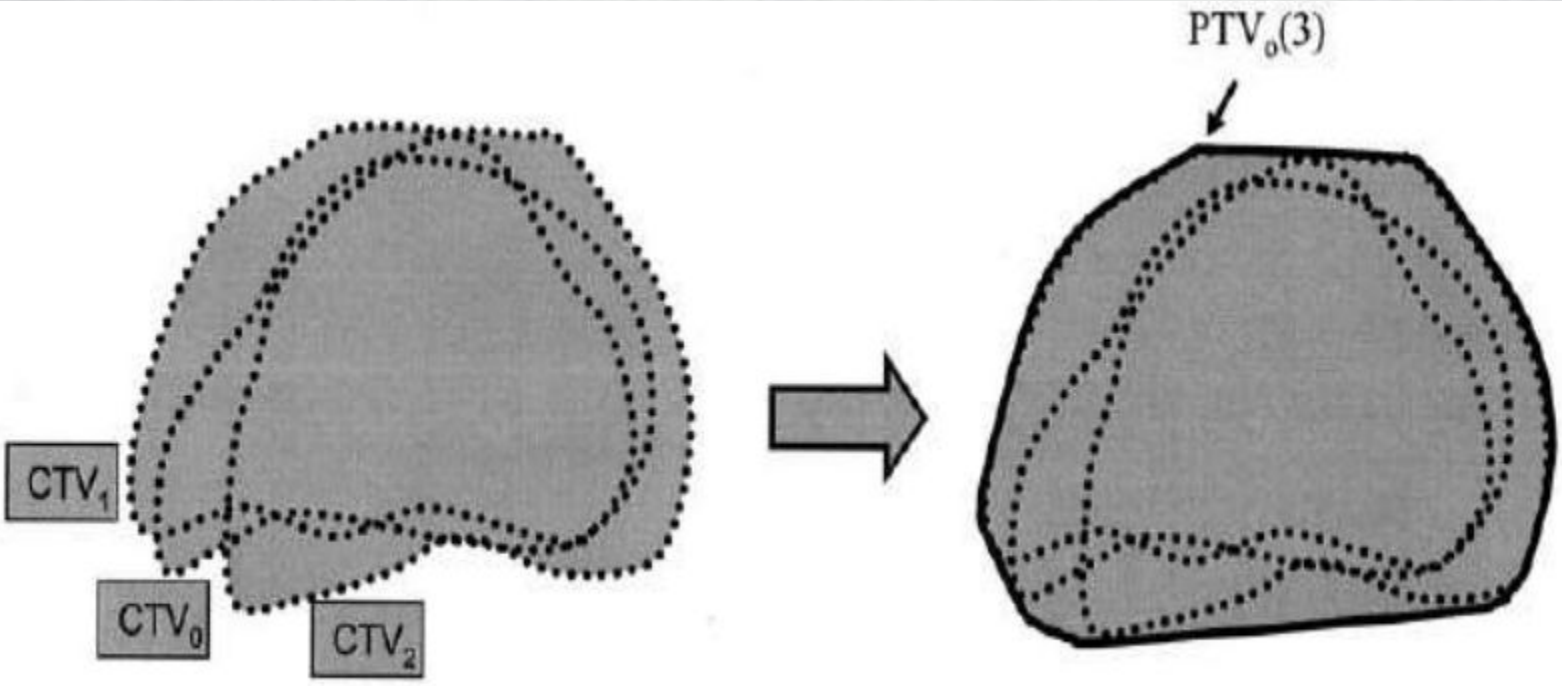
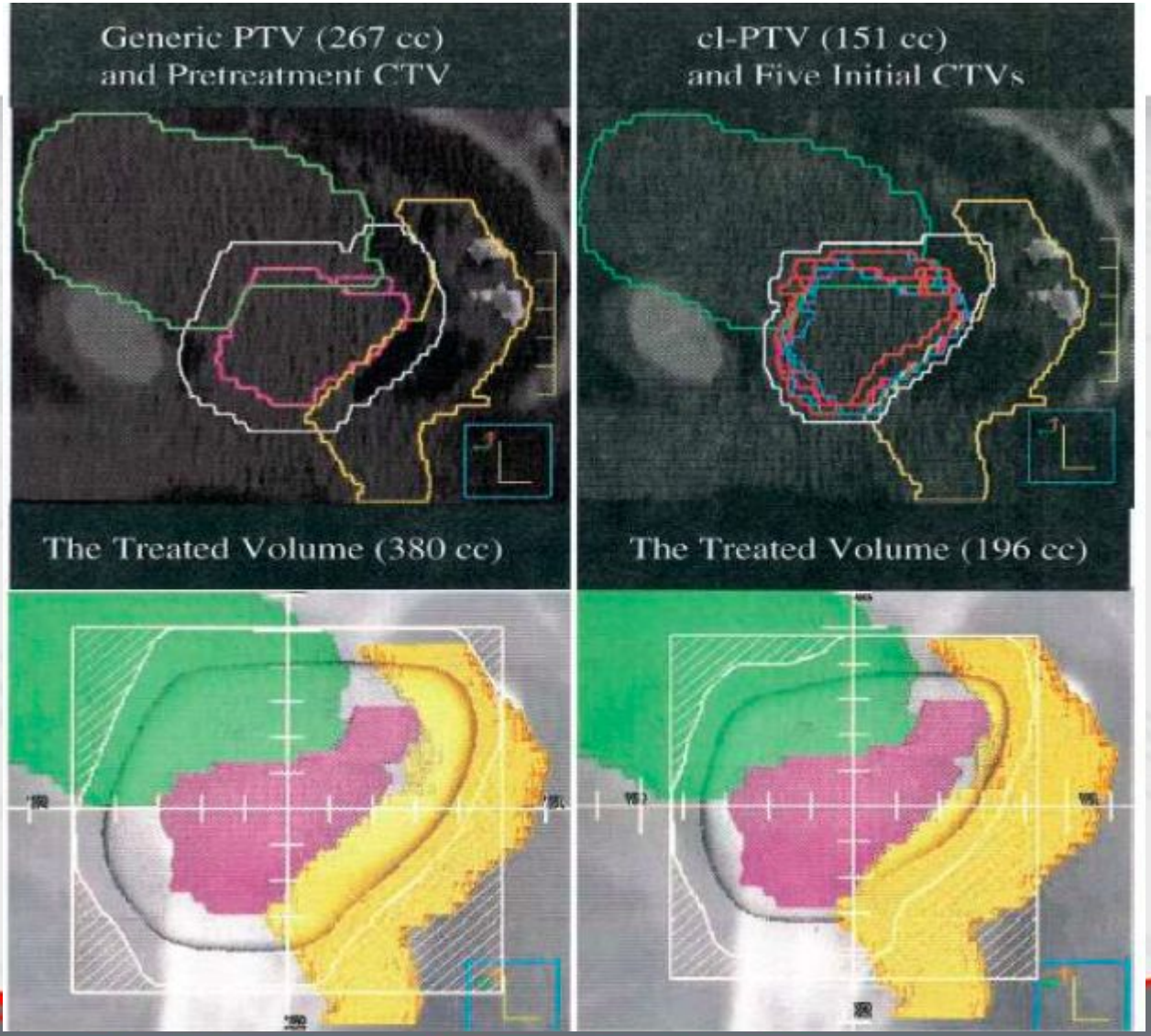


Fig. 1. Illustration of the convex hull of multiple clinical target volumes (CTVs) and planning target volume (PTV).

Ejemplo clínico: RTA en cáncer de próstata



Gracias

Preguntas?