

CBCT como Ferramenta para Radioterapia Adaptativa

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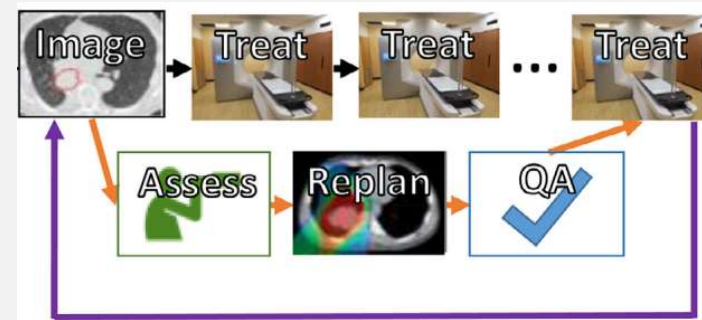


Declaro não ter conflito de interesses

ART – Radioterapia Adaptativa

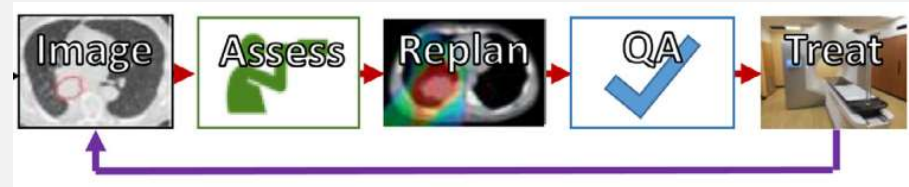
Adaptar o plano de tratamento baseado na monitoração de variações anatômicas graduais ao longo do curso terapêutico;

OFFLINE

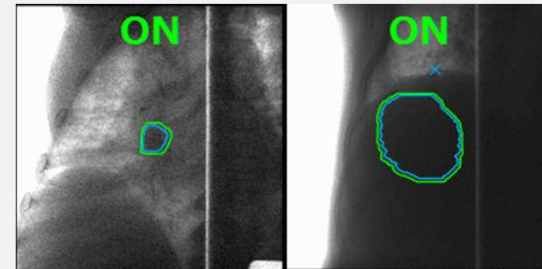


ART

ONLINE

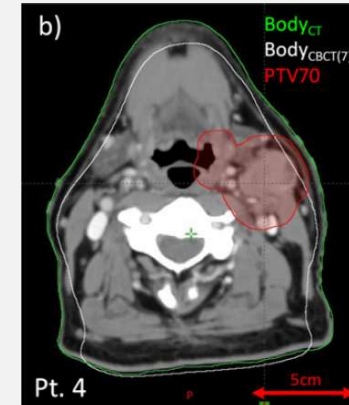
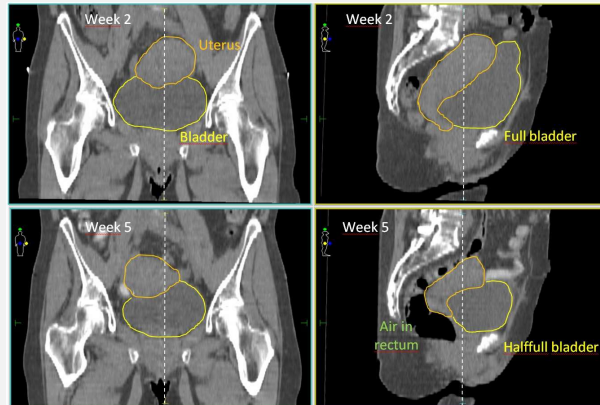
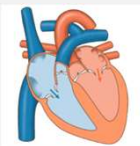


“TEMPO-REAL”



ART – Radioterapia Adaptativa

ART



intrafraction change

interfraction change

offline ART replanning

online ART replanning

gating, tracking, and realtime ART planning

Segundos

Semanas

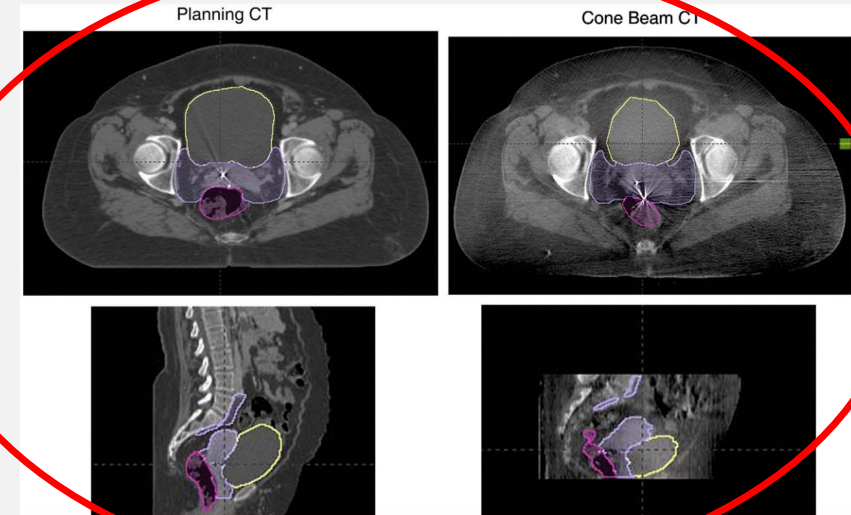
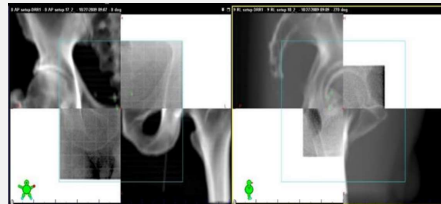
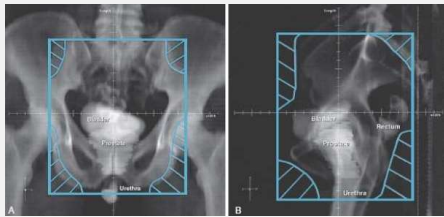
CBCT e ART – Uma feliz coincidência...

HOSPITAL DE AMOR

Evolução
do IGRT

Imagens 3D
(Osso/Tecido
Mole/Ar)

Imagens 2D
(Referência Óssea)



Tempo

- CBCT: Ferramenta de IGRT de grande importância para avaliação/correção do setup e posicionamento...
- Detalhamento anatômico único -> Reais condições do paciente no dia do tratamento..
- Novo Plano? Simulação da real distribuição dosimétrica? CBCT e ART: uma possibilidade?



CBCT e ART: Parâmetros Importantes

Contraste

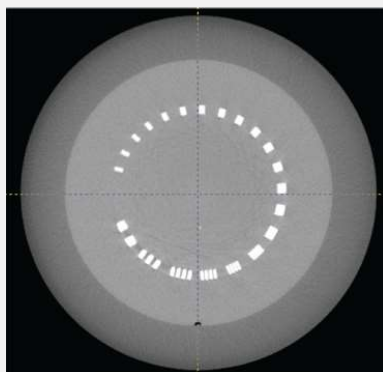


Diferenças de Densidade
(Osso, Tecido Mole e Ar)

(Relação LCV // Protocolo de Aquisição // Filtro "Full Fan & Half Fan")



Resolução Espacial



Similar à pCT
(Milimétrica)



Limitações do FOV



- Até 50 cm;

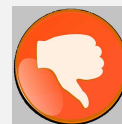
FOV



Qualidade da
Imagem

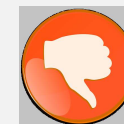


- Perda de Informação Anatômica;



Dose Adicional ao Paciente

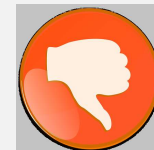
- *Qualidade x Dose;*
- *(Relação FOV, kV, mAs, Modo de Imagem);*
- *Pode chegar a até 6 cGy por scan (TG-180 - kVCBCT);*



Ding, G. X. Image guidance doses delivered during radiotherapy: Quantification, management, and reduction: Report of the AAPM Therapy Physics Committee Task Group 180, 2018

CBCT e ART: Parâmetros Importantes

Artefatos de Reconstrução



Feixe de Raios-X

- *Beam-Hardening*
- *Cupping Effect*

Paciente

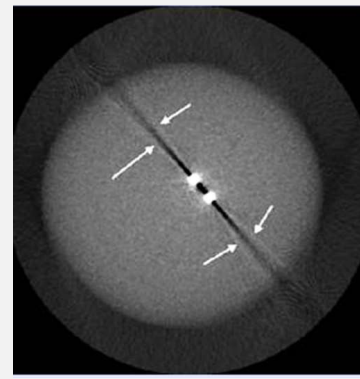
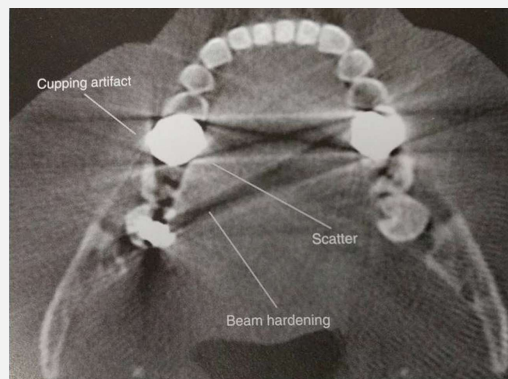
- *Implantes metálicos*
- *Movimentos*
*Fonte, Objeto, Detector
(Efeito "Double Contour")

Varredura do Scanner

- *Artefatos de Anéis ("Rings")*

Ruído

- *Aliasing;*
- *Espalhamento*
- *Extinction Artifacts;*



CBCT e ART – Quais Recursos Usar?

RIR

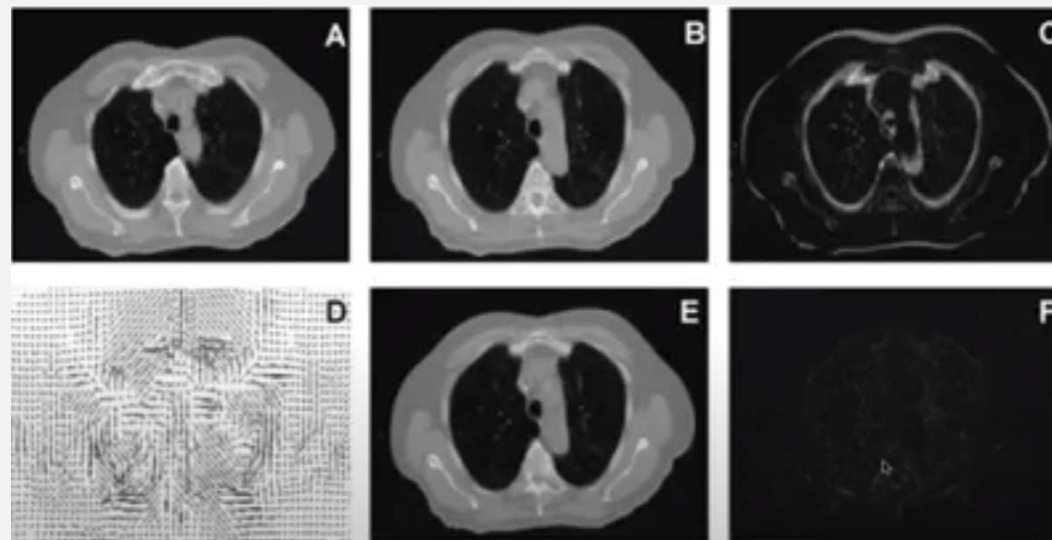
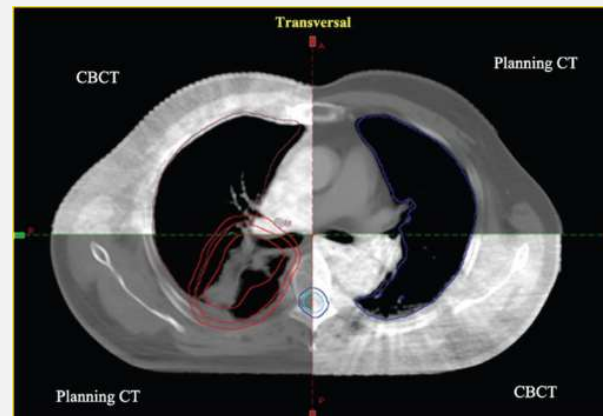
Rígido

Registro de Imagens

DIR

Deformável

Vetor de Deformação de Campos
(DVF's) – Matriz de Deformação 3D;



Huang, T-C. Semi-automated CT segmentation using optic flow and Fourier interpolation techniques. Elsevier, 2006.

CBCT e ART – Quais Recursos Usar?

Registro de Imagens

DIR

Deformável

Identificar mudanças no formato e tamanho de estruturas internas;

Pode ser usado para ART Online ou Offline;

Hurst CK, G et al. Adaptive radiation therapy (ART) strategies and technical considerations: A state of the ART review from NRG Oncology, International Journal of Radiation Oncology (2020)

Vendor	DIR Algorithm	Unimodal Registration (CT, CBCT)	Multimodal Registration (CT, PET, MR)	Contour Propagation	Dose Warping and Summation	Offline ART	Online ART
Stand-alone deformable image registration products							
MIM (v6.8)	Free-form, Demons optical flow ^{27, 28}	YES	YES	YES	YES	NO	NO
Velocity (v3.2)	Multipass B-spline ²⁹	YES	YES	YES	YES	YES ⁺	NO
Mirada (vRTX1.8)	Unimodal: free-form Multimodal: Radial basis function ³⁰	YES	YES	YES	YES	YES ⁺	NO
Treatment planning systems with deformable image registration modules							
Raystation (v9A)	ANACONDA ³¹ , MORFEUS ³²	YES	YES	YES	YES	YES	NO
Eclipse (v15.6)	Unimodal: Accelerated Demons ³³ Multimodal: Adaptive gridbased Radial basis function	YES	YES	YES	YES	YES	NO
Pinnacle (v9.10)	Fast symmetric Demons, Salient-Feature-Based Registration (SFBR) ^{34, 35}	YES	YES	YES	YES	NO	NO
Monaco (v5.51)	Gradient-free Dense Hybrid MI Deformation ^{36, 37}	YES	YES	YES	YES	YES	YES
Precision (v2.1)	Multi-organ B-Spline ³⁸	YES	YES	YES	YES	YES	YES
ViewRay (v5.2.5)	Free-form Unimodal: Correlation coefficient Multimodal: Mutual Information	YES	YES	YES	NO	YES	YES

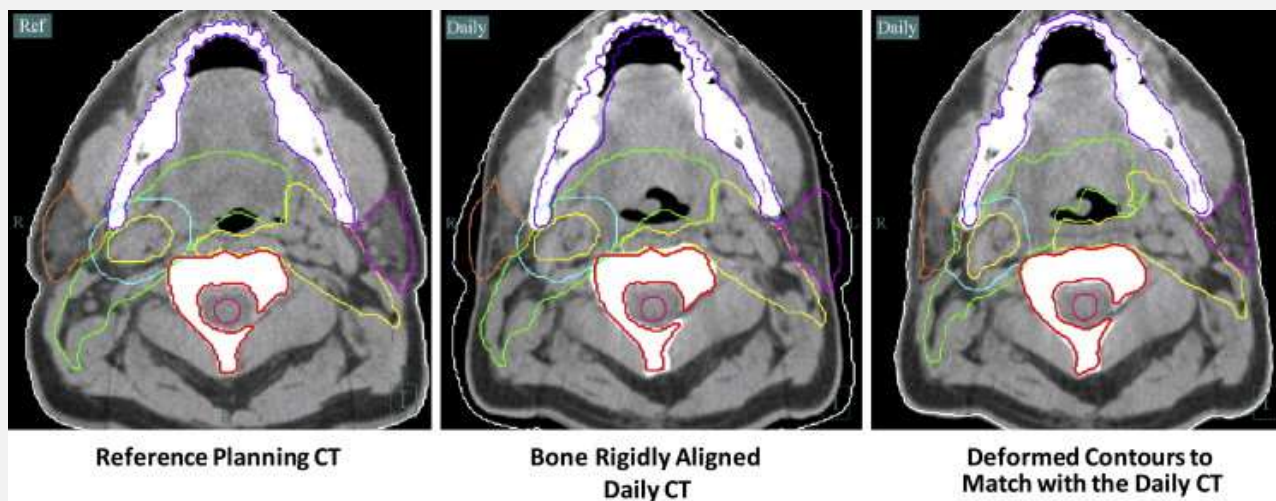
CBCT e ART – Quais Recursos Usar?

Registro de Imagens

DIR



Delineamento



Schwartz, D. L. et al. Adaptive Radiotherapy for Head-and-Neck Cancer: Initial Clinical Outcomes From a Prospective Trial. International Journal of Radiation Oncology, 2011

→ Pode-se usar recursos de Propagação de Estruturas e/ou AutoSegmentação, disponíveis nos softwares já citados;

→ Mas como validar esse registro?



CBCT e ART – Quais Recursos Usar?

Registro de Imagens

DIR



Delineamento

➡ TG 132: Inclui métodos qualitativos (*visual checkings*) e métricas quantitativas;

TABLE III. Quantitative metrics to evaluate image registration.

Technique	Evaluation metric	Tolerance
Target registration error (TRE)	Point-based accuracy metric using implanted or naturally occurring landmarks visualized on a pair of images	Maximum voxel dimension (~2–3 mm)
Mean distance to agreement (MDA)	Mean surface distance between 2 contours on registered images	Within the contouring uncertainty of the structure or maximum voxel dimension (~2–3 mm)
Dice similarity coefficient (DSC)	Volumetric overlap of 2 contours on registered images	Within the contouring uncertainty of the structure (~0.80–0.90 ^a)
Jacobian determinant	Volume expansion or contraction resulting from a deformable image registration	No negative values, values deviating from 1 as expected from clinical scenario (0–1 for structures expected to reduce in volume, greater than 1 for structures expected to expand in volume)
Consistency	Independence of an algorithm to the direction of the registration (image A to image B or image B to image A)	Maximum voxel dimension (~2–3 mm)

^aDSC calculations are dependent on the volume of the structure, therefore very large or very small structures may have different expected DSC values for contour uncertainty.

Use of image re
radiotherapy: R
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ÊNCIA



CBCT e ART – Estratégias para Cálculo de Dose

Distribuição de Dose
a partir do CBCT

Cálculo na CBCT usando Calibração HU-ED padrão



Curva da pCT

Curvas de Calibração HU-ED p/ CBCT - Fantomas



Catphan®
Gammex RMI®
CIRS 062M®

Curvas de Calibração HU Paciente-Específico



Co-Relação
CBCT + pCT

Bulk Density Override (Seleção manual de HU)



Osso
Tecido Mole
Ar

Mapeamento de HU-ED baseado em DIR



DIR CBCT-> pCT

Soluções Comerciais (Ex. Ethos®)



iCBCT
Adaptive x Schedule plan



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Review paper

A review of dose calculation approaches with cone beam CT in photon and proton therapy

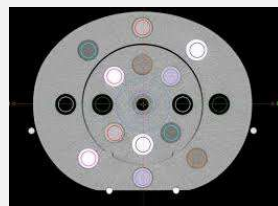
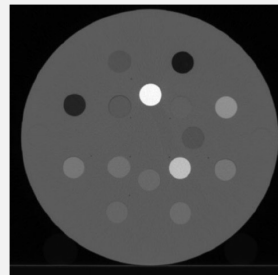
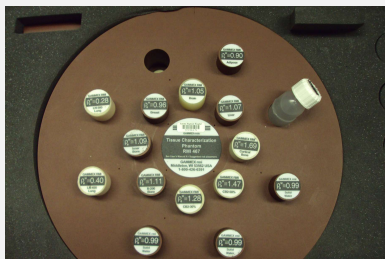
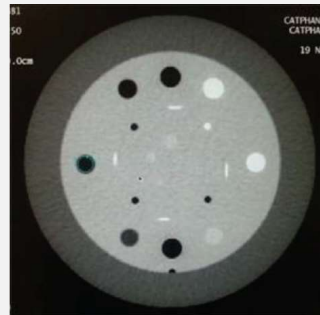
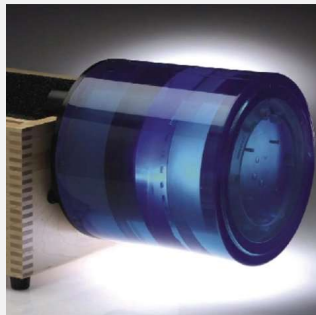
Valentina Giacometti^{a,*}, Alan H. Hounsell^{a,b}, Conor K. McGarry^{a,b}

^a Patrick G Johnston Centre for Cancer Research, Queen's University Belfast, Belfast, Northern Ireland, UK

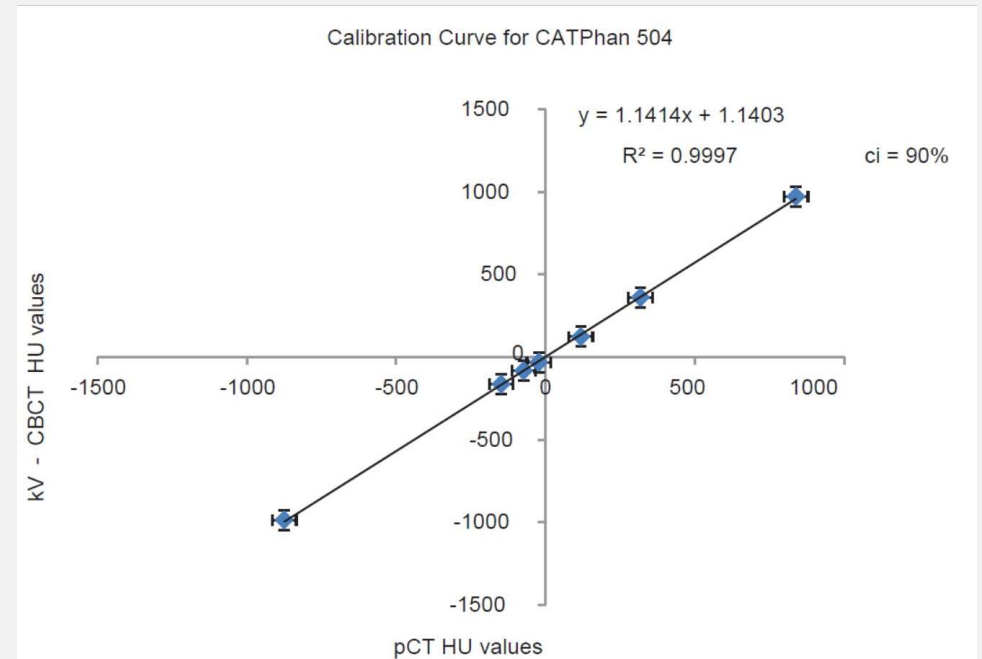
^b Radiotherapy Physics, Northern Ireland Cancer Centre, Belfast, Northern Ireland, UK

CBCT e ART – Estratégias para Cálculo de Dose

Cálculo na CBCT usando Calibração HU-ED padrão



Curvas de Calibração HU-ED p/ CBCT - Fantomas



Annikah, J.K. Assessment of the dosimetric accuracies of CATPhan 504 and CIRS 062 using kV-CBCT for performing direct calculations. Journal of Medical Physics, 2014.

CBCT e ART – Estratégias para Cálculo de Dose

Cálculo na CBCT usando Calibração HU-ED padrão

→ Não requer medidas extras, além de ser uma ferramenta rápida;

→ Traz incertezas em volumes grandes e heterogêneos devido a diferença de radiação espalhada em scans de pCT e CBCT;

→ Literatura: Diferenças de dose até 6,0%; Maiores discrepâncias: Regiões de Pulmão;

Table 1a

CBCT dose calculation studies using the pCT calibration for different tumour sites in patients, in chronological order.

Author	Make / Model	TPS	Algorithm	Site	Protocol	Artefact Correction	Calibration Curve	Reference	Difference [%]		γ -analysis [%]	Difference (OAR) [%]	
Ding et al. (2007) [41]	Varian Trilogy	Eclipse	AAA	Prostate (2)	Not defined (HF, 125kV, 80mA)	Inhomogeneity (modified Batho)	n/s	pCT	$D_{\text{mean-PTV}}$	0.5	n/s	D_{mean} : Bld = 1.3, Rct = 0.6, SemVsc = 0.6, Urt = 0.7, LHip = 0.1, RHip = 0.0 D_{mean} : LPar = 0.5, RPar = 0.5, SC = 1.2	
				H&N (1)	Not defined (FF, 125kV, 80mA)					0.4			
Onozato et al. (2014) [42]	Varian OBI (v1.5)	Eclipse (v8.6.15)	AAA	Prostate (10)	Pelvis	n/a	User specified CT# to ED	pCT	$D_{\text{mean-PTV}}$	1.2 ± 0.5	2%/2mm	97.0	D_{mean} : Bld = 1.24 ± 0.91 , Rct = 1.02 ± 1.11
De Smet et al. (2016) [37]	Varian Truebeam STx (v1.5)	Eclipse	AXB 10.0	Lung (6)	Thorax	n/a	User specified CT# to PD	rCT	$D_{\text{mean-PTV}}$	< 1.0	n/s	Histogram – Lng-GTV($V_{20\text{Gy}}$) < 2.0, D_{max} (0.1cc): SC < 2.0, Oes($V_{35\text{Gy}}$) < 3.0 – D_{mean} : Lng < 2.5, H < 2.5, Oes < 3.0 Histogram – Lng-GTV($V_{20\text{Gy}}$) < 8.0, D_{max} (0.1cc): SC < 8.0, Oes($V_{35\text{Gy}}$) < 8.0 – D_{mean} : Lng < 6.0, H < 8.0, Oes < 9.0	
	Elekta Synergy XVI (v5.0)	Pinnacle (v9.8)	n/s	Lung (10)	Clinical optimized	n/a	n/s		< 6.0				

CBCT e ART – Estratégias para Cálculo de Dose

Curvas de Calibração HU-ED p/ CBCT - Fantomas

Deterioração da Uniformidade do HU aumenta com o tamanho do objeto escaneado (Contaminação por espalhamento);

Recomendado utilizar ferramentas sítio-específicas -> Diferenças de dose entre -1,2% e +1,0%;

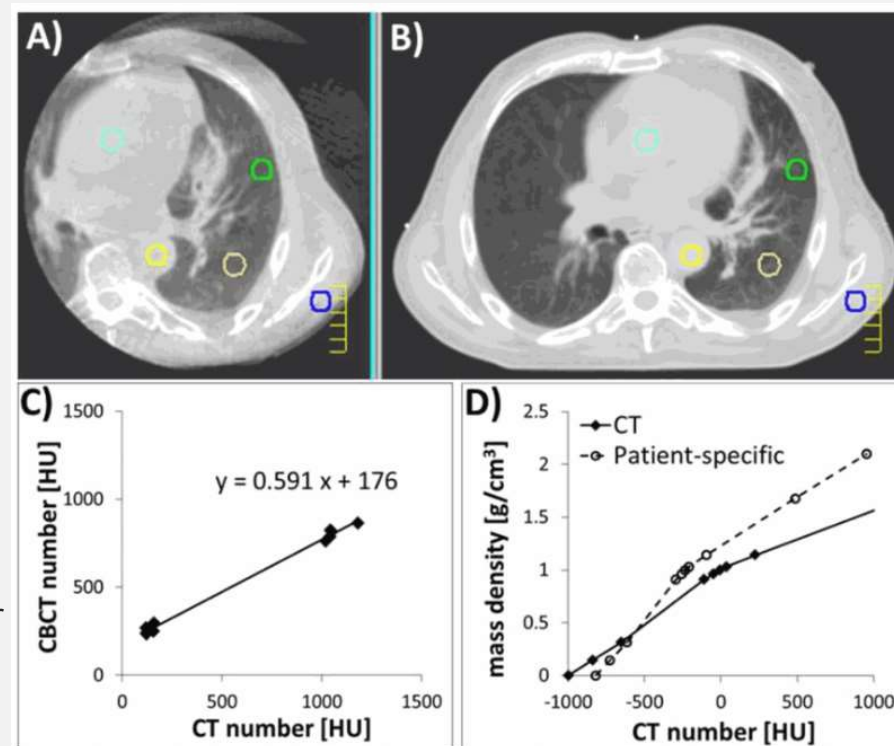
Problema: Artefatos de imagem -> Inacurácias e incertezas dosimétricas/tecidualis;

Author	Make/model	TPS	Algorithm	Phantom	Protocol	CBCT Calibration	Artefact Correction	Reference	Difference [%]	γ -analysis [%]	Difference (OAR) [%]		
Barateau et al. (2015) [46]	Varian OBI (v1.5)				Standard Head	Phantom (Catphan 600 CTP404) CBCT# to RED		pCT (CT# to RED Gammex RMI467)			D_{mean} : LPar = 0.21, RPar = -0.36, $D_{2\%}$: SC = 1.53		
						Phantom (CIRS 062M head) CBCT# to RED		-0.6		D_{mean} : LPar = -0.41, RPar = -1.09, $D_{2\%}$: SC = -0.41			
					Standard Pelvis	Phantom (CIRS 062M body) CBCT# to RED		-1.1		$D_{50\%}$: Bld = -1.06, Rct = -0.09			
					Phantom (Gammex RMI467) CBCT# to RED		0.4		$D_{50\%}$: Bld = 0.00, Rct = 0.36				
Giacometti et al. (2018) [43]	Varian Truebeam	Eclipse (v13.5)	AAA	Prostate (5)	Pelvis	Phantom (Inner cylinder CIRS062M + wax + water blocks) CBCT# to RED	n/a	pCT	$D_{medianPTV-99\%}$	-0.2	2%/0.1mm (50% threshold)	99.6	D_{median} : Bld = 0.0, Rct = -0.1
				Lung (5)	Thorax	Phantom (Outer ring CIRS062M + inner cylinder low density material + wax + water blocks) CBCT# to RED			-0.7		99.6	D_{median} : SC = 0.0, BS = 0.2	
				H&N (5)	Head	Phantom (CIRS062M + wax + water blocks) CBCT# to RED			-0.1		94.6	$D_{max}(0.01cc)$: SC = 0.0, $D_{max}(0.1cc)$: Oes = 0.0, H = 0.0	

CBCT e ART – Estratégias para Cálculo de Dose

Curvas de Calibração HU Paciente-Específico

- Volumes de interesse desenhados em áreas com densidade homogêneas;
- Relação HU CT x HU CBCT – Associação de ED;
- Criação de uma Curva de calibração CBCT baseado nas informações do paciente;
- CT x CBCT → Boa concordância p/ regiões de baixa densidade (< HU); Discrepância em regiões de > HU;
- De forma geral, a literatura mostra melhores resultados do que usar curvas de calibração baseada em fantasmas;
 - Estudos reportam reduzir diferenças < 3% comparadas com os métodos de Phantom-HU;
- Requer tempo -> Clinicamente difícil sem automação;



Example of a patient-specific CBCT HU table. Homogeneous areas of different tissues were manually selected on the CBCT (A) and the registered planning CT (B). A linear curve was fitted through the average CBCT and CT numbers of these regions (C). The linear relation was used to calculate the patient-specific CBCT HU table from the standard CT HU table (D). The example shown is for an Elekta CBCT.

CBCT e ART – Estratégias para Cálculo de Dose

Curvas de Calibração HU Paciente-Específico

↳ Diferenças de dose, em geral, abaixo de 2,0%;

Author	Make/model	TPS	Algorithm	Site	Protocol	CBCT Calibration	Artefact Correction	Reference	Difference [%]	γ -analysis [%]	Difference (OAR) [%]
De Smet et al. (2016) [37]	Varian Truebeam (v1.5)	Eclipse	AXB 10.0	Lung (6)	Thorax	Population-based (thorax) CBCT# to PD	n/a	rCT	$D_{\text{mean-PTV}}$	< 0.5	n/s
						Patient-specific CBCT# to PD				< 1.0	
	Elekta Synergy XVI (v5.0)	Pinnacle (v9.8)	n/s	Lung (10)	Clinical optimized	Population-based (thorax) CBCT# to PD				< 1.5	
						Patient-specific CBCT# to PD				< 1.0	

CBCT e ART – Estratégias para Cálculo de Dose

Bulk Density Override (Seleção manual de HU)

→ Estratégia para reduzir a influência dos artefatos de CBCT e a variabilidade de HU no cálculo de Dose;

→ Aplicar um valor de HU médio de estruturas correspondentes da pCT/rCT, ou aplicar valores padrões da Literatura (Osso / Ar / Água);

→ Problema em regiões de alta variação de densidade (Ex: Pulmões);

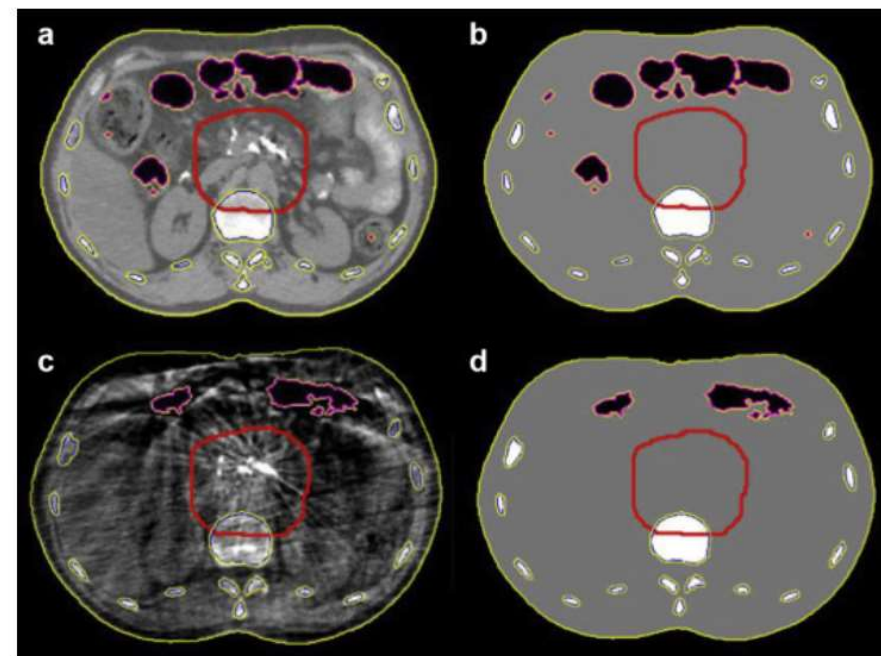


Figure 1. (a) Reference plan. (b) Reference plan with density overrides applied to bone, soft tissue, and gas contours. (c) Fraction 1 cone beam computed tomography. (d) Fraction 1 cone beam computed tomography with density overrides applied. Lines show bone (dark blue), soft tissue (yellow), gas (pink), and planning target volume (red).

Scott J et al. Quantifying and Assessing the Dosimetric Impact of Changing Gas Volumes Throughout the Course of VMAT Radiation Therapy of Upper Gastrointestinal Tumors. *Advances in Radiation Oncology*, 2021.

CBCT e ART – Estratégias para Cálculo de Dose

Bulk Density Override (Seleção manual de HU)

CP e Próstata -> Boas concordâncias;
Pulmão -> Diferenças de dose de até 5%;

Author	Make/ model	TPS	Algorithm	Site	Protocol	HU override	Artefact Correction	Calibration Curve	Reference	Difference [%]	γ -analysis [%]	Difference (OAR) [%]	
Fotina et al. (2012) [53]	Elekta Synergy XVI	iPlan (v4.5.0)	XV MC	Prostate (10)	Prostate (no bowtie)	Auto HU _{MLT} (7 thresholds)	n/a	User specified CT# to ED	Population- based CBCT# to ED	D _{median- PTV}	1.9	n/s	D _{mean} : Bld = 0.5, Rct = 0.1, FemHeads = 0.0
						HU _{ROI}				0.1	D _{mean} : Bld = 0.3, Rct = 0.0, FemHeads = 0.0		
				Lung (10)	Thorax (no bowtie)	Auto HU _{MLT} (7 thresholds)				< 5.0	D _{max} : SC = −0.2, OES = 0.1%, D _{mean} : Lng = 0.0		
						HU _{ROI}				< 5.0	D _{max} : SC = 0.2, OES = −0.1%, D _{mean} : Lng = 0.1		
				H&N (7)	Head (no bowtie)	Auto HU _{MLT} (7 thresholds)				< 0.5	D _{max} : SC = −1.3, BS = 0.2, D _{mean} : Par = 0.4		
						HU _{ROI}				< −3.0	D _{max} : SC = −1.3, BS = 0.2, D _{mean} : Par = 0.4		

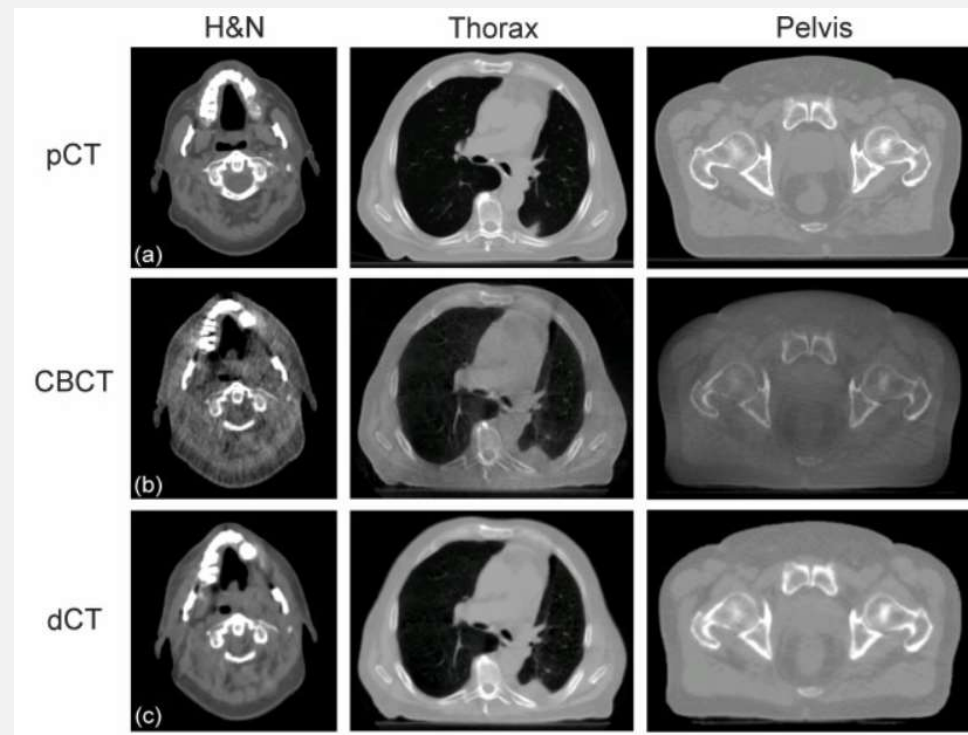
CBCT e ART – Estratégias para Cálculo de Dose

Mapeamento de HU-ED baseado em DIR

Deformação dos dados da CBCT na pCT, em conjunto com a propagação de estruturas e cálculo de dose;

dCT não é afetada por incertezas no valor de HU, já que os números da CT não são modificados durante a deformação;

Grandes diferenças em anatomia podem levar a discrepâncias no DIR (Ex: Interfaces Tecido-Ar, como Pulmão e Intestino);
- Métricas do TG 132



CBCT e ART – Estratégias para Cálculo de Dose

Mapeamento de HU-ED baseado em DIR

Diferenças de dose abaixo de 0,7%;

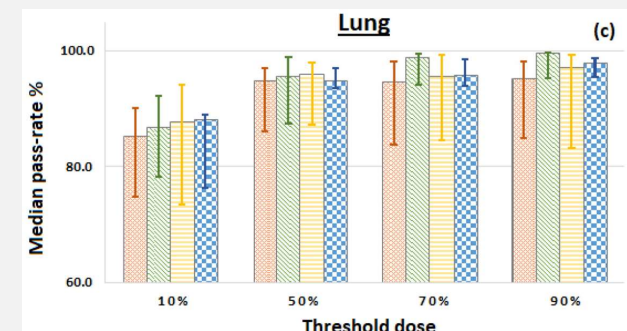
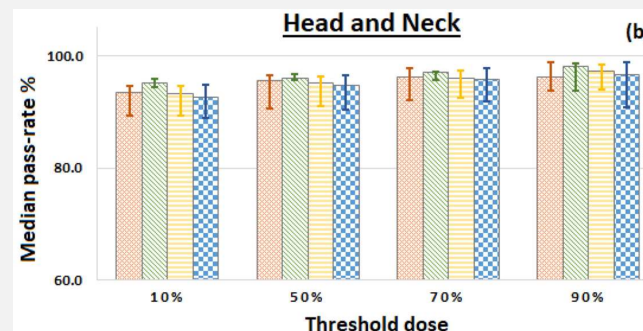
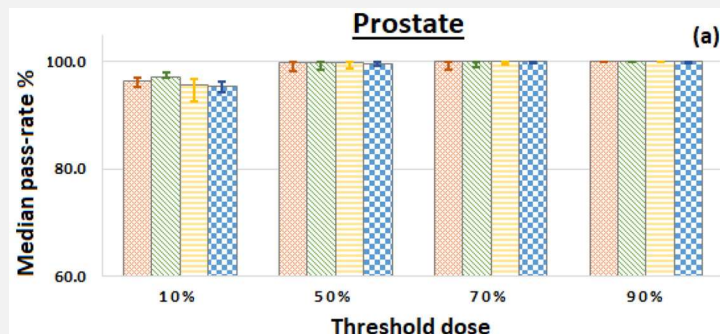
Author	Make/ model	TPS	Algorithm	Site	Protocol	DIR algorithm	Artefact Correction	Calibration Curve	Reference	Difference [%]		γ -analysis [%]		Difference (OAR) [%]	
Giacometti et al. (2018) [43]	Varian Truebeam	Eclipse (v13.5)	AAA	Prostate (5)	Pelvis	n/s	n/a	User specified CT# to RED	pCT	$D_{\text{medianPTV-99\%}}$	0.1	2%/0.1mm (50% threshold)	99.8	D_{median} : Bld = 0.0, Rct = 0.1	
				Lung (5)	Thorax						-0.3	95.7	D_{median} : SC = 0.0, BS = -0.1		
				H&N (5)	Head						0.0	96.0	D_{max} (0.01cc): SC = -0.2, D_{max} (0.1cc): Oes = 0.1, H = -0.1		
Veiga et al. (2014) [71]	Varian OBI (v1.4)	Eclipse	AAA	H&N (5)	Low dose thorax	BSpline (NiftyReg)	n/a	n/s	rCT	$D_{\text{PTV-95\%}}$	0.7 ± 0.2	2%/2mm	97.1 ± 4.3	DVH of one patient & histograms for BS, SC, LPar, RPar	
Marchant et al. (2018) [38]	Elekta Synergy XVI (v4.5-5.0)	Pinnacle (v9.8)	n/s	Pelvis (15)	n/s	BSpline (Elastix)	n/a	n/s	pCT	$D_{\text{mean-PTV}}$	0.1 ± 0.2	n/s		$\text{Rct}(V_{40\text{Gy}}) = -0.16 \pm 0.66$	
						Free form BSpline (NiftyReg)					0.0 ± 0.2			$\text{Rct}(V_{40\text{Gy}}) = -0.11 \pm 0.52$	
				Lung (15)		BSpline (Elastix)					0.4 ± 0.8			$D_{\text{max}}(1\text{cc}): \text{SC} = 0.31 \pm 1.14$	
						Free form BSpline (NiftyReg)					0.3 ± 0.7			$D_{\text{max}}(1\text{cc}): \text{SC} = 0.15 \pm 1.27$	
				H&N (14)		BSpline (Elastix)					0.2 ± 0.1			$D_{\text{mean}}: \text{CPar} = 0.28 \pm 0.20$	
						Free form BSpline (NiftyReg)					-0.1 ± 0.2			$D_{\text{mean}}: \text{CPar} = 0.00 \pm 0.30$	

CBCT e ART – Estratégias para Cálculo de Dose

- Comparação entre 4 técnicas ($\gamma = 2\%/0.1 \text{ mm}$) – Em relação à dose na pCT;
- 15 pacientes tratados com VMAT;
 - Próstata (5);
 - Cabeça e Pescoço (5);
 - Tórax (5);
- Varian Eclipse 13.6 (AAA);

■ CBCT site specific calibration curve ■ Standard pCT calibration curve
■ Deformable registration ■ HU density override

Method	Description
Standard pCT calibration curve	Dose calculated using standard pCT calibration curve
CBCT site-specific calibration curve	Dose calculated using calibration curve specifically derived for CBCT images
HU override	CBCT pixel data overridden using regions of interest or alternative bulk method.
Deformable registration	pCT image deformed to CBCT anatomy.



- Próstata: Resultados Similares e com Boa Concordância para as 4 técnicas;
- CP e Pulmão -> Regiões que requerem maior atenção devido à mudanças de densidades;
- Não recomenda usar o método “*Standard pCT calibration curve*”;

CBCT e ART – O que a literatura traz...

CABEÇA E PESCOÇO

Brivio D, et al. Selection of head and neck cancer patients for adaptive replanning of radiation treatment using kV-CBCT. Biomed. Phys. Eng. Express (2018).

- 11 Pacientes – IMRT
- 11 CT's / 70 CBCT's / 5 rCT;
- Contorno modificado do Body através dos dados do CBCT;
- Margem de 3mm caso algum volume extrapolasse o novo Body;
- Fatores Importantes: Perda de Peso; Resposta Tumoral; Progressão de Doença;

■ **Métricas geométricas:** avaliação das mudanças geométricas através da análise das alterações do contorno do corpo.

- Diminuição da dose mínima do PTV (Média de 2,5 Gy);
- Aumento da Dose máxima na Medula de até 1,7 Gy (Co-relacionado com maior perda de volume do pescoço);
- Incertezas: Não se modificou o PTV e OAR's – Erros na estimativa de dose, especialmente em estruturas que alteram seu volume e se movem ao longo do curso do tratamento (Ex: Parótidas);

Métricas dosimétricas: servem como um alerta aos médicos

Órgãos de risco OARs:

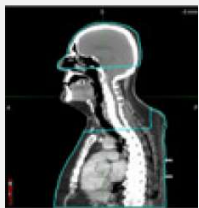
- $D_{max} \geq 103\%$ em relação ao plano inicial.

PTVs:

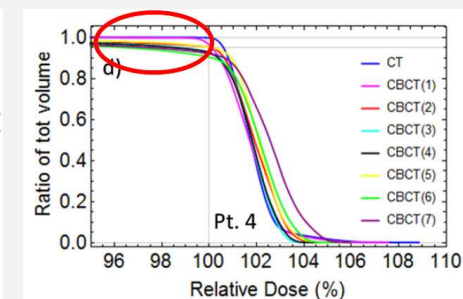
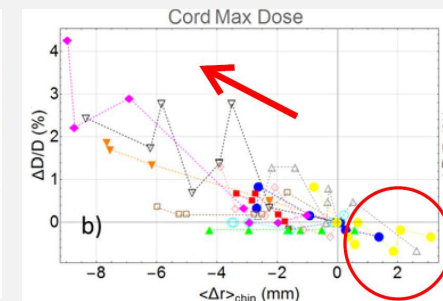
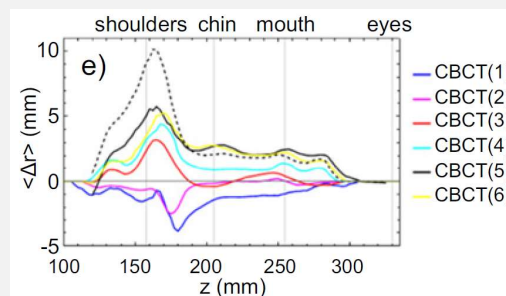
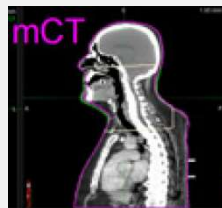
- Decréscimo de 3% no volume coberto pela dose de prescrição.



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CBCT e ART – O que a literatura traz...

TÓRAX

Cole, A. J. et al. Toward adaptive radiotherapy for lung patients: feasibility study on deforming planning CT to CBCT to assess the impact of anatomical changes on dosimetry. *Physics in Medicine & Biology*, 2018.

- 7 Pacientes
- Fatores Importantes: Atelectasia, Redução/Aumento Tumoral;
- CBCT como Template para o DIR da pCT;
- Algoritmo DIR (*NiftyReg*);
- Validação Geométrica – Escápula, Medula e Traquéia (DSC, DTA);
- Validação Dosimétrica – Dose dCT x Dose rCT;

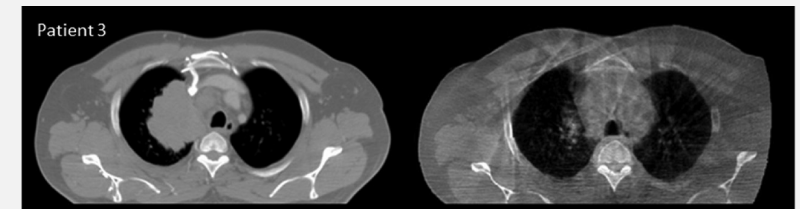
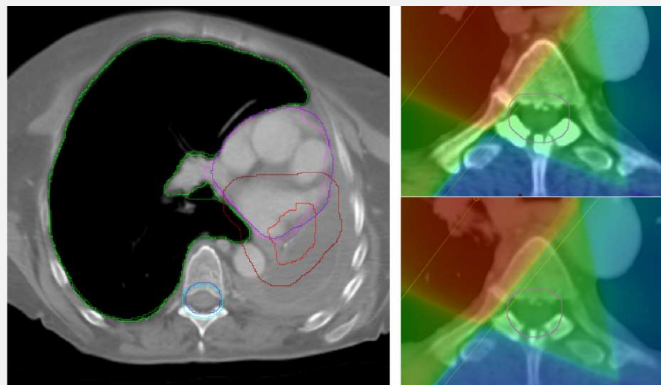


Table 4. Changes in relevant DVH statistics over the course of treatment calculated from dCT images for a single patient. All values are given to one decimal place.

	pCT		dCT Week 1		dCT Week 2		dCT Week 3		dCT Week 4	
	%	Gy	%	Gy	%	Gy	%	Gy	%	Gy
CTV (original) max	107.2	68.6	107.1	68.5	106.7	68.3	107.1	68.6	108.4	69.4
CTV (original) V99% ^a	96.2	—	92.7	—	92.3	—	96.3	—	96.1	—
CTV (deformed) max	107.2	68.6	107.0	68.5	106.5	68.2	107.1	68.6	107.9	69.0
CTV (deformed) V99% ^a	96.2	—	94.8	—	94.5	—	95.0	—	96.1	—
Spinal canal max	71.6	45.8	71.7	45.9	72.1	46.1	71.4	45.7	71.0	45.4
Spinal canal + 5 mm max	74.5	47.6	75.0	48.0	89.2	57.1	91.9	58.8	73.3	46.9
Lung ^b max	106.0	67.9	105.7	67.7	105.0	67.2	105.4	67.5	106.5	68.2
Lung ^b V20	19.5	—	18.1	—	17.8	—	19.2	—	18.1	—
Heart max	106.4	68.1	106.3	68.1	105.4	67.5	105.5	67.5	107.0	68.5
Heart V40	7.1	—	7.0	—	8.7	—	9.8	—	7.7	—

- Recomendado que o médico desenhe as estruturas na dCT – Estruturas próximas às bordas do campo devem ser cuidadosamente avaliadas (Ex: Medula);
- Deformação da CT Average -> Incertezas no cálculo (Movimentos Internos);
- Ferramenta para auxiliar na decisão do replan;

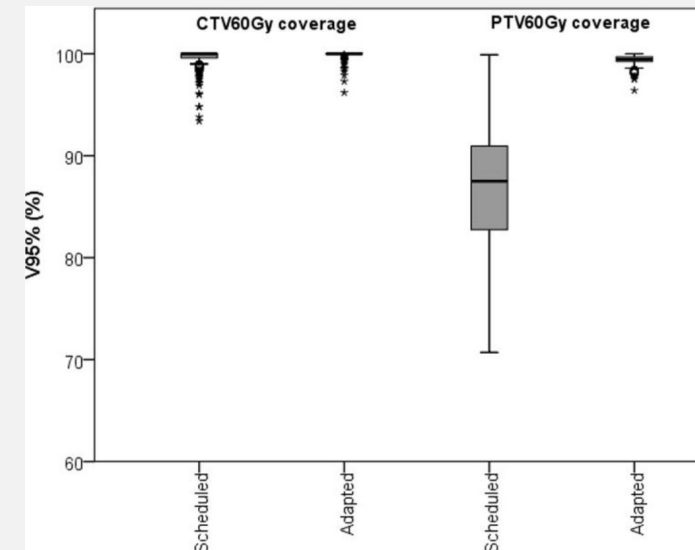
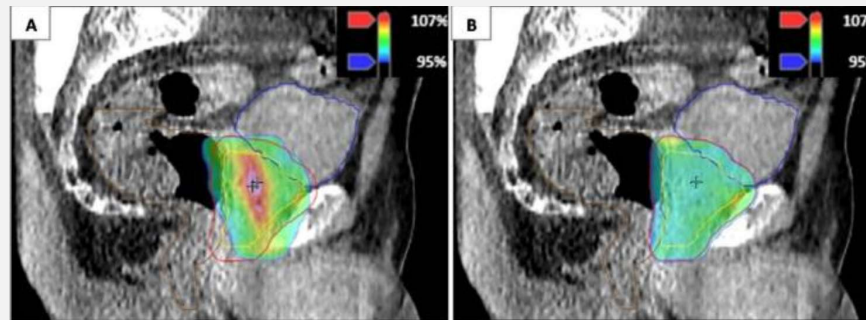
CBCT e ART – O que a literatura traz...

Próstata

Zwart L. et al. Cone-beam computed tomography-guided online adaptive radiotherapy is feasible for prostate cancer patients. *Phys Imaging Radiat Oncol*, 2022.

- 11 pacientes tratados com oART Ethos Therapy (Varian Medical Systems ®);
- Fatores Importantes: Preparo de Reto e Bexiga; Tensão dos músculos pélvicos;
- Fluxo: Auto-Contorno (Revisão) -> Adaptação do Plano de Tratamento -> QA;
- *Schedule Plan x Adapted Plan*;
- Tempo Médio – CBCT até o fim do tratamento -> 17,5 minutos;

	Mean (minutes)
Influencer generation and review	6.5
Target generation and review	0.8
Treatment plan generation and review	4.6



- Escolha do Plano adaptado em todos os casos;
- Redução no tempo total de tratamento -> Treinamento na avaliação dos contornos adaptados;
- Limitação do Estudo -> Não levar em conta a distribuição de dose acumulada de frações anteriores;

CBCT e ART – Reflexão...

- Brasil: CBCT com grande uso para tomadas de decisão de ART offline;
- Muitos recursos tecnológicos (DIR, Auto Segmentação, Algoritmos p/ melhora da imagem);
 - Importante serem validados;
- Sempre importante usar mais de um método de cálculo de dose na CBCT – Auxiliar em tomadas de decisões;
- Tais técnicas podem servir de auxílio para elaboração de protocolos de replanejamento dentro do setor;
 - Criar guias de predição p/ quando aplicar ART e usar critérios na seleção de pacientes;
- ART Online / Real Time:
 - Revolução na forma como enxergamos adaptação em Radioterapia;
 - Reduzir Margens, melhorar toxicidade em OAR's e controle tumoral;

Obrigado



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