

Arcoterapia (ADC e VMAT) para planejamento de múltiplos volumes alvo intracranianos - Pontos e Contrapontos de cada técnica

Físico Anselmo Mancini



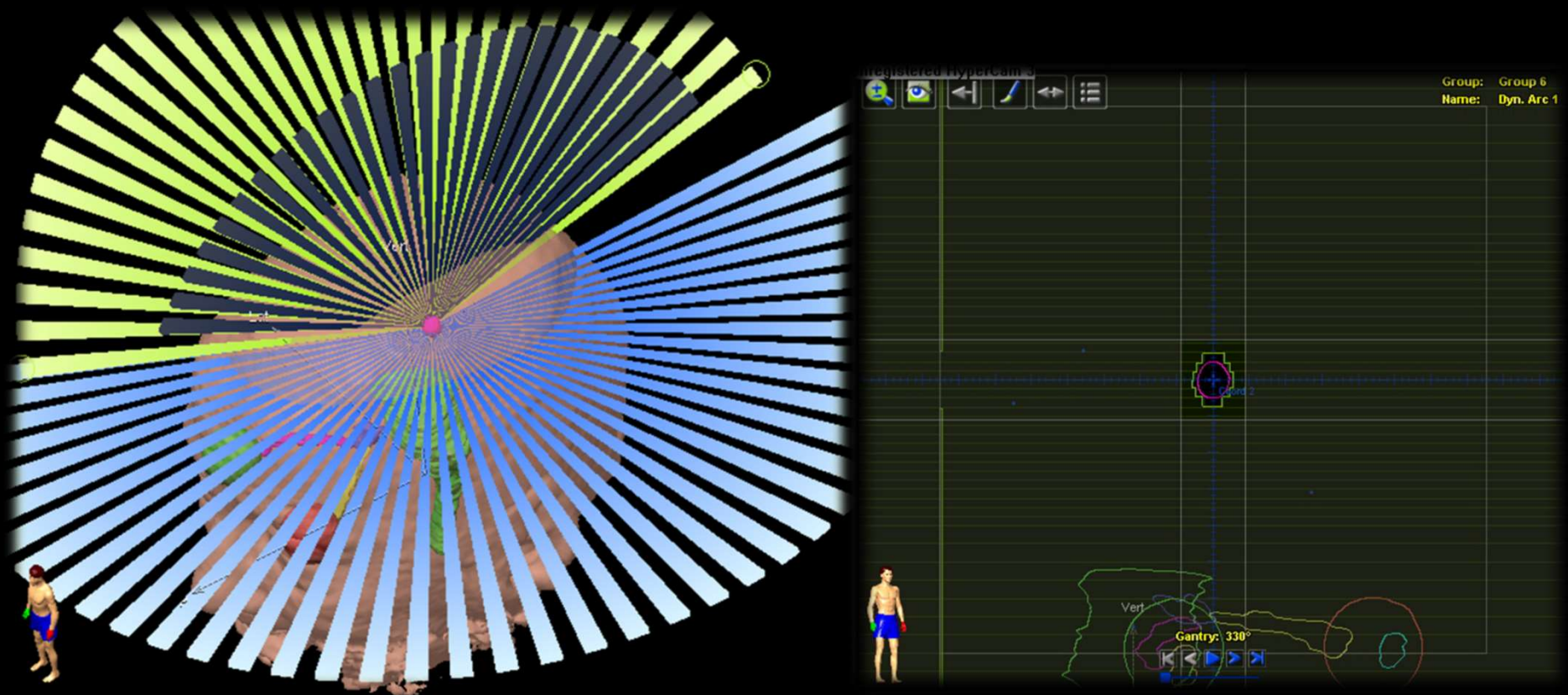
HOSPITAL
SÍRIO-LIBANÊS

Radiocirurgia Estereotática (SRS)

→ Características

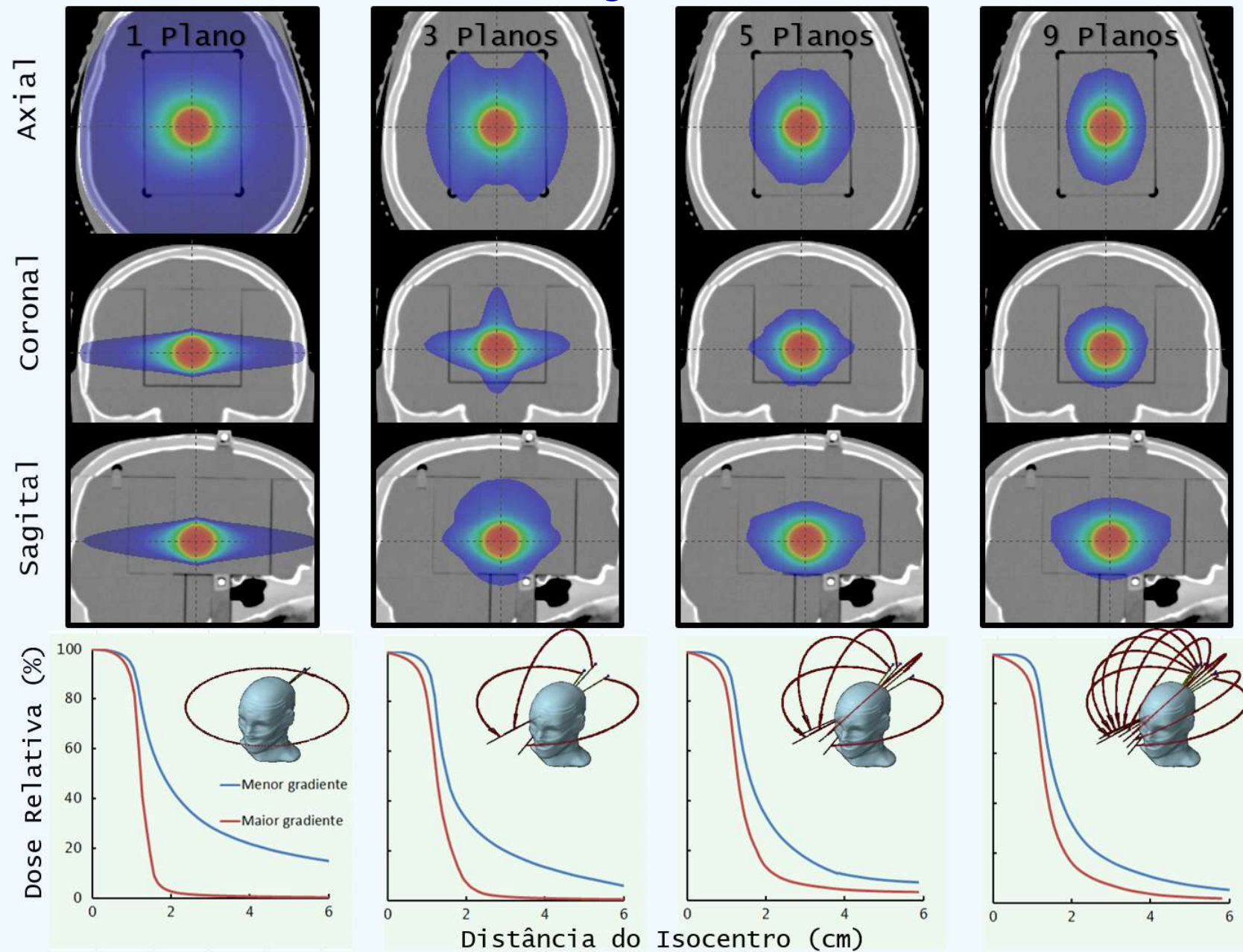
- Altas doses
- Aplicação única ou poucas frações
- Alto grau de conformidade da dose ao alvo e declínio íngreme de dose ao seu redor
- Posicionamento preciso e imobilização eficiente do paciente

Arco Dinâmico Conformacional (ADC)



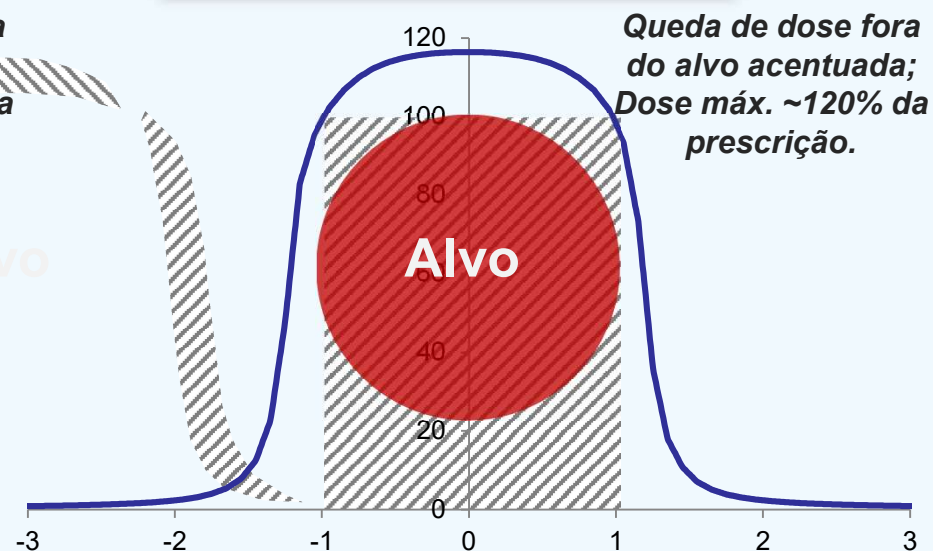
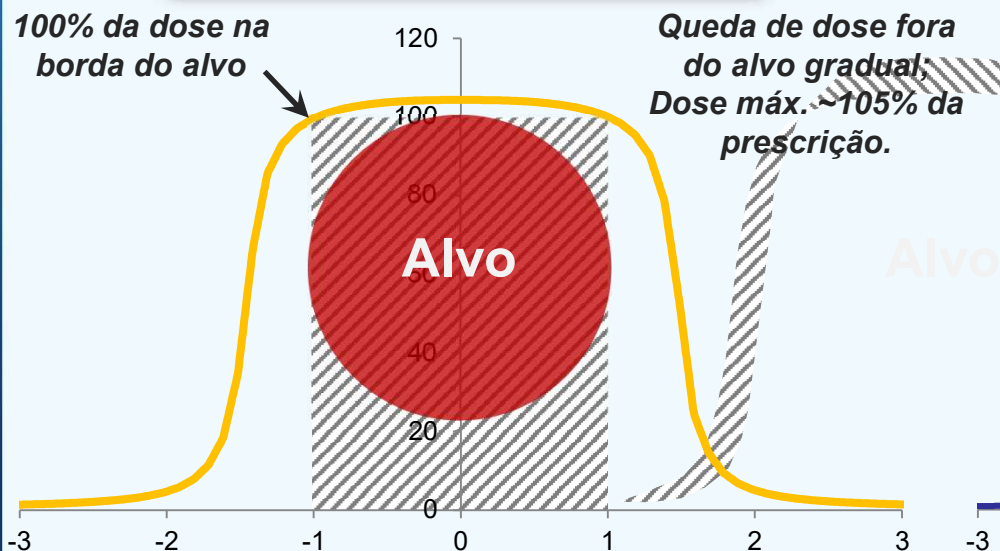
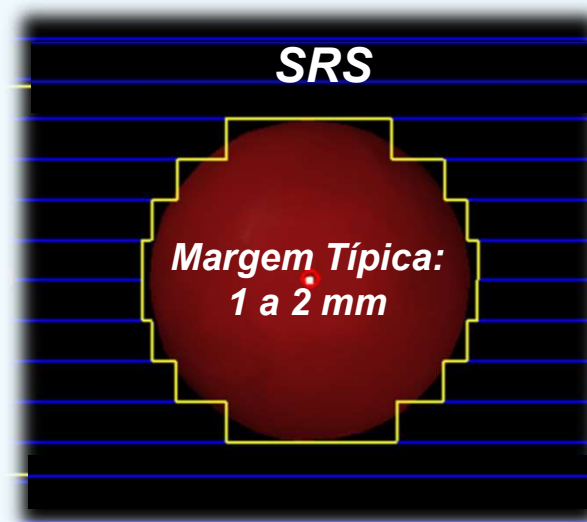
Campo adaptado continuamente ao formato do alvo durante rotação do *gantry* com o uso de mMLC dinâmico.

ADC - Arranjo dos Arcos

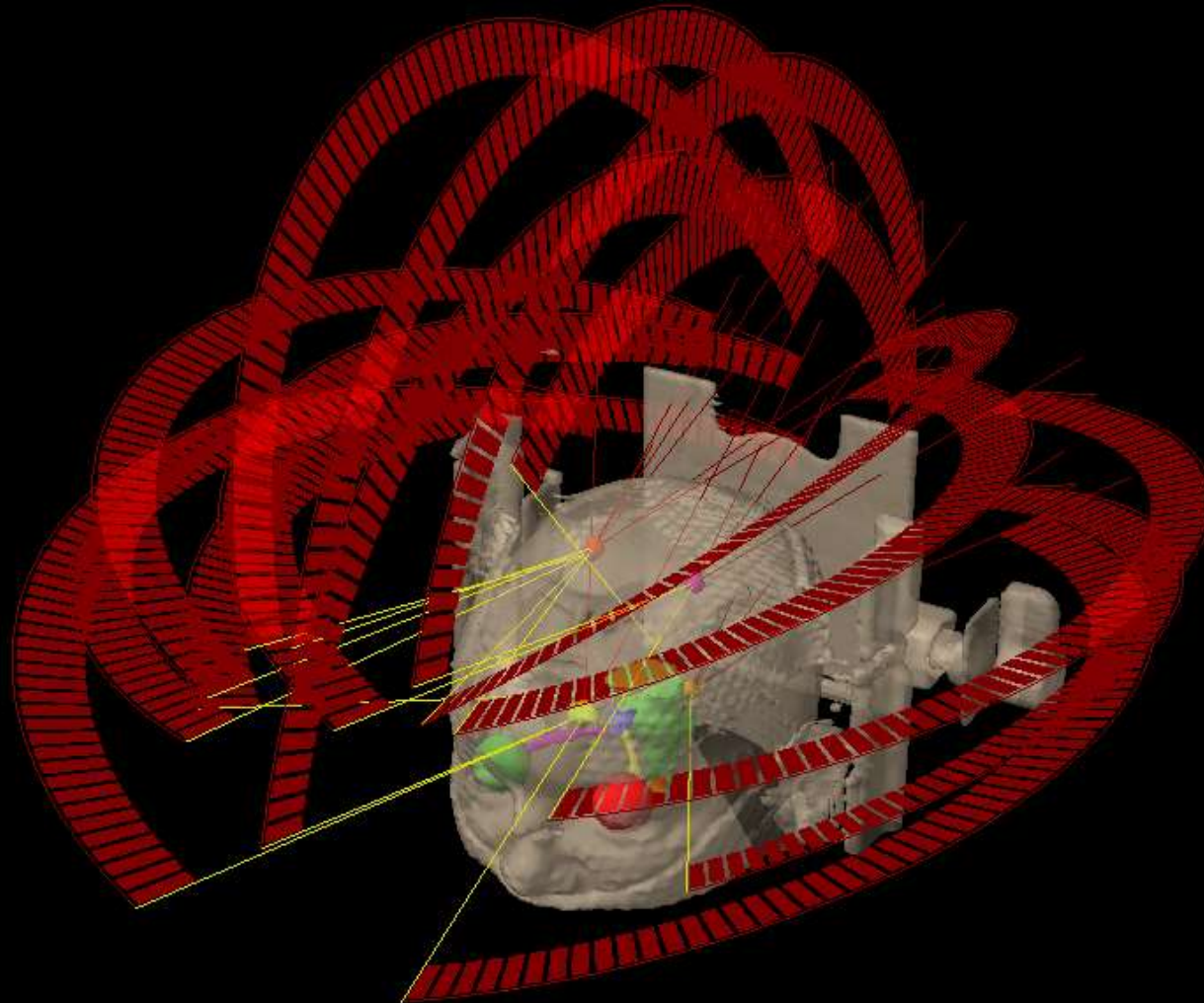


ADC - Margem de Colimador

Formato do campo no BEV ~ Alvo.: Margem de colimador $\rightarrow 0$

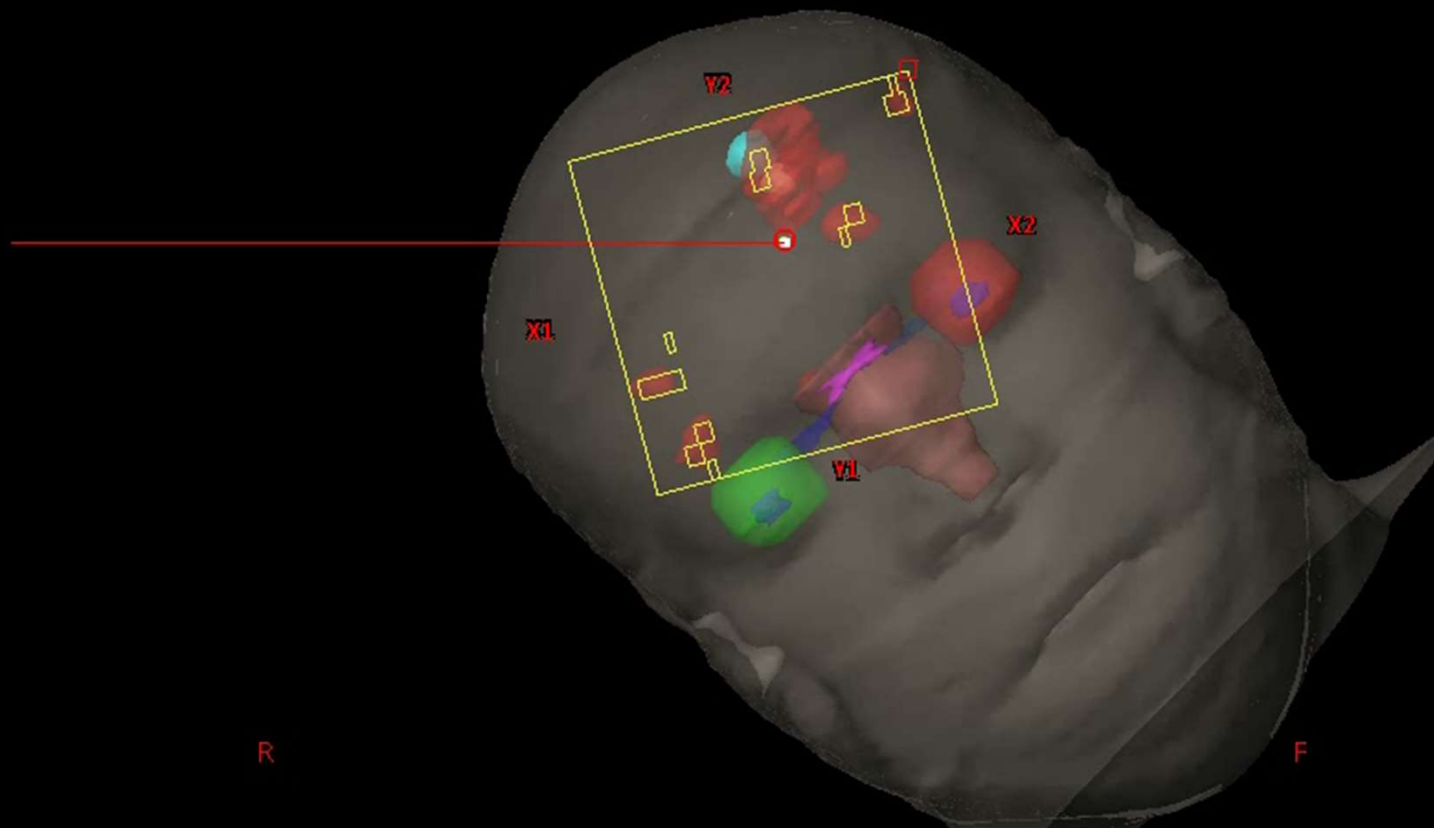


ADC – Múltiplas Lesões



Cada alvo possui seu próprio planejamento/tratamento com seu respectivo isocentro → planejamento complexo e longo tempo de execução.

VMAT – Múltiplas Lesões



Velocidade de rotação do gantry, posição do MLC e taxa de dose variam.
→ Distribuições de dose altamente adaptadas à forma do alvo.
→ Tratamento de múltiplos alvos em um único isocentro.

Comparison of Plan Quality and Delivery Time Between Volumetric Arc Therapy (RapidArc) and Gamma Knife Radiosurgery for Multiple Cranial Metastases

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OBJECTIVE: To investigate whether equivalent radiosurgical plan quality and reduced delivery time could be achieved in VMAT for patients with multiple intracranial targets previously treated with Gamma Knife (GK) radiosurgery.

METHODS: We identified 28 GK treatments of multiple metastases. These were re-planned for multiarc and single-arc, single-isocenter VMAT (RapidArc) in Eclipse. The prescription for all targets was standardized to 18 Gy. Each plan was normalized for 100% prescription dose to 99% to 100% of target volume. Plan quality was analyzed by target conformity (Radiation Therapy Oncology Group and Paddick conformity indices [CIs]), dose falloff (area under the dose-volume histogram curve), as well as the V4.5, V9, V12, and V18 isodose volumes. Other end points included beam-on and treatment time.

RESULTS: Compared with GK, multiarc VMAT improved median plan conformity ($CI_{VMAT} = 1.14$, $CI_{GK} = 1.65$; $P < .001$) with no significant difference in median dose falloff ($P = .269$), 12 Gy isodose volume ($P = .500$), or low isodose spill ($P = .49$). Multiarc VMAT plans were associated with markedly reduced treatment time. A predictive model of the 12 Gy isodose volume as a function of tumor number and volume was also developed.

CONCLUSION: For multiple target stereotactic radiosurgery, 4-arc VMAT produced clinically equivalent conformity, dose falloff, 12 Gy isodose volume, and low isodose spill, and reduced treatment time compared with GK. Because of its similar plan quality and increased delivery efficiency, single-isocenter VMAT radiosurgery may constitute an attractive alternative to multi-isocenter radiosurgery for some patients.

Comparison of Plan Quality and Delivery Time Between Volumetric Arc Therapy (RapidArc) and Gamma Knife Radiosurgery for Multiple Cranial Metastases

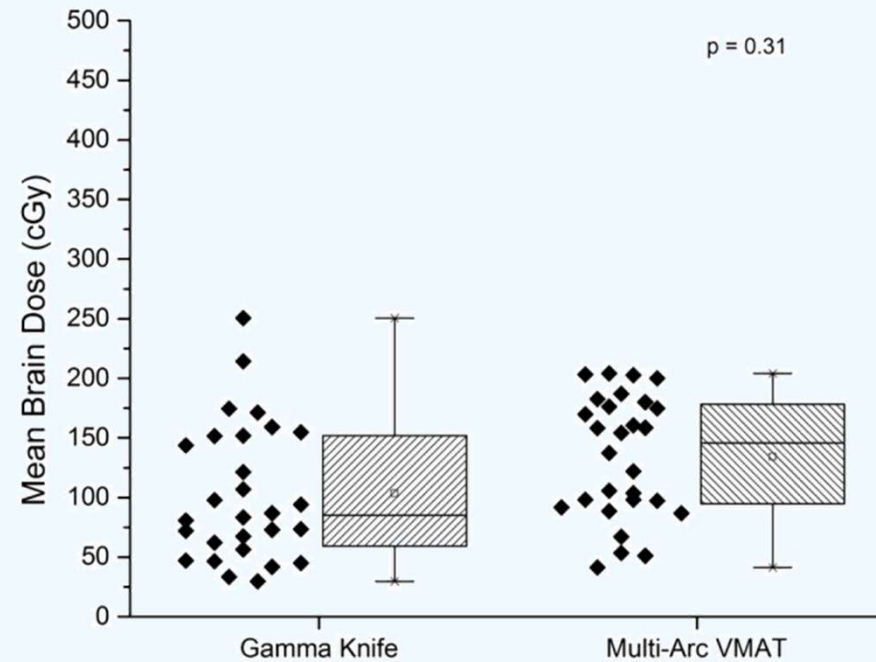
The figure consists of two side-by-side box plots comparing Gamma Knife and Multi-Arc VMAT for cranial metastases.

Left Plot: RTOG Index

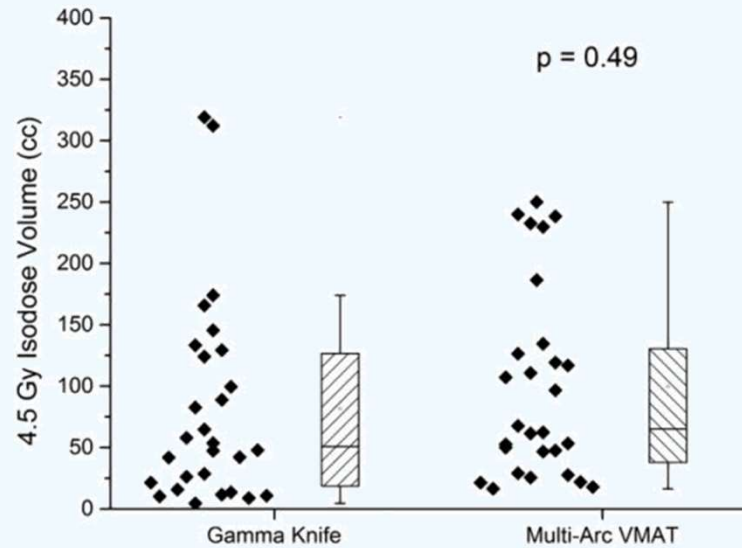
- Y-axis:** RTOG Index, ranging from 0 to 5.
- X-axis:** Gamma Knife and Multi-Arc VMAT.
- Gamma Knife:** Median RTOG Index is approximately 1.8. The box spans from approximately 1.4 to 2.1. Whiskers extend from approximately 1.3 to 2.5. Individual data points are overlaid.
- Multi-Arc VMAT:** Median RTOG Index is approximately 1.2. The box spans from approximately 1.1 to 1.3. Whiskers extend from approximately 1.0 to 1.6. Individual data points are overlaid.
- p-value:** $p < 0.0001$.

Right Plot: Mean Brain Dose (cGy)

- Y-axis:** Mean Brain Dose (cGy), ranging from 0 to 500.
- X-axis:** Gamma Knife and Multi-Arc VMAT.
- Gamma Knife:** Median Mean Brain Dose is approximately 80 cGy. The box spans from approximately 60 to 150 cGy. Whiskers extend from approximately 30 to 250 cGy. Individual data points are overlaid.
- Multi-Arc VMAT:** Median Mean Brain Dose is approximately 140 cGy. The box spans from approximately 90 to 175 cGy. Whiskers extend from approximately 40 to 200 cGy. Individual data points are overlaid.
- p-value:** $p = 0.31$.

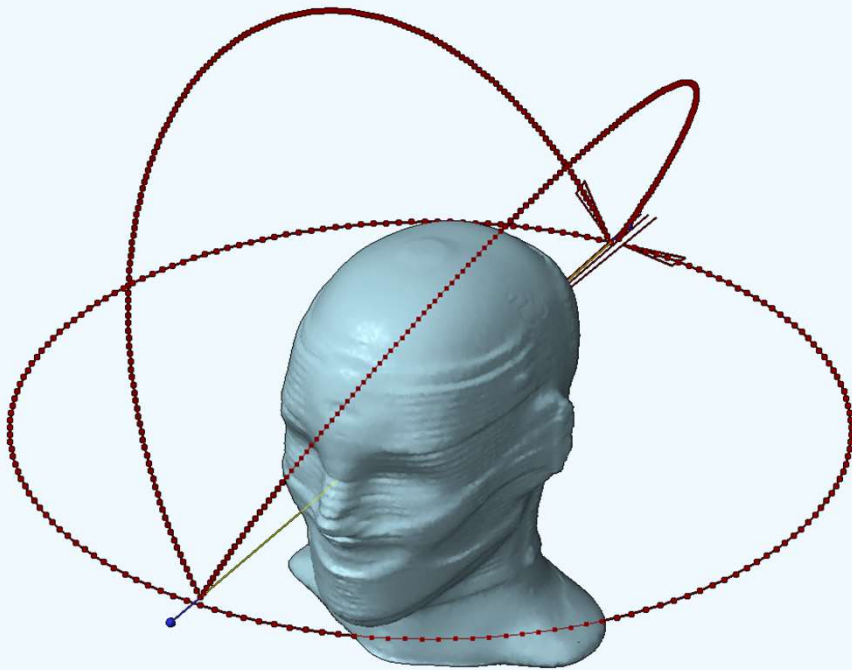


Comparison of Plan Quality and Delivery Time Between Volumetric Arc Therapy (RapidArc) and Gamma Knife Radiosurgery for Multiple Cranial Metastases



VMAT - Arranjo dos Arcos

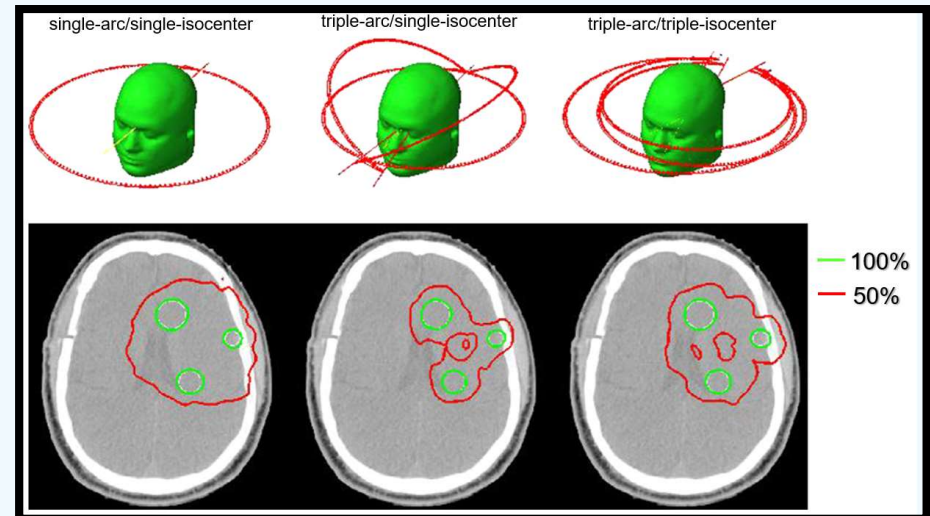
→ Arcos não-coplanares



Mesa 0° 2 x 360°

Mesa 60° 2 x 180°

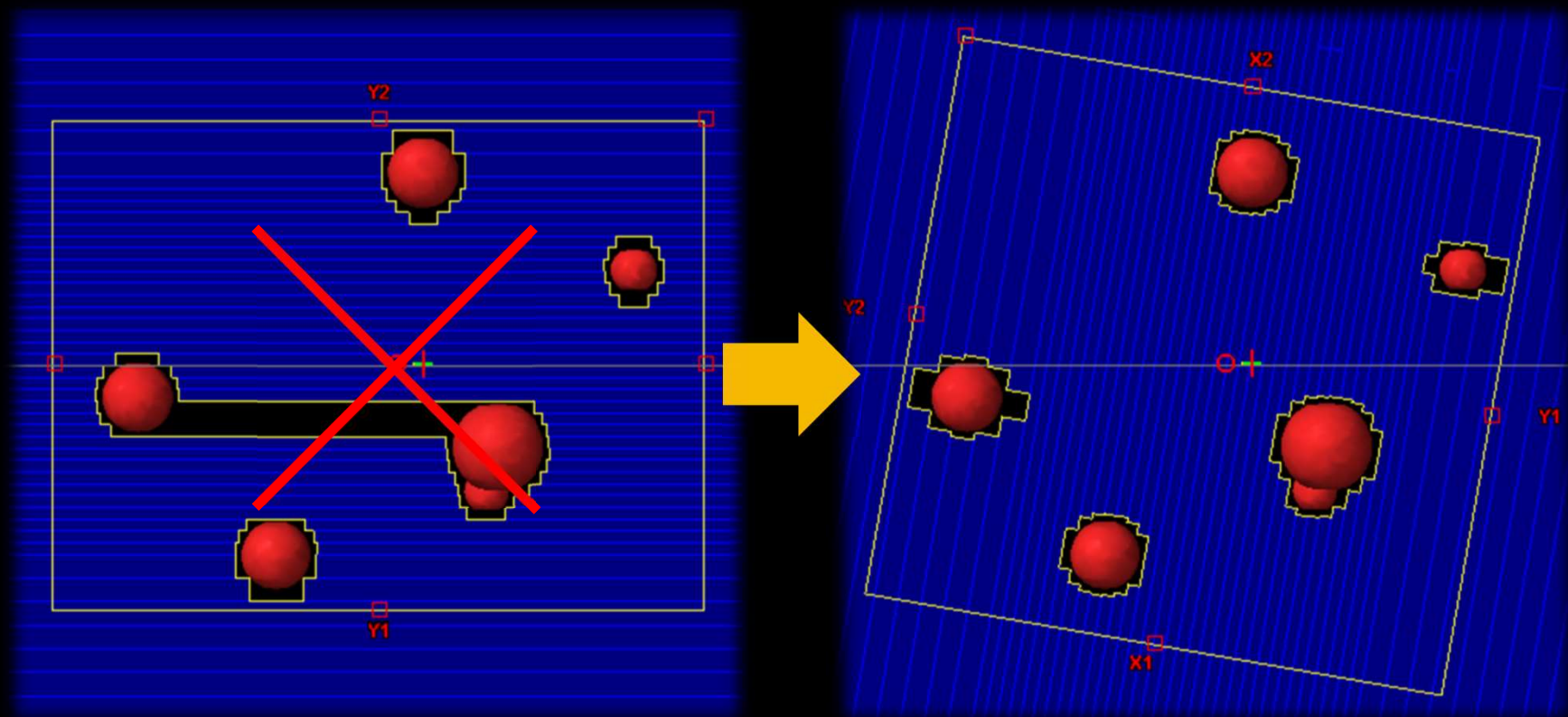
Mesa 300° 2 x 180°



Clark et al. Int J Radiat Oncol Biol Phys. 2010;76(1):296–302

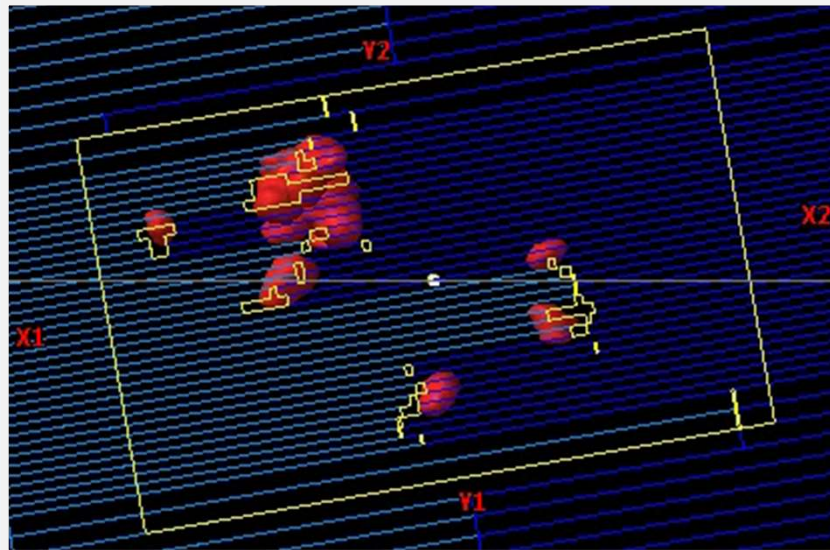
VMAT - Ângulo do Colimador

→ Minimizar compartilhamento das lâminas por diferentes alvos

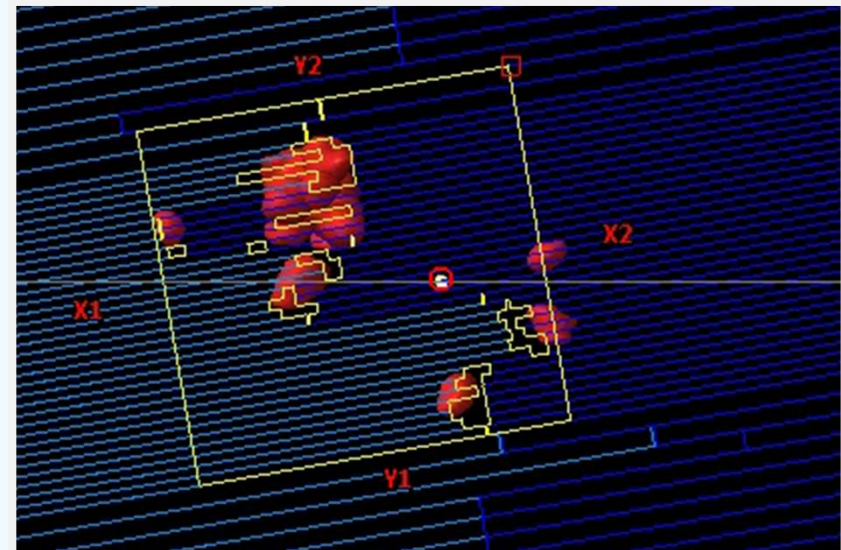


VMAT - Jaw Tracking

→ Tamanho do colimador secundário variável para reduzir vazamento e transmissão de dose



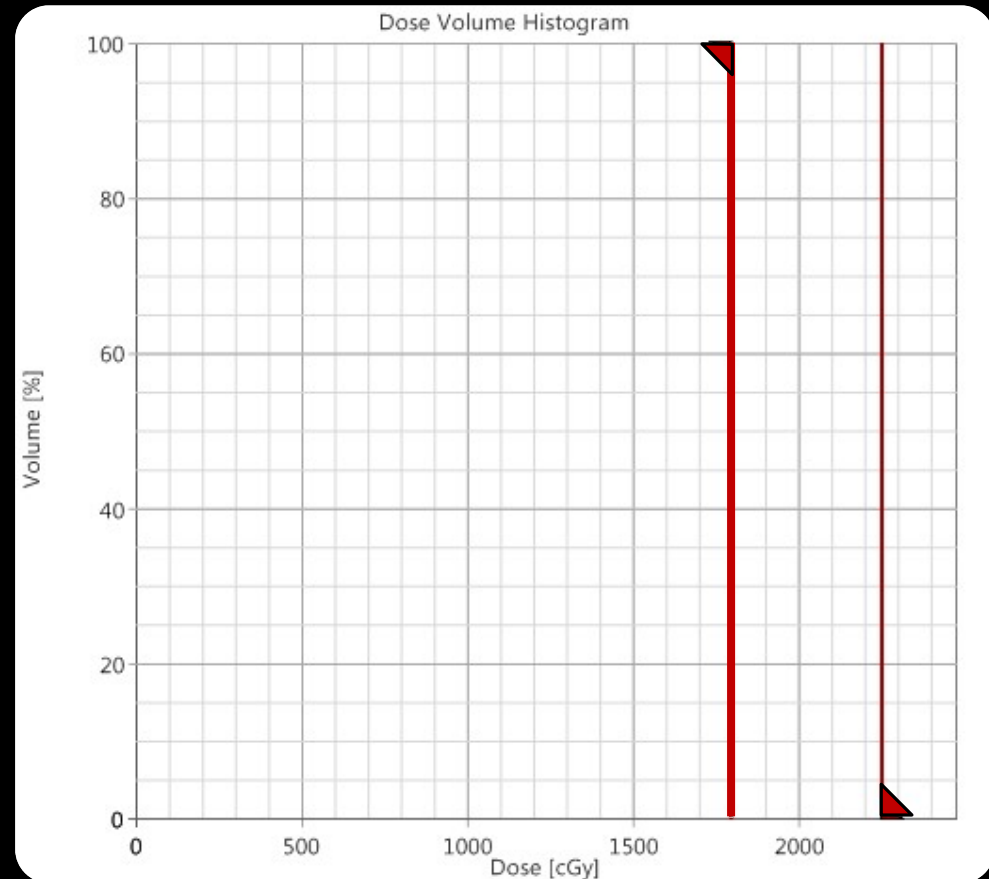
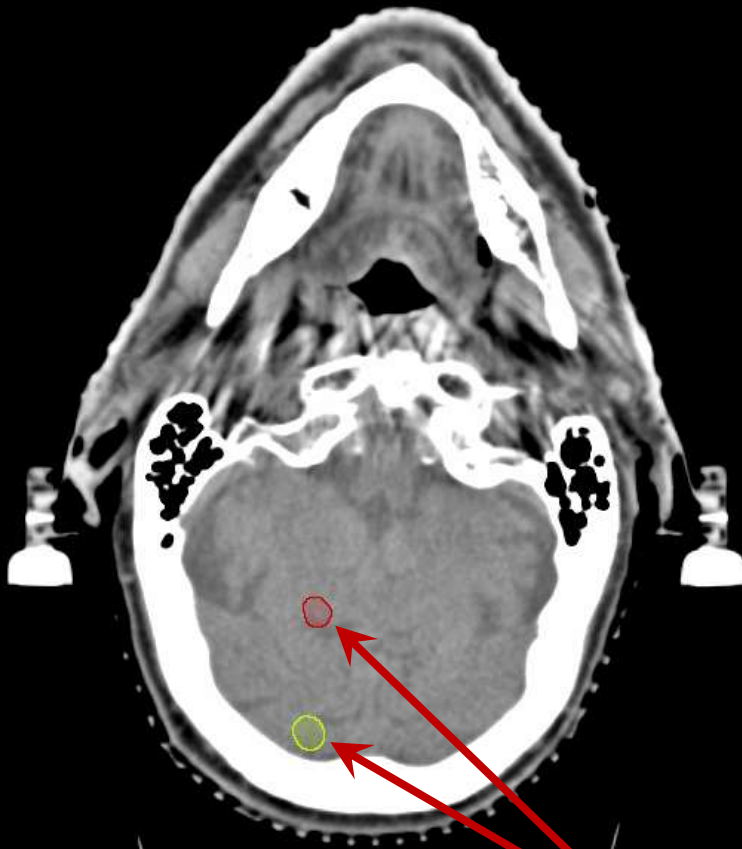
Fixed Jaw



Jaw Tracking

VMAT - Estratégias de Otimização

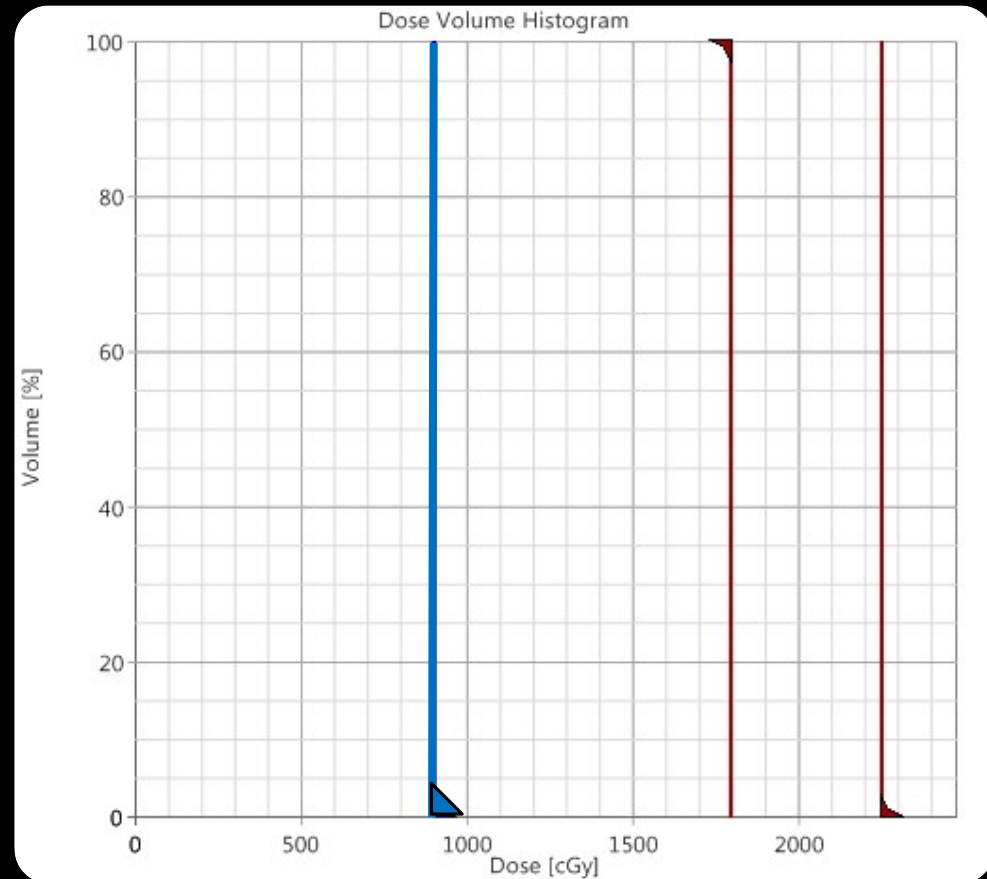
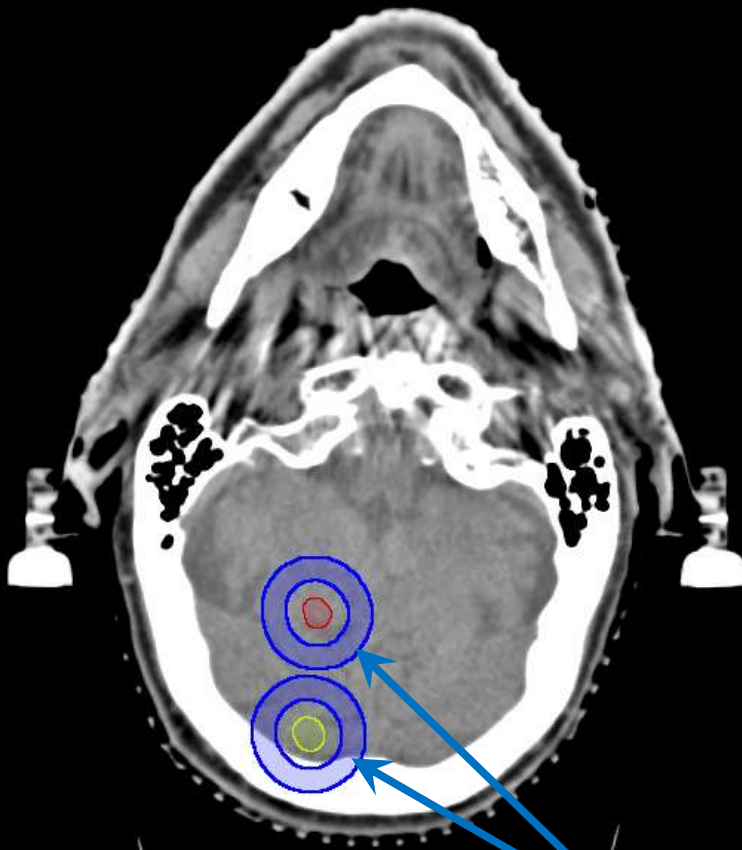
→ Índice de Gradiente ($V_{50\%Rx}/V_{100\%Rx}$)



Alvos → permitir pontos quentes

VMAT - Estratégias de Otimização

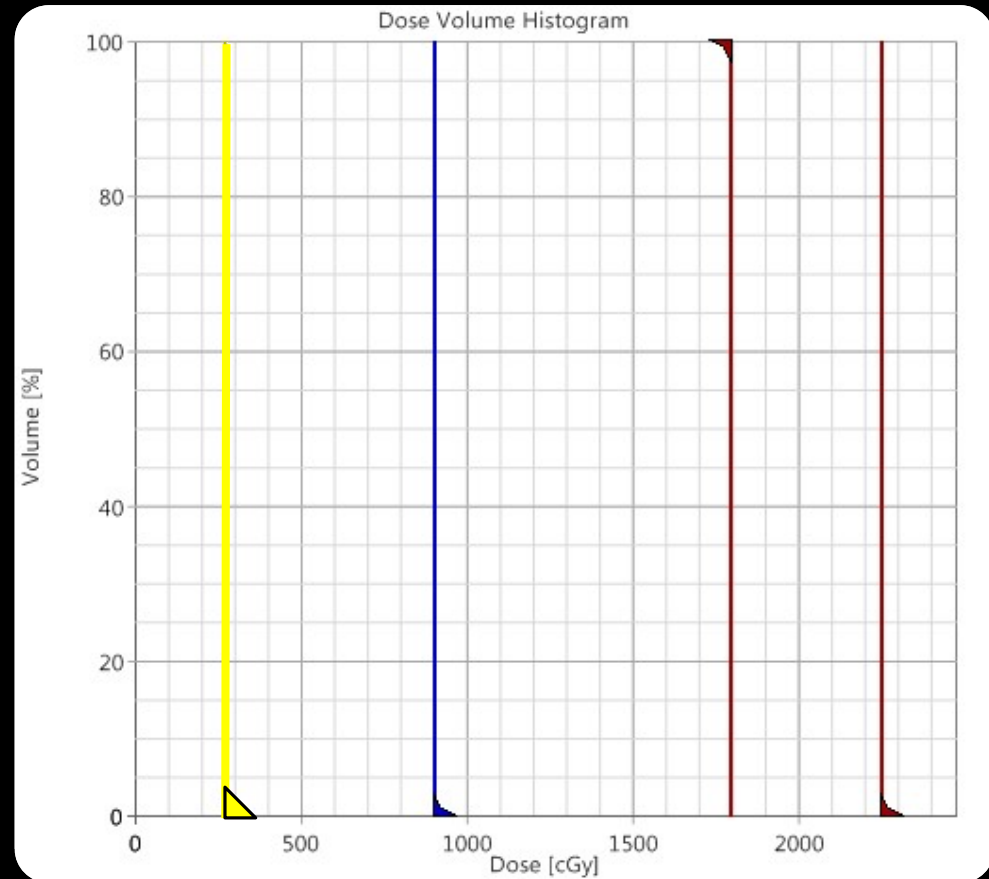
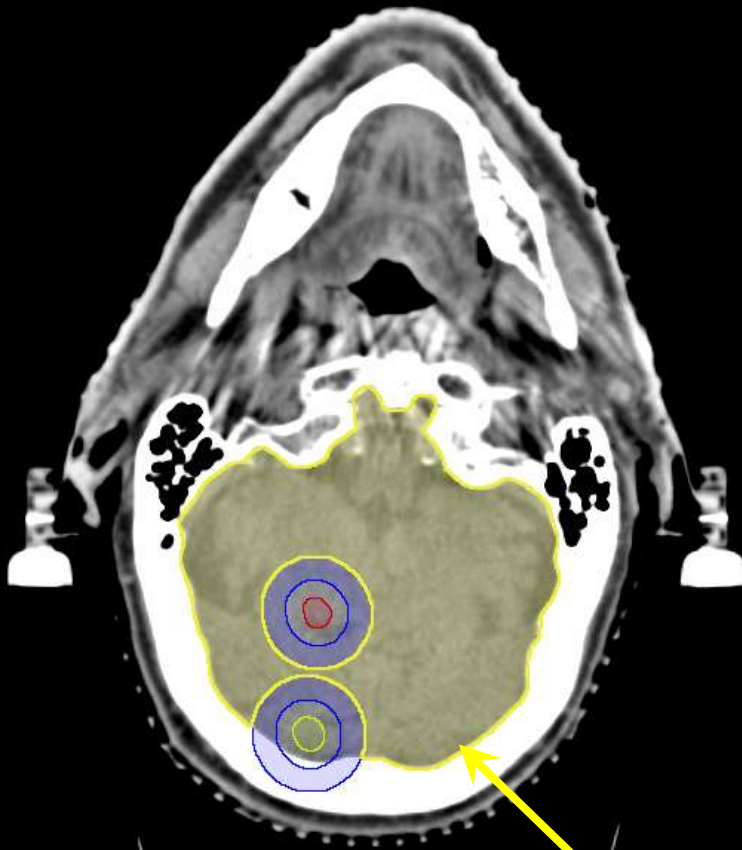
→ Índice de Gradiente ($V_{50\%Rx}/V_{100\%Rx}$)



Anéis → ~50%Rx @ 5mm

VMAT - Estratégias de Otimização

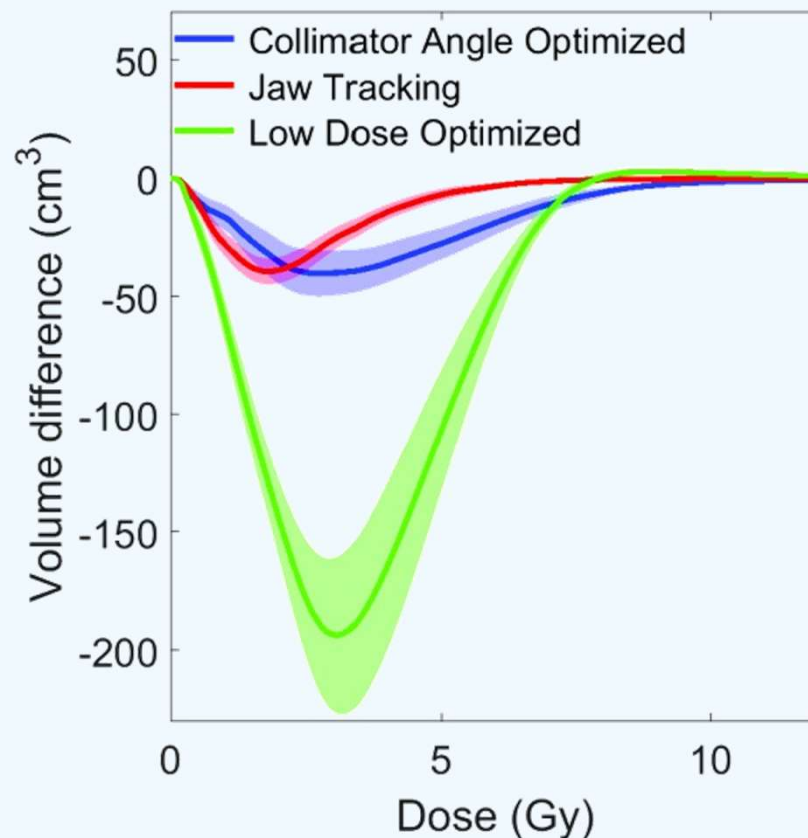
→ Controle de doses baixas no cérebro



Cerebro - [Anéis] → ~15%Rx @ 10mm

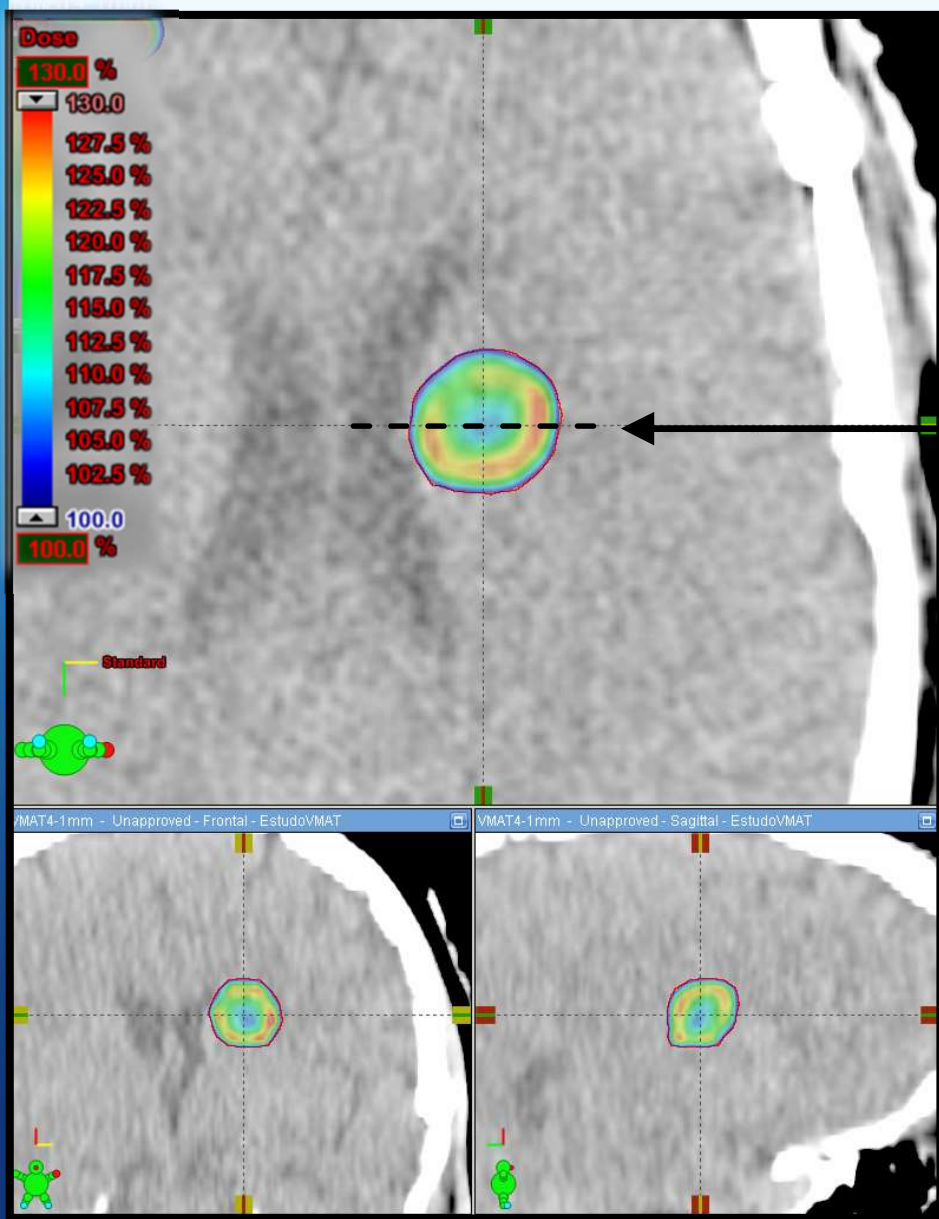
VMAT - Estratégias de Otimização

→ Impacto causado por diferentes parâmetros de planejamento

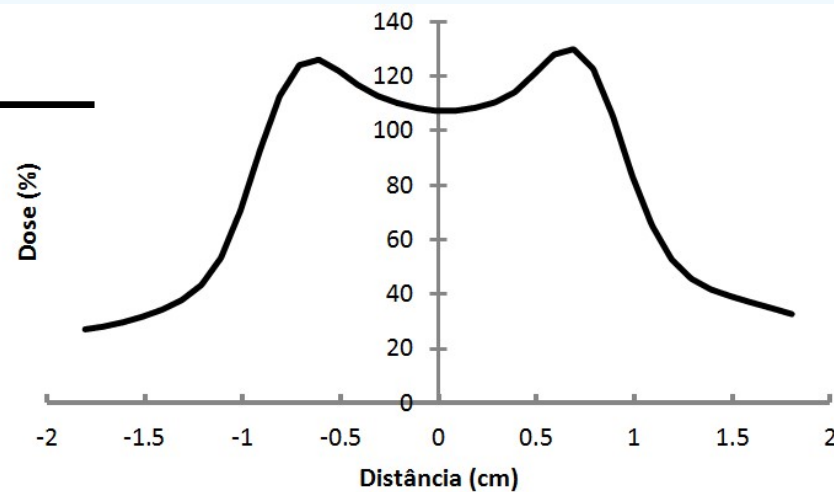


Redução do volume de cérebro normal para diferentes valores de dose

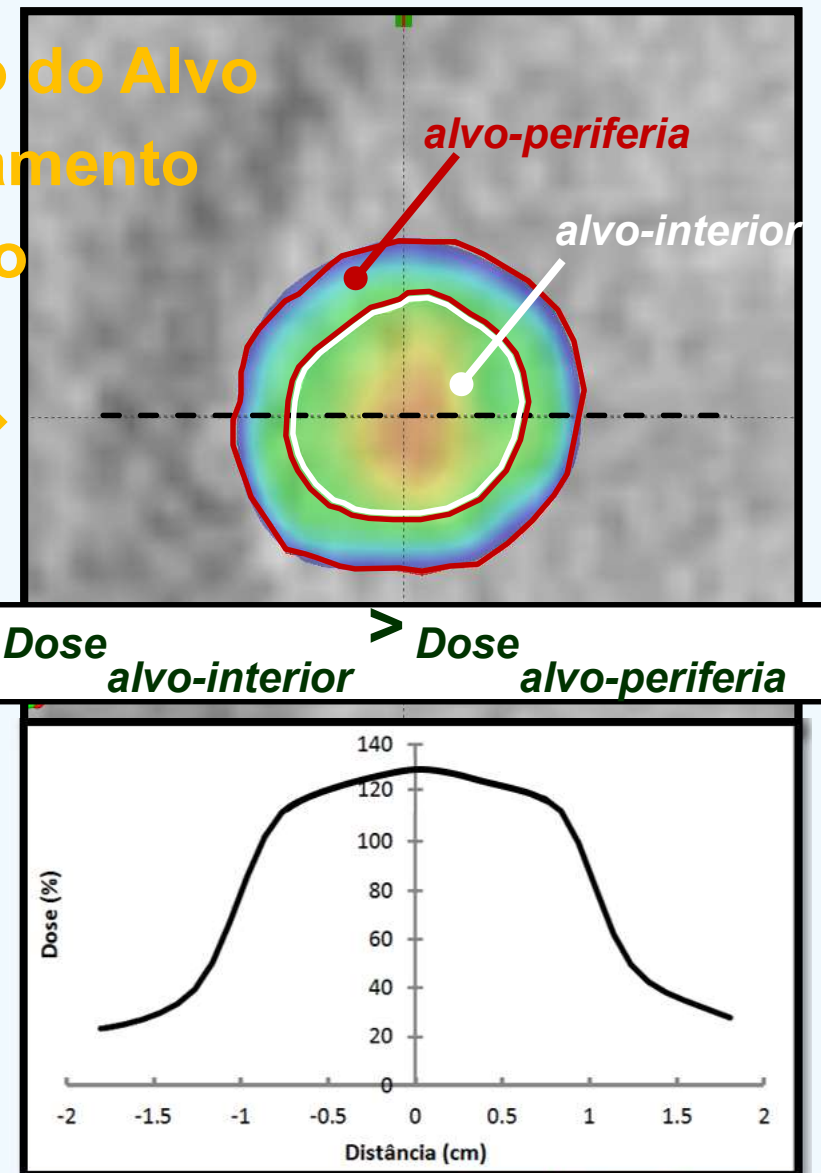
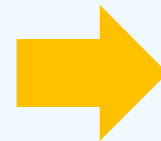
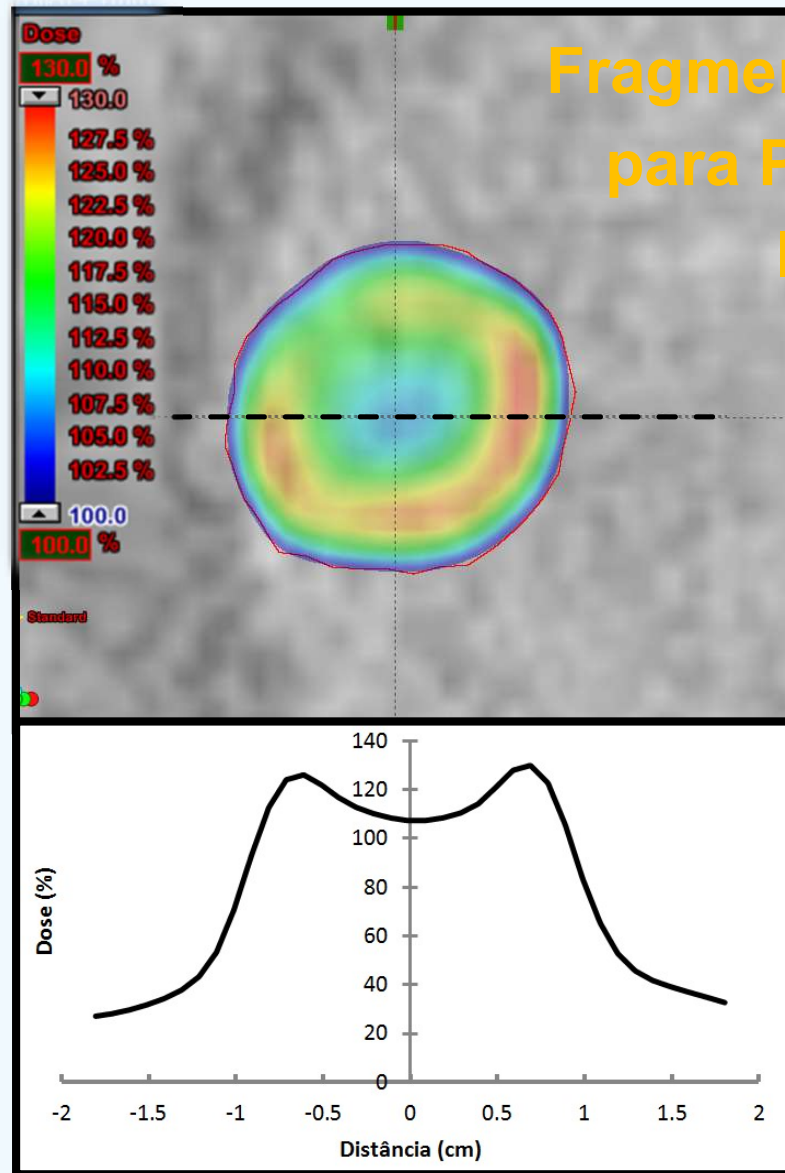
VMAT - Estratégias de Otimização



**Maior dose na
periferia do alvo**



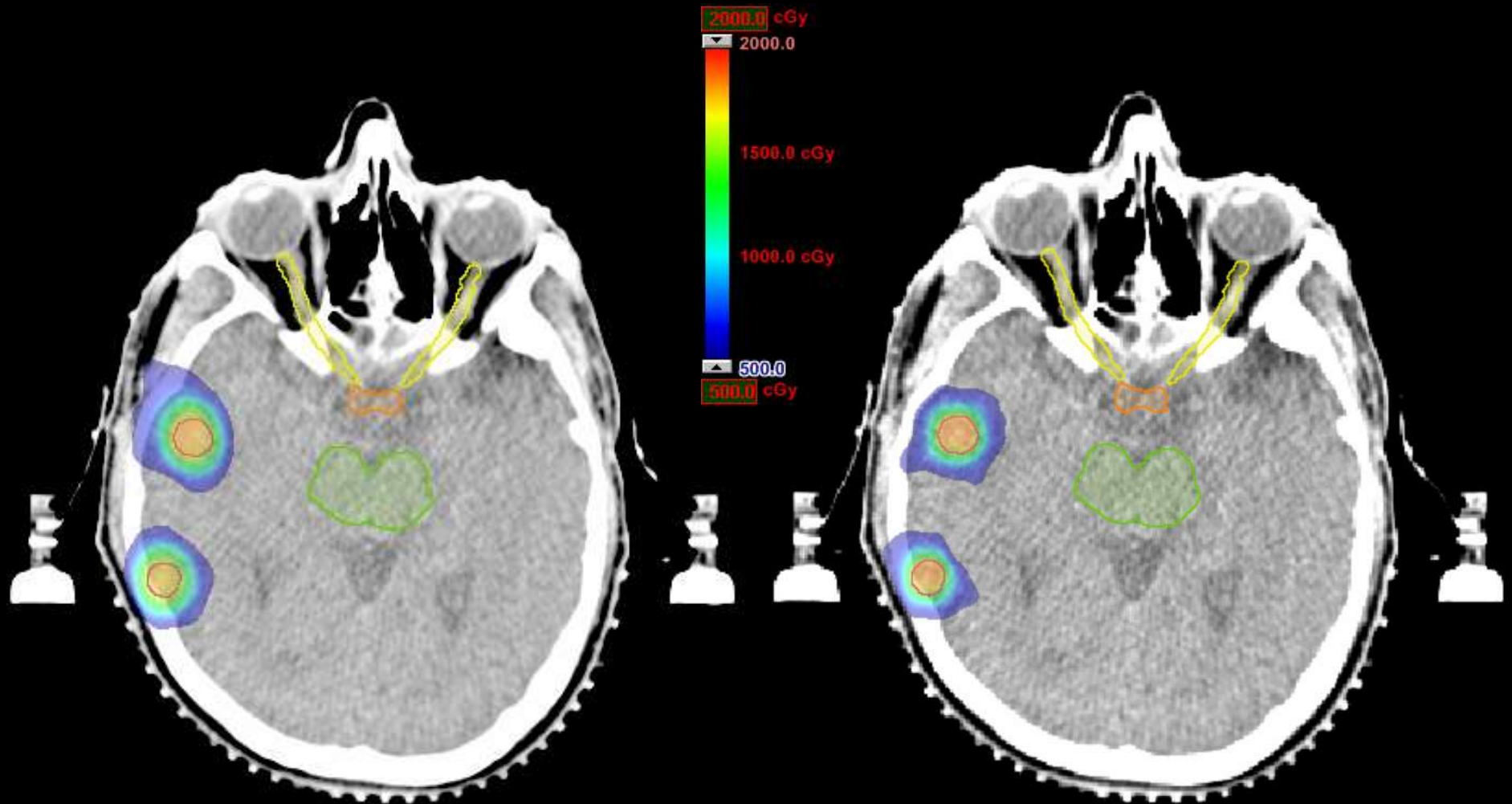
VMAT - Estratégias de Otimização



Distribuição de Dose

ADC - 8 isocentros

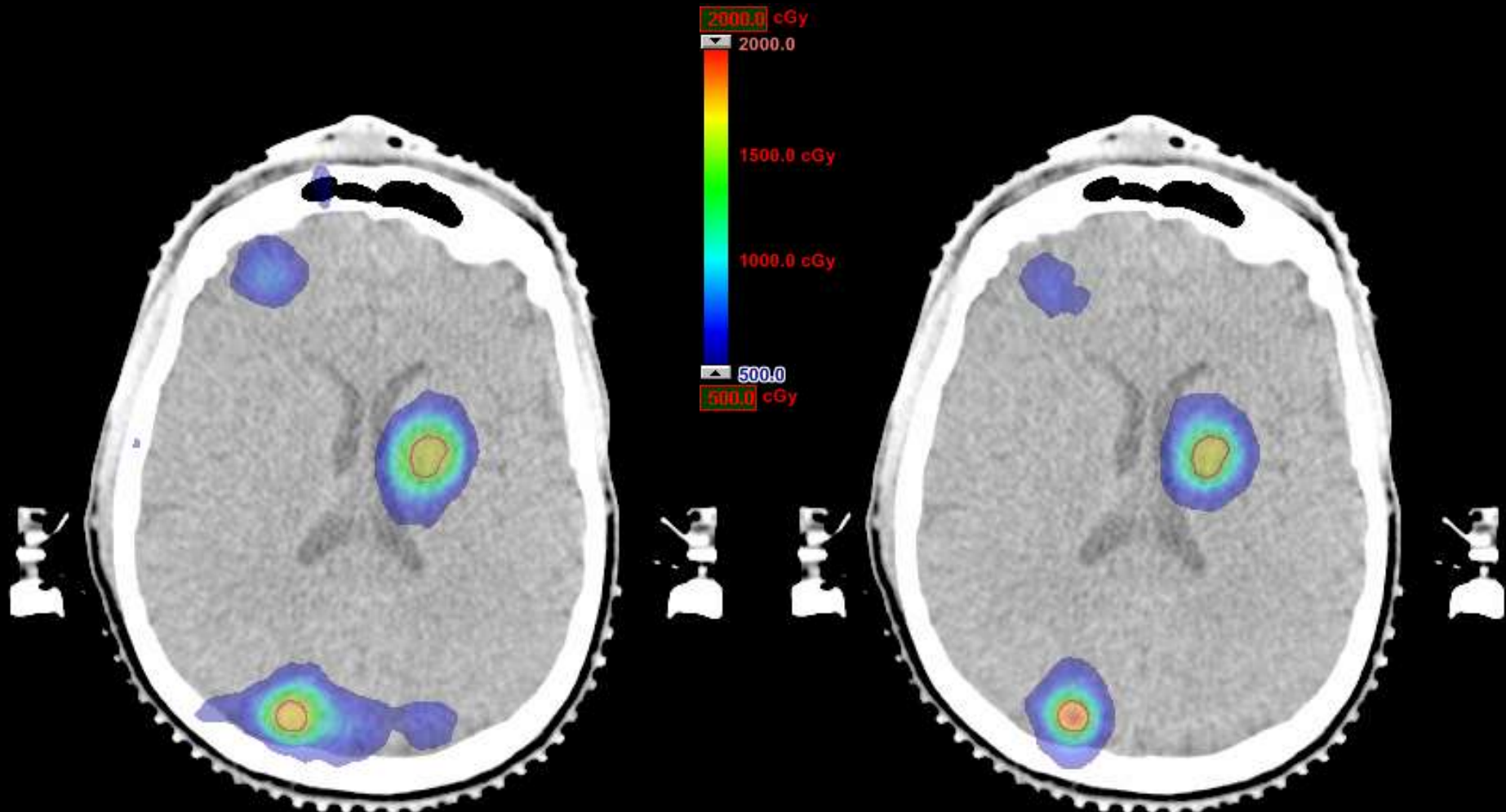
VMAT - 1 isocentro



Distribuição de Dose

ADC - 8 isocentros

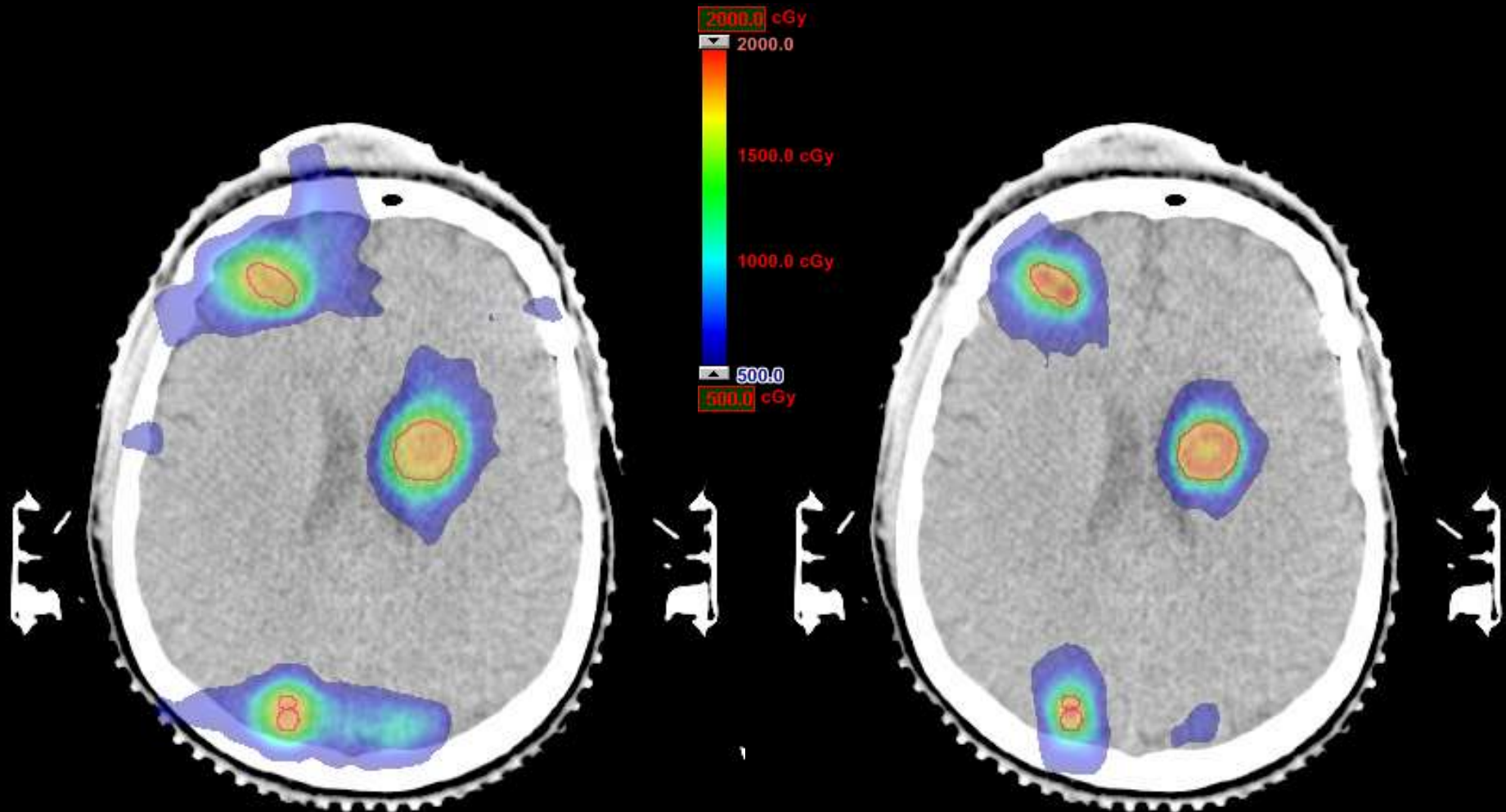
VMAT - 1 isocentro



Distribuição de Dose

ADC - 8 isocentros

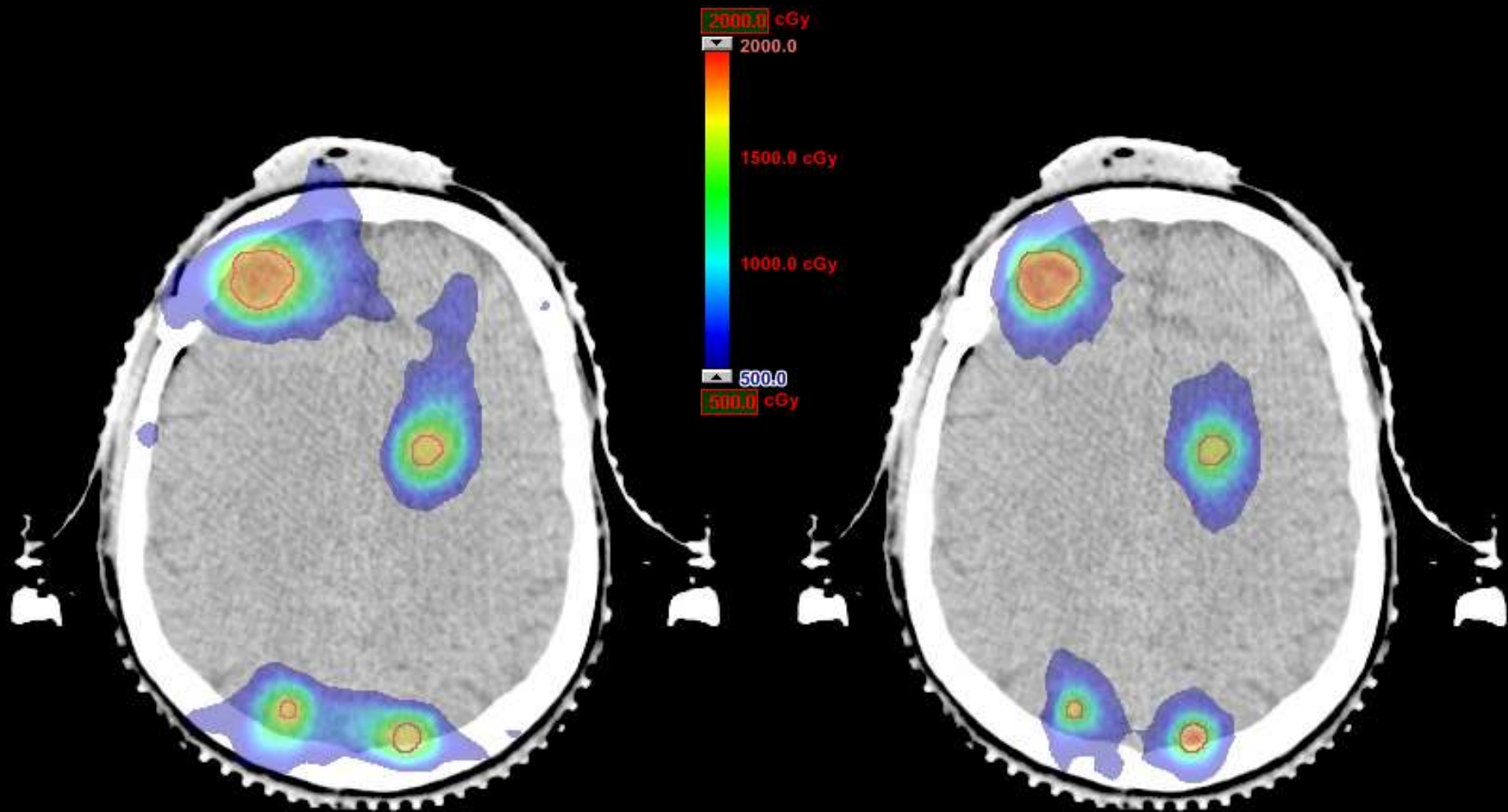
VMAT - 1 isocentro



Distribuição de Dose

ADC - 8 isocentros

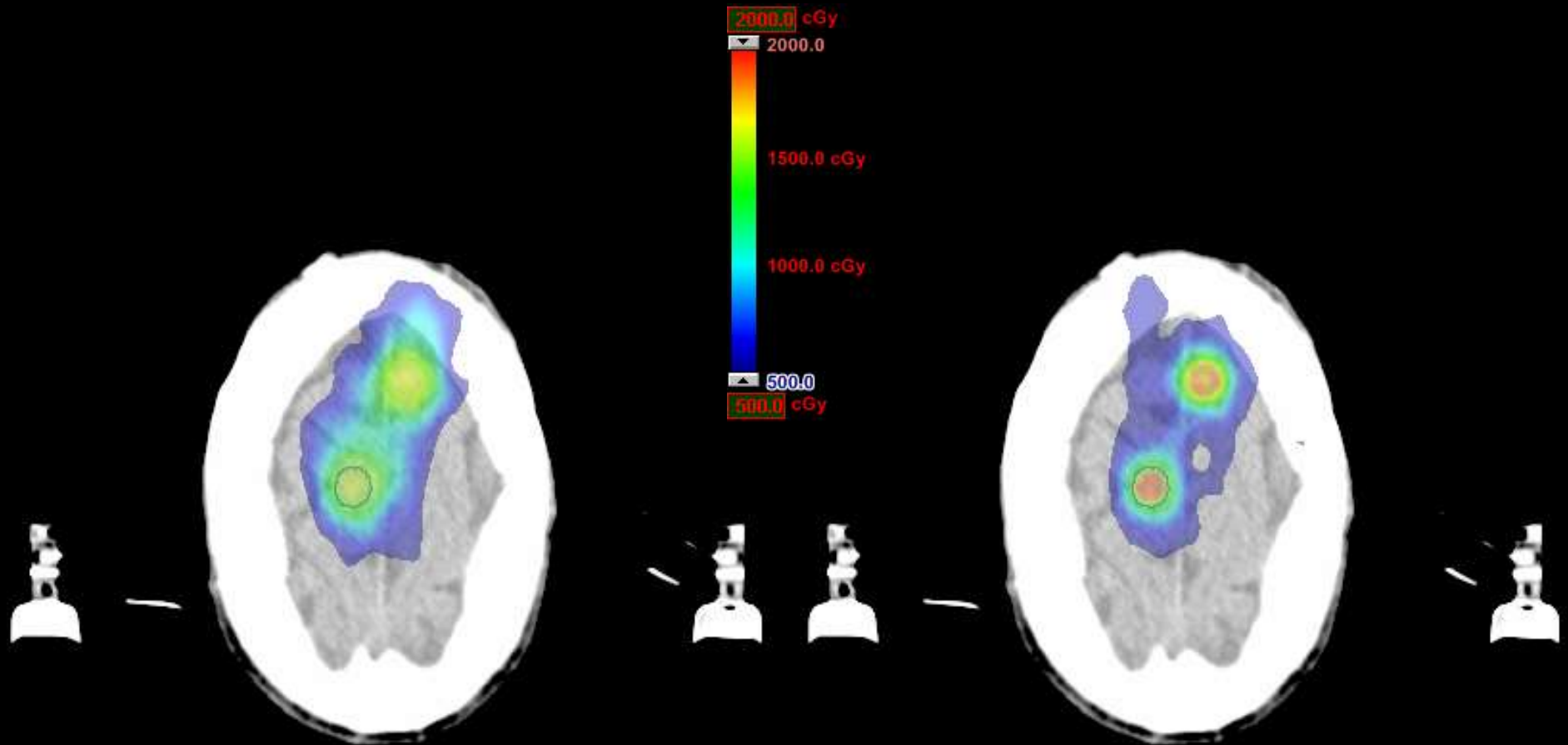
VMAT - 1 isocentro



Distribuição de Dose

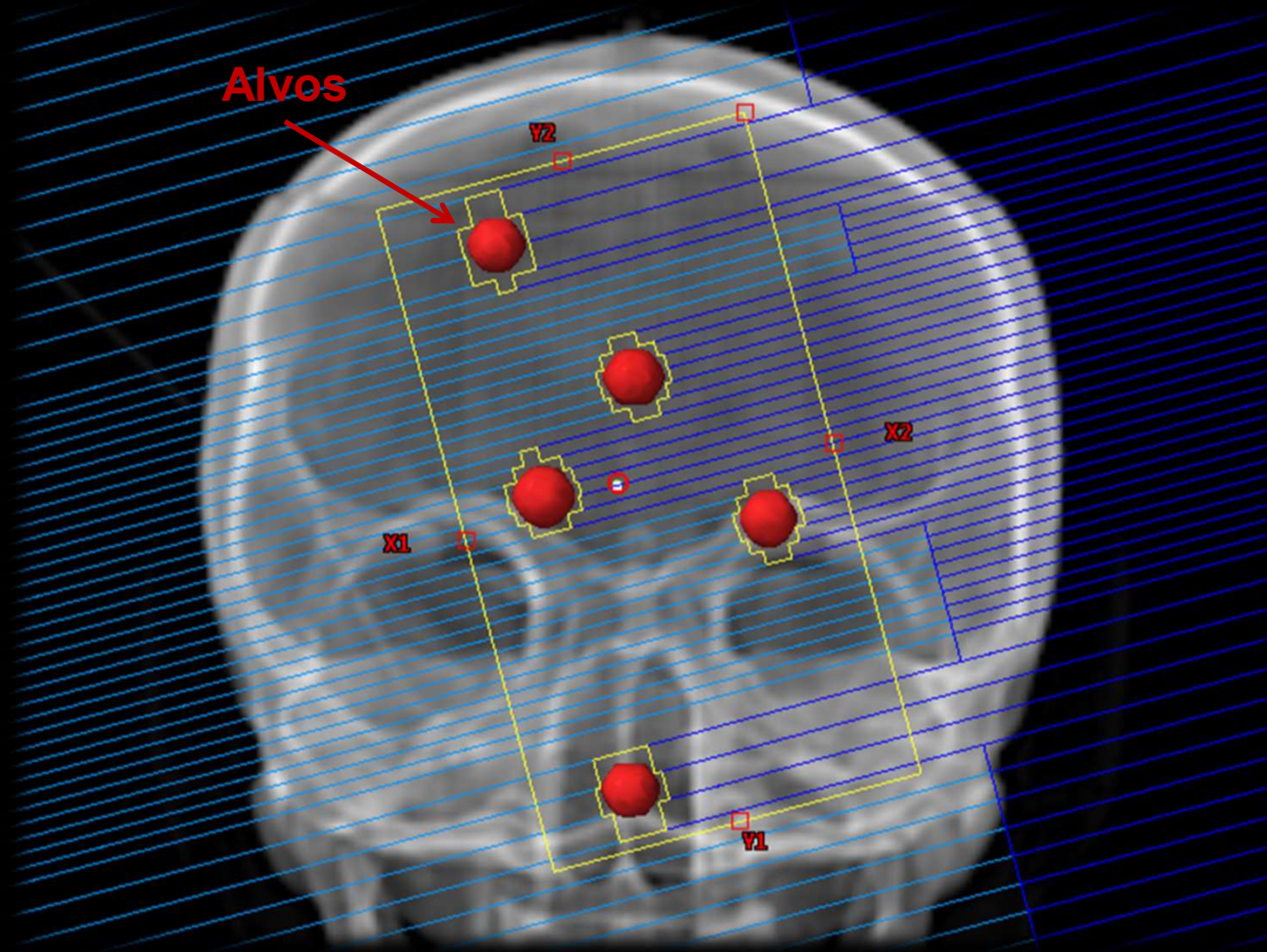
ADC - 8 isocentros

VMAT - 1 isocentro



VMAT - Múltiplas Lesões

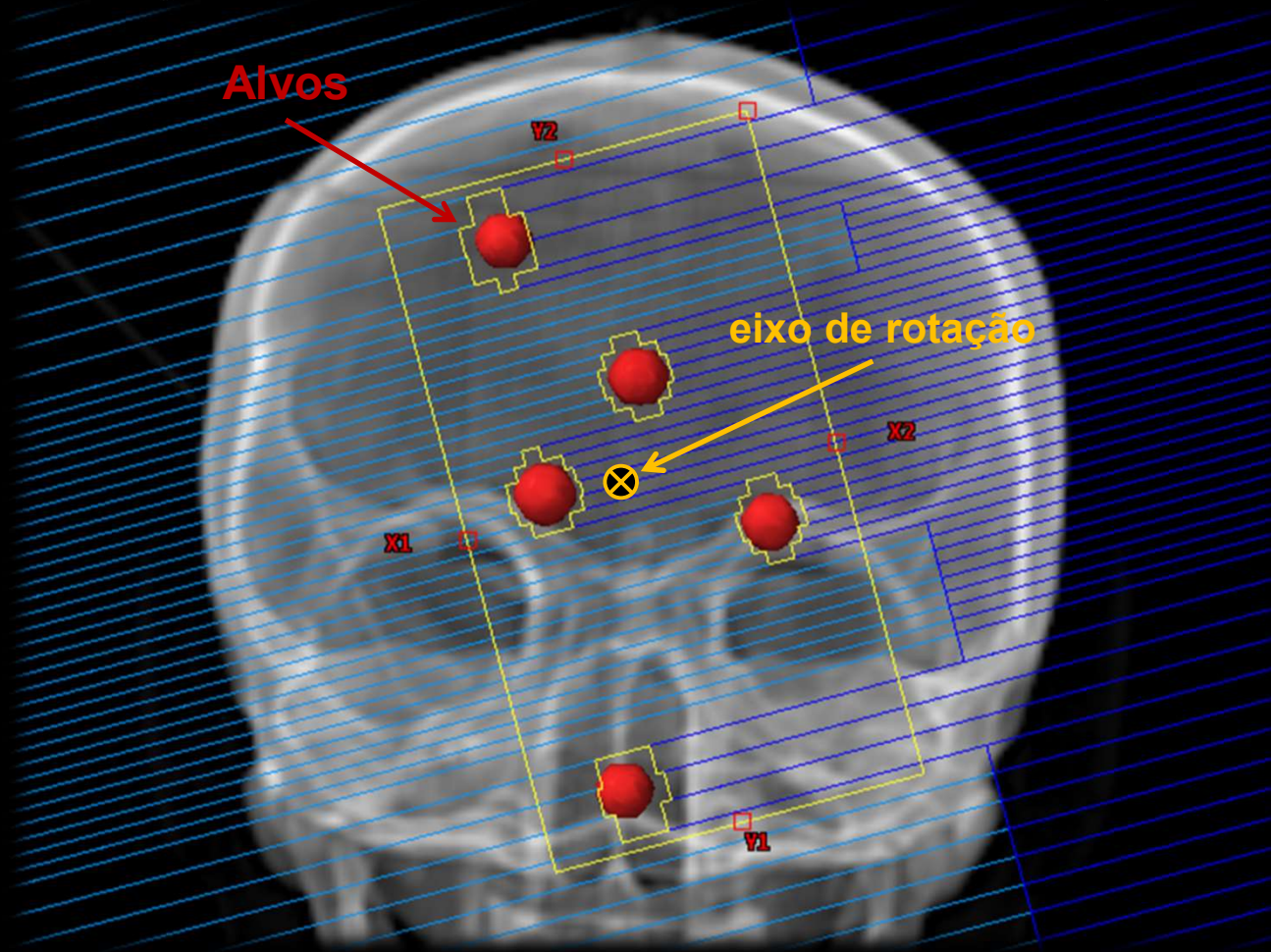
Isocentro único para vários alvos → incertezas de rotação administradas



Posicionamento Ideal

VMAT - Múltiplas Lesões

Isocentro único para vários alvos → incertezas de rotação administradas



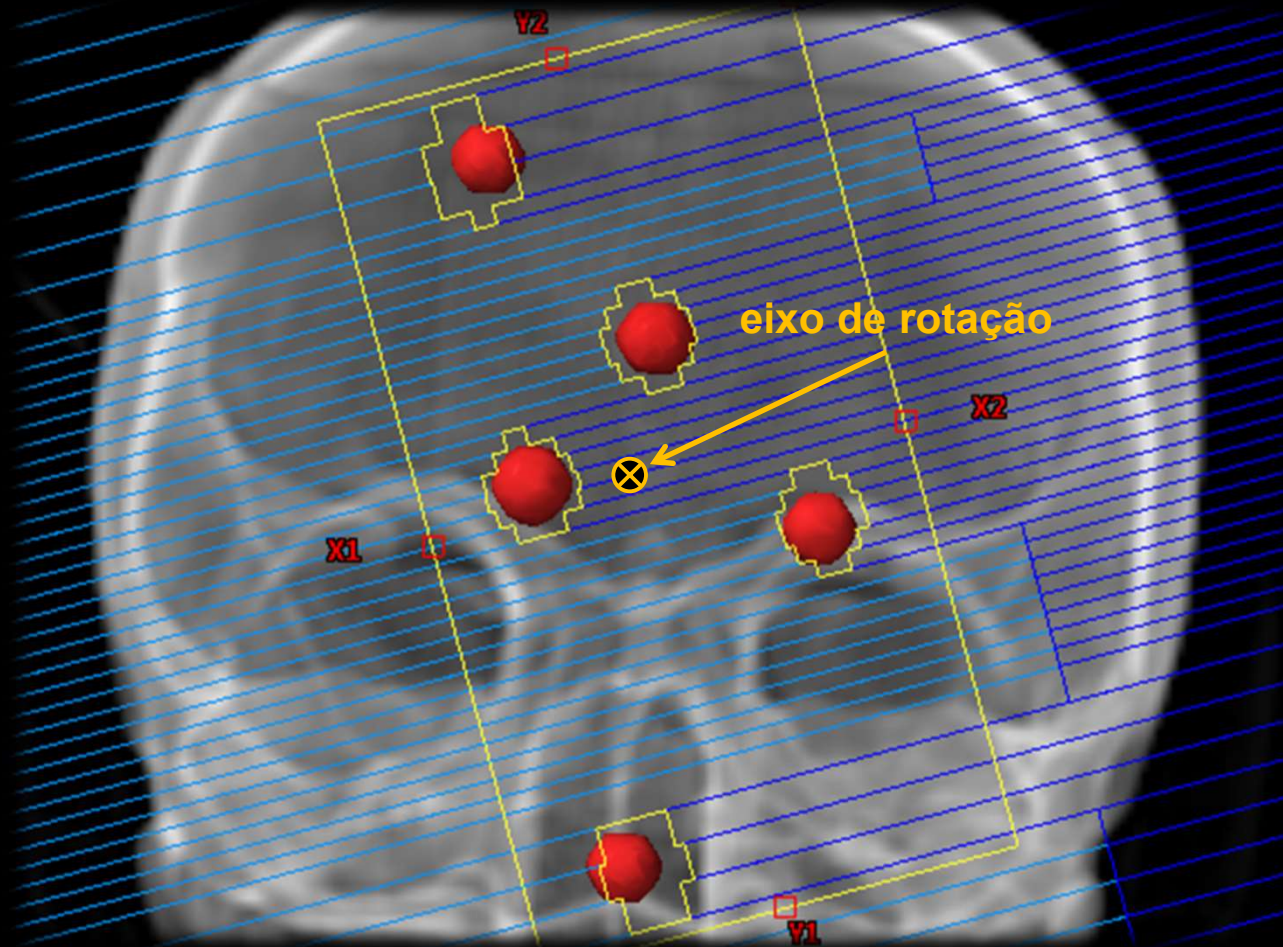
VMAT - Múltiplas Lesões

Isocentro único para vários alvos → incertezas de rotação administradas



VMAT - Múltiplas Lesões

Isocentro único para vários alvos → incertezas de rotação administradas

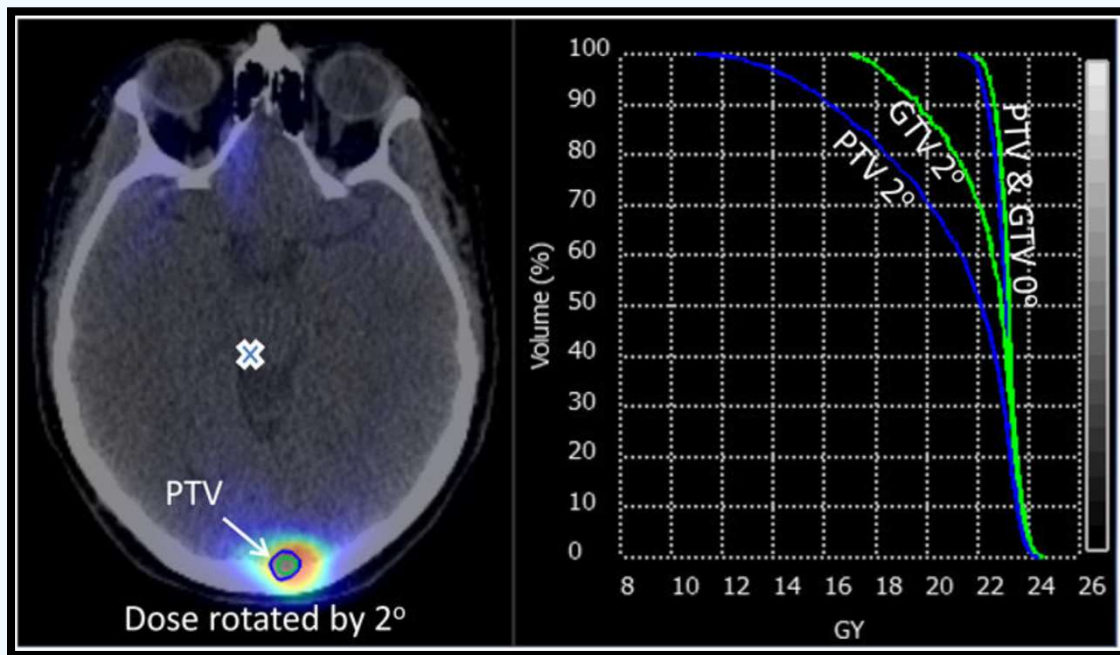


$\text{sen}(2^\circ \text{ desvio na rotação}) * \text{alvo à } 60 \text{ mm} = 2 \text{ mm de deslocamento}$

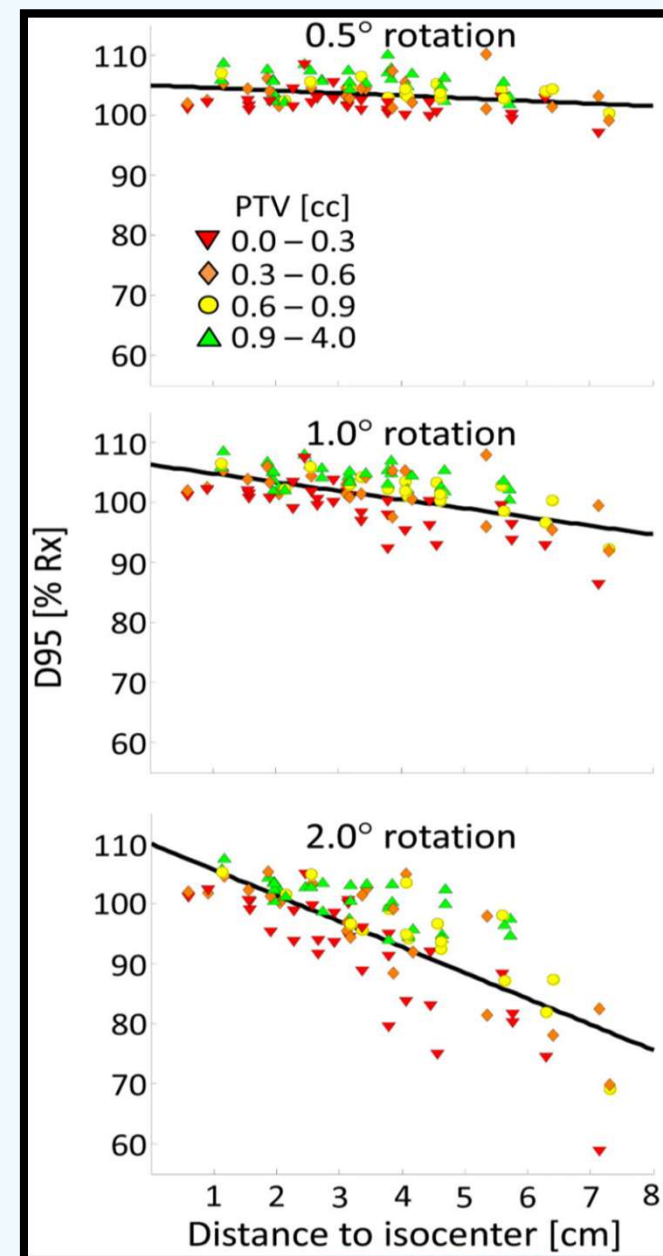
Fonte de erro elevado

VMAT - Risco de Comprometer a Cobertura

- Erro de Rotação
- Distância do Alvo ao ponto de rotação
- Tamanho do Alvo

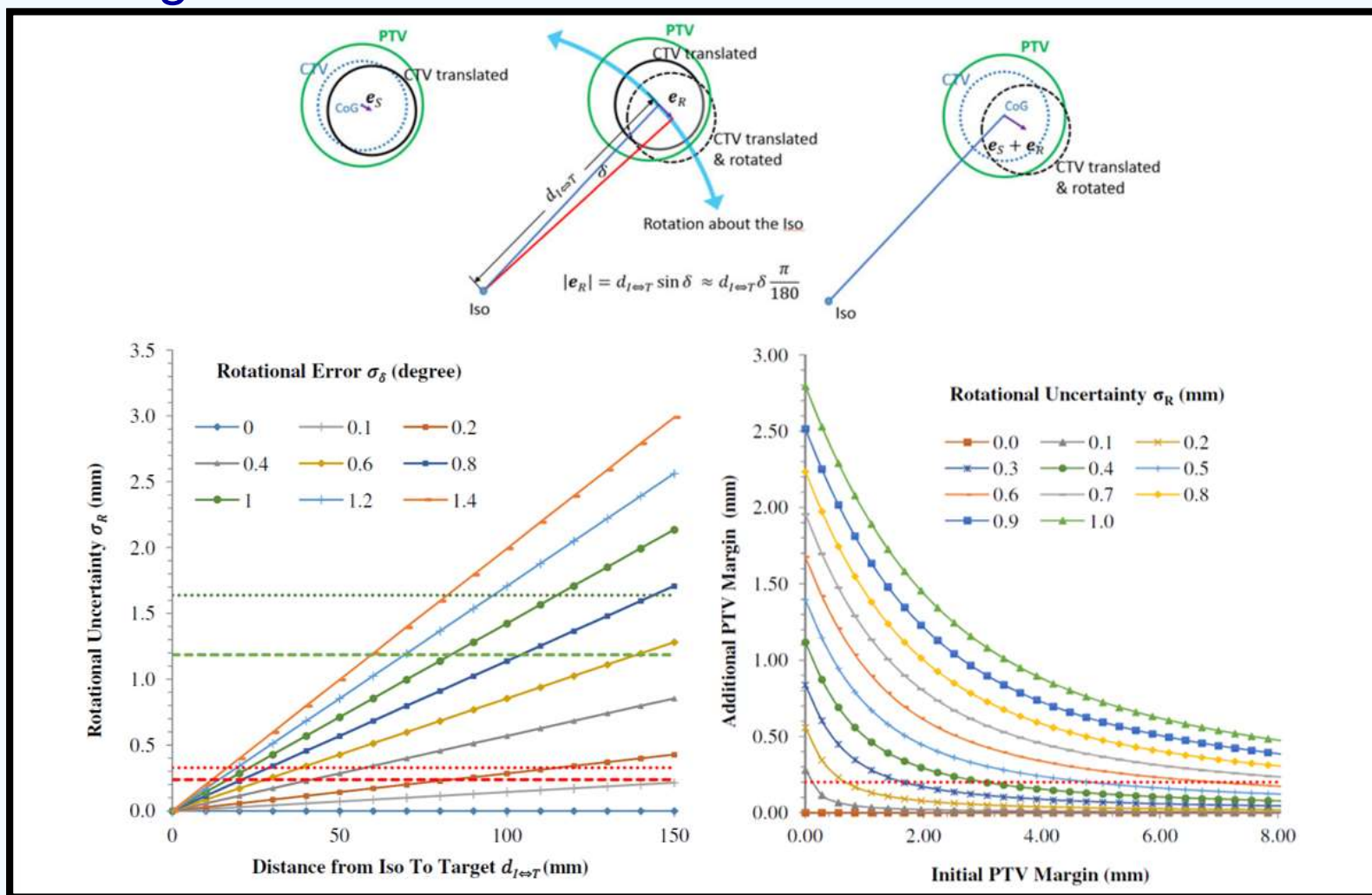


Roper et al. Int J Radiat Oncol Biol Phys. 2015;93(3):540–546



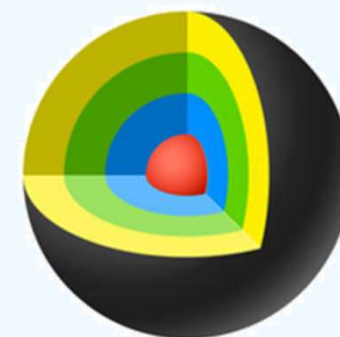
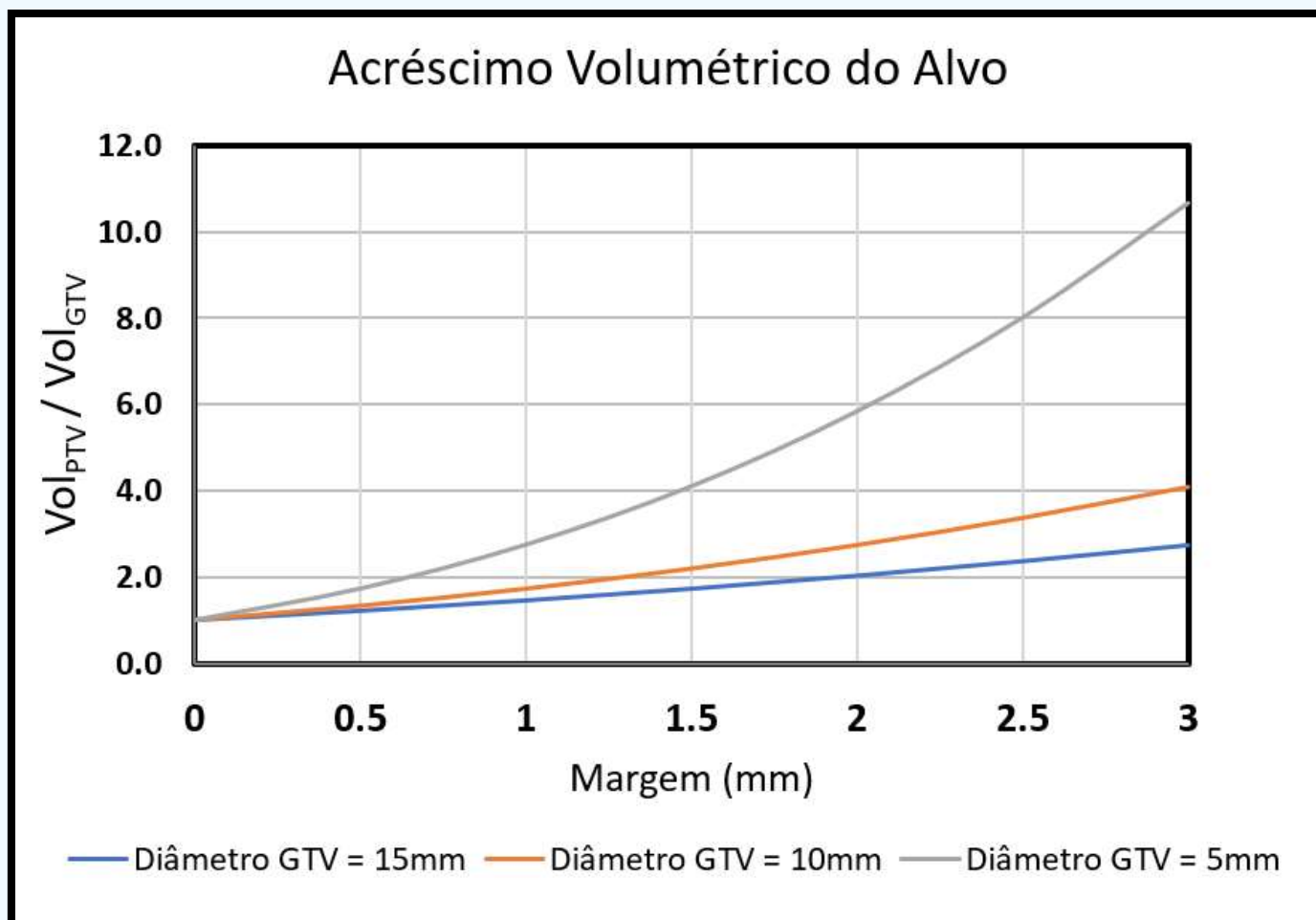
Erros de Rotação - Estratégia de Compensação

→ Margem de PTV



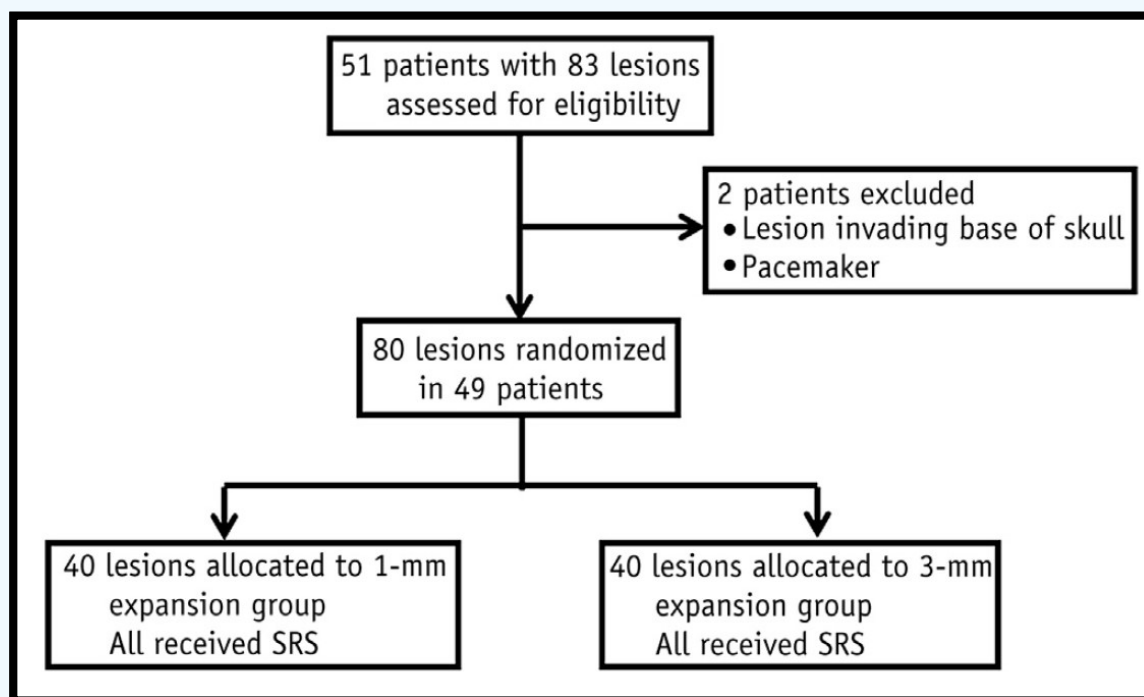
Erros de Rotação - Estratégia de Compensação

→ Margem de PTV



Erros de Rotação - Estratégia de Compensação

→ Margem de PTV: 1mm vs 3mm



Radionecrose:

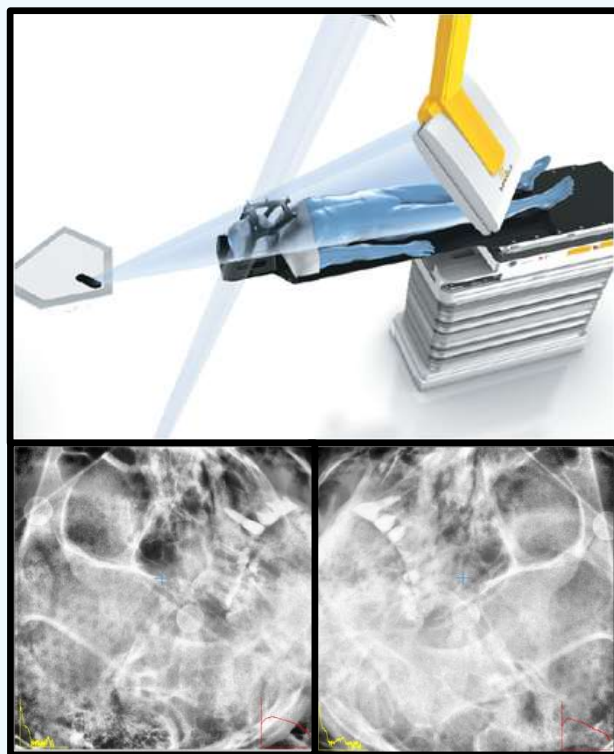
- 1mm: 1
- 3mm: 5

Kirkpatrick et al. Int J Radiat Oncol Biol Phys. 2015;91(1):100–108

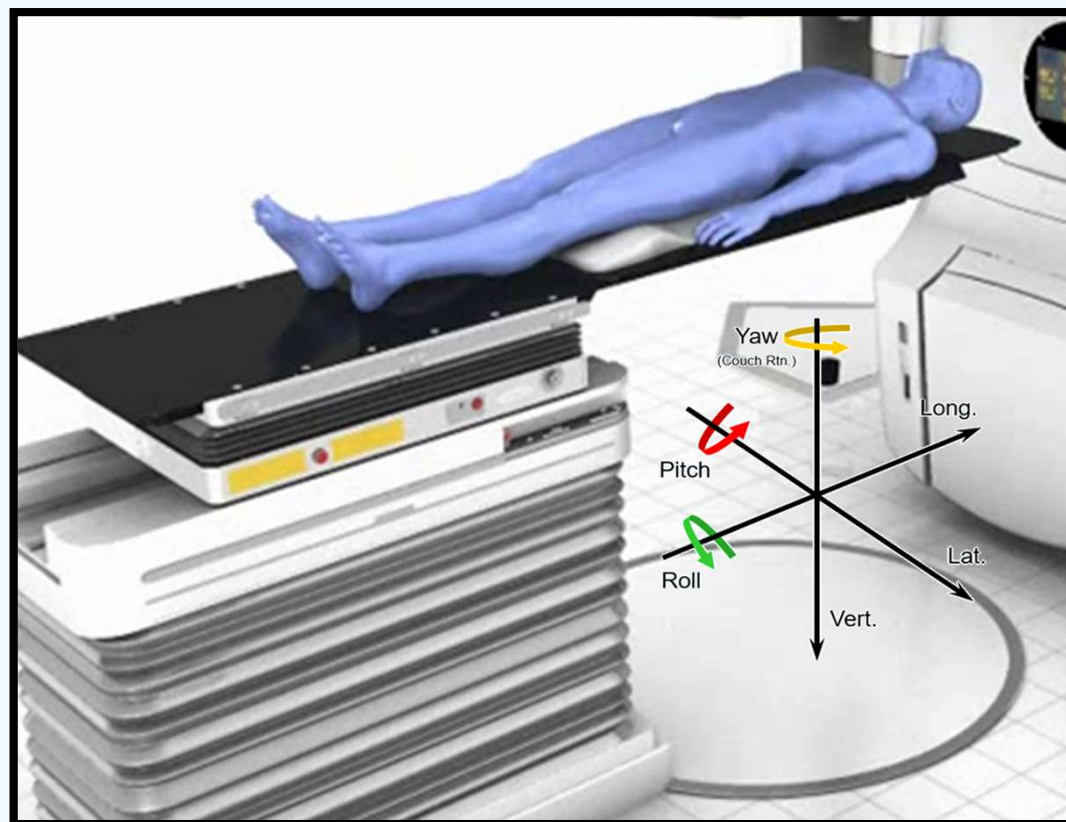
Taxa de recorrência local semelhante; Maior risco potencial de radionecrose para margem de 3 mm.

Erros de Rotação - Estratégia de Correção

→ Mesa 6DoF

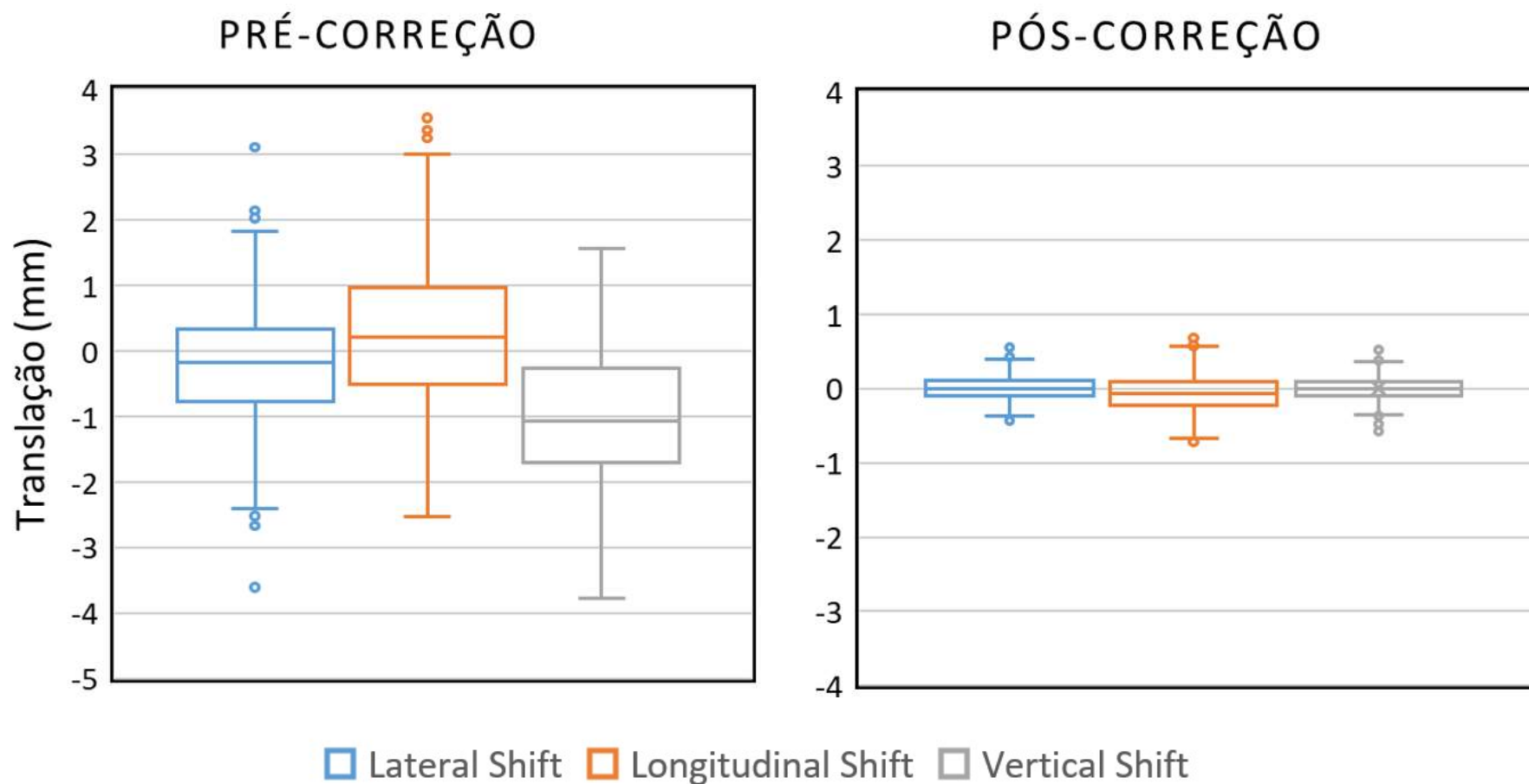


ExacTrac



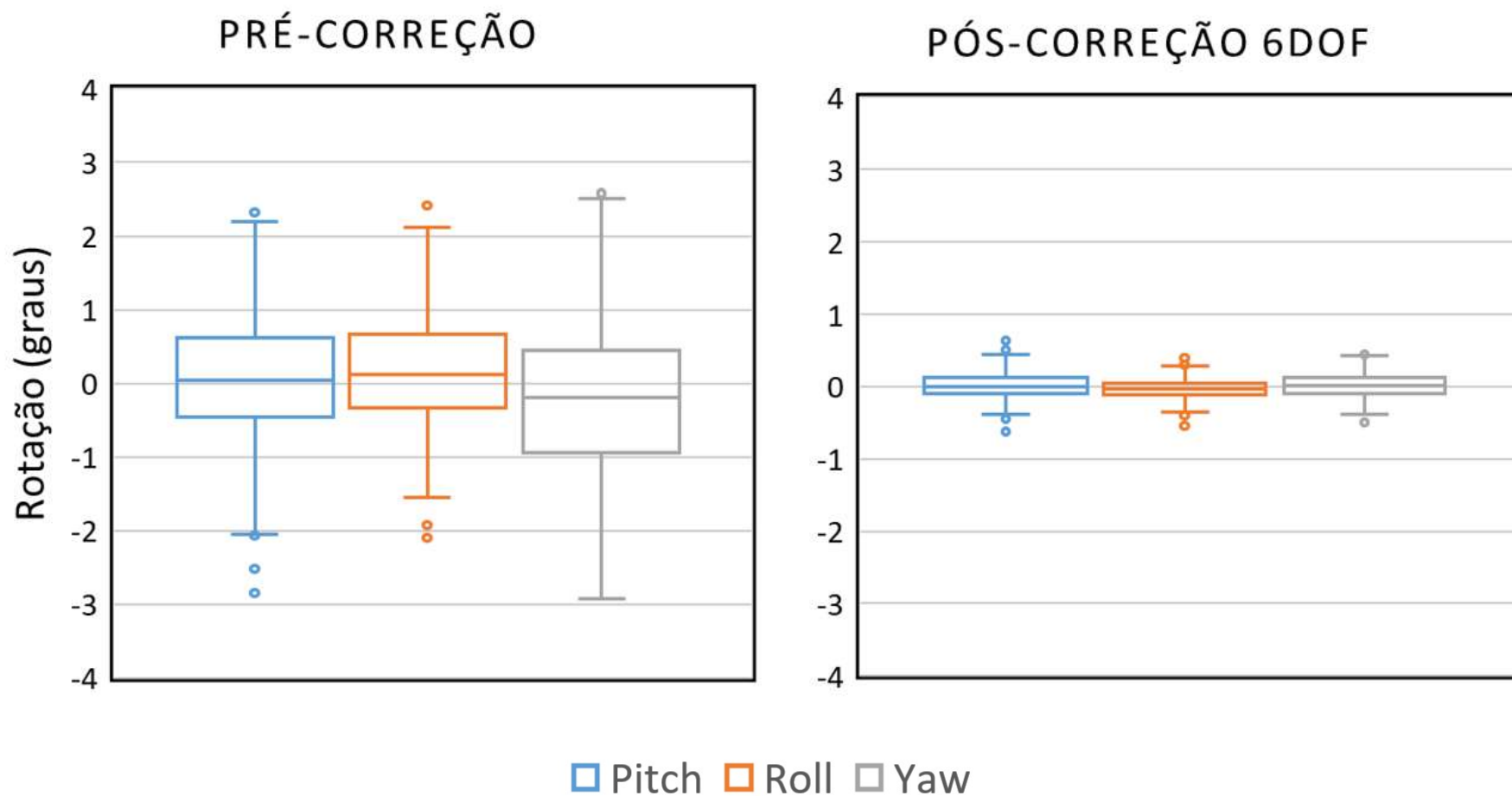
Posicionamento Inicial – Translação

→ Frameless SRS / ExacTrac – HSL (200 casos)



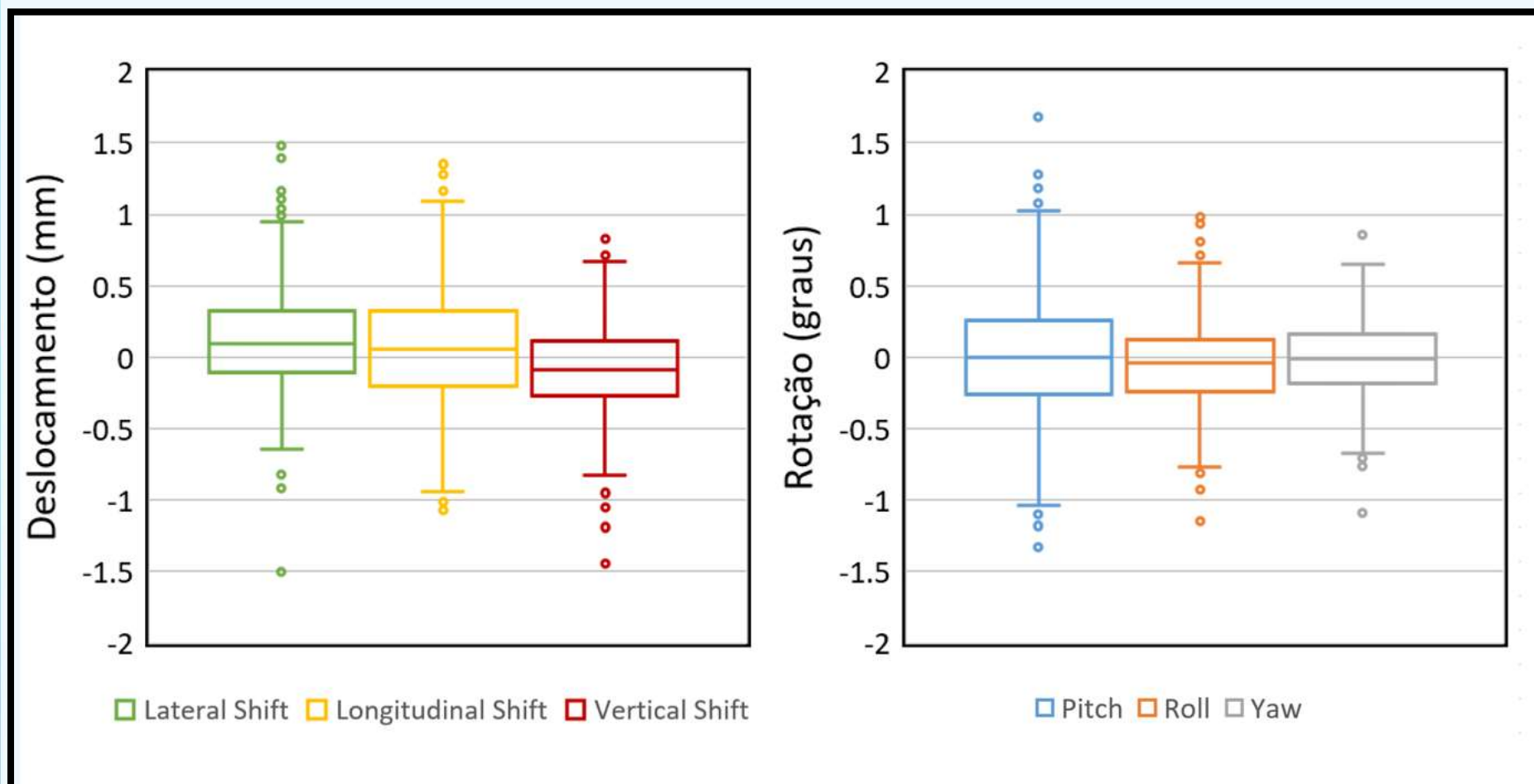
Posicionamento Inicial - Erros de Rotação

→ Frameless SRS / ExacTrac – HSL (200 casos)



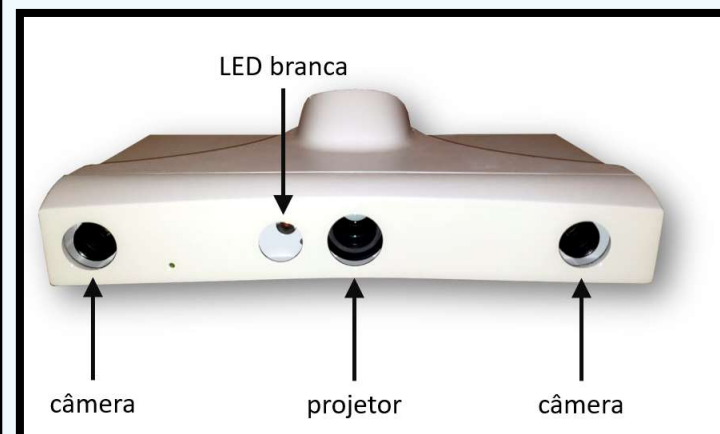
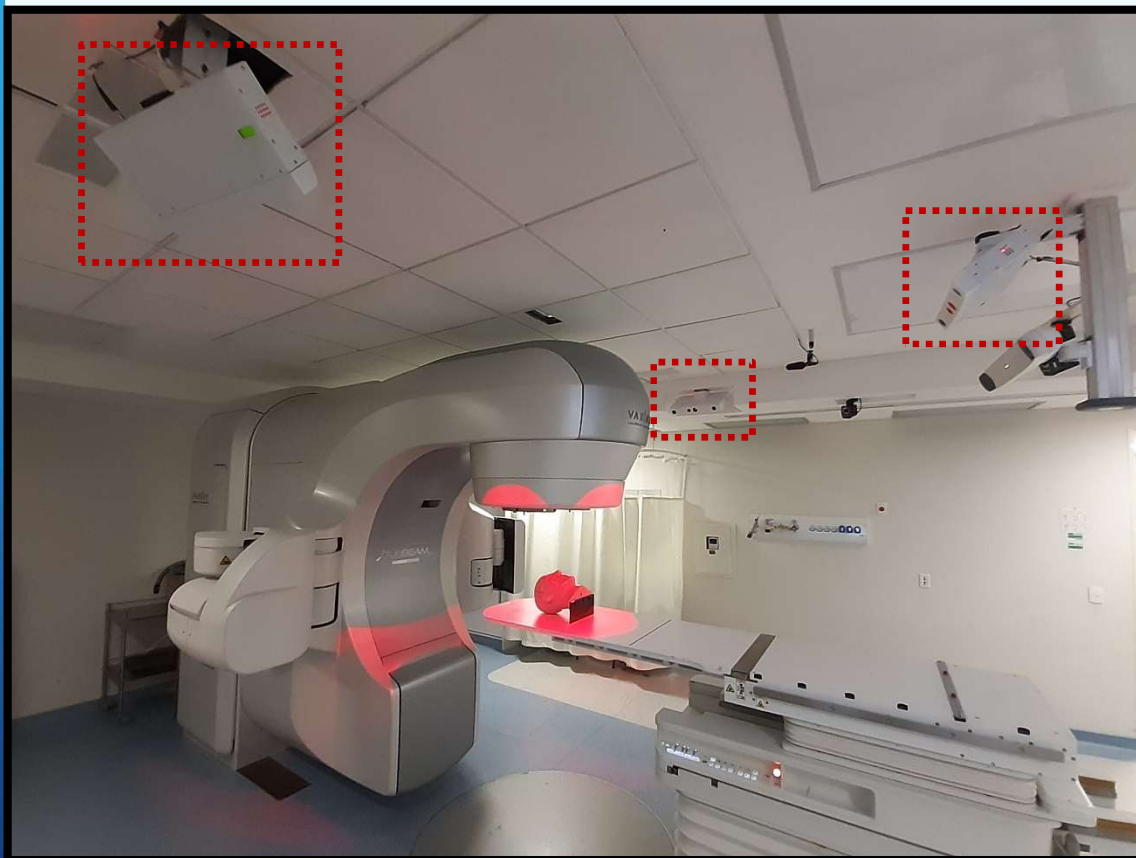
Intrafração – Translação e Rotacão

→ Frameless SRS / ExacTrac – HSL (200 casos)



Surface Guided Radiation Therapy

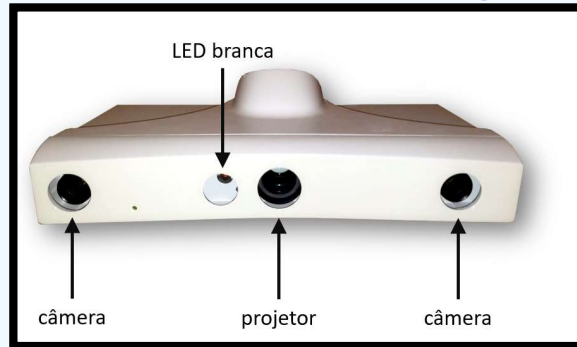
→ OSMS / Align RT



6 câmeras monitoram de modo contínuo a superfície do corpo → posicionamento do paciente e o rastreamento da localização intrafração, de modo contínuo e em tempo real.

Surface Guided Radiation Therapy

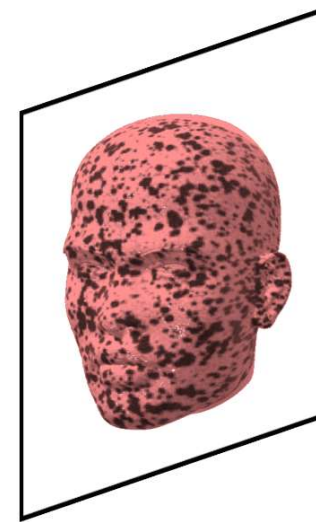
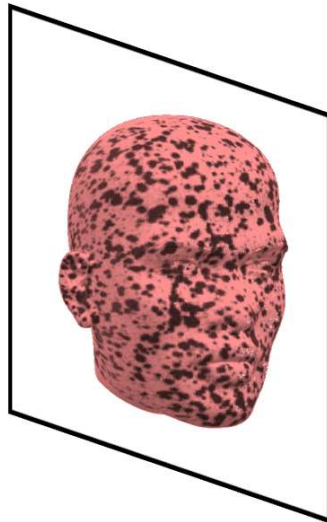
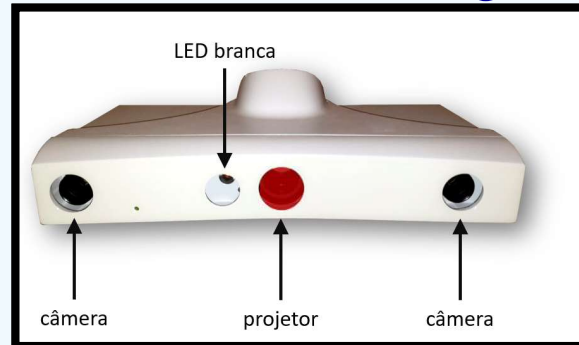
→ OSMS / Align RT



2 câmeras em cada módulo, imagens da mesma cena com diferentes perspectivas → mapa de profundidade por triangulação → requer a identificação dos pontos correspondentes nas duas imagens

Surface Guided Radiation Therapy

→ OSMS / AlignRT



Imagens da pele não contêm informações suficientes para essa identificação → padrão de manchas projetado no paciente, fornecendo informações necessárias para a correspondência dos pontos.

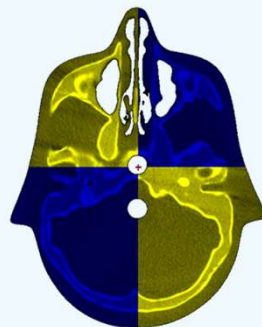
SGRT e CBCT – Processo para SRS

1- Posicionamento OSMS

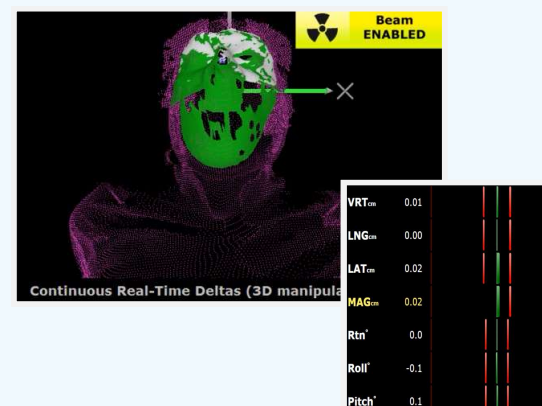
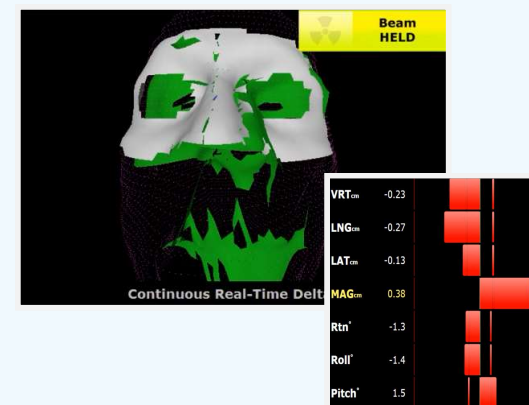
- a) Rotações (manual)
- b) Translações (auto)



2 - CBCT (6 DoF)



3 - Diferença entre OSMS e CBCT



4 - Aquisição de Nova Superfície de Ref.



5 - Monitoramento Intrafração

Tempo de Tratamento

SRS – ADC

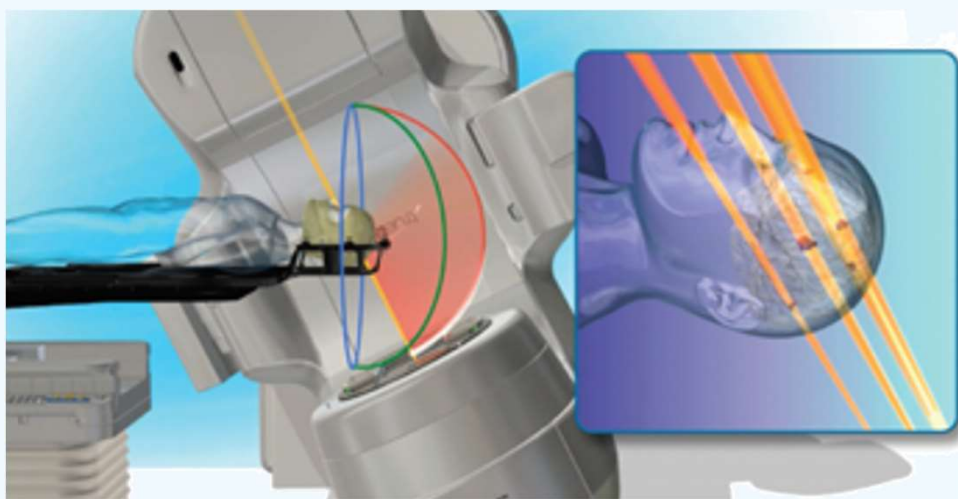
- Tempo médio por isocentro ≈ 20 min (1400 MU / min)
- Tempo de tratamento $\propto$ (*Nº de lesões = Nº de isocentros*) ≈ 20 min * *Nº de lesões*

SRS – VMAT

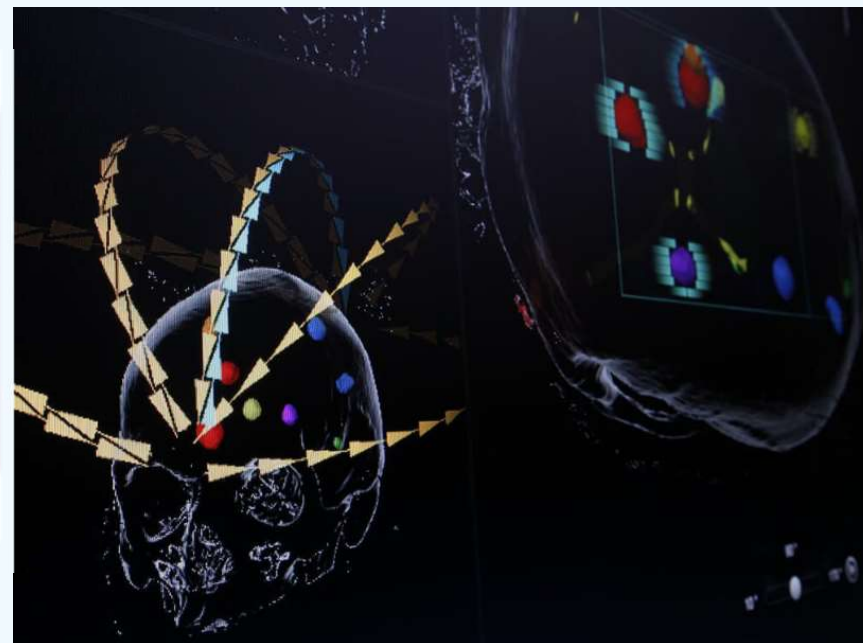
- Independente do *Nº de lesões*
- Tempo médio de tratamento ≈ 20 min (1400 MU / min)

Automação

→ Soluções automatizadas de planejamento para múltiplos alvos cerebrais



HyperArc



Elements



SÍRIO-LIBANÊS

XIX Curso de Radioterapia de Última Geração e Controle da Qualidade

20 a 22 de novembro de 2019

Inscrições gratuitas

Um espaço para troca de experiência sobre as inovações na radioterapia e atualização sobre as recomendações para controle de qualidade nos serviços de radioterapia.

Palestrantes Internacionais



Michael J. Zelefsky

Vice Chairman do Departamento de Rádio Oncologia. Chefe Serviço de Braquiterapia do MSKCC – New York

Temas:

- Meeting the Professor
- Discussão de casos clínicos



Saiful Huq

Presidente Eleito da AAPM – American Association of Physicists in Medicine. Diretor da Divisão de Física Médica da UPMC – University of Pittsburgh School of Medicine. Professor de Oncologia da Radiação UPMC – Pittsburgh

Temas:

- Impactos das novas tecnologias para os pacientes, familiares e o sistema de saúde



Cem Onal

Professor e Chefe de Departamento na Universidade Baskent em Adana – Turquia
Departamento de Radio-oncologia

Temas:

- Radioterapia adaptativa: Quais são os desafios e benefícios?



Laurent Collignon

Master em Gerenciamento de inovações Chair de Programa Flash Terapia

Temas:

- Flash terapia
- Estamos perto da realidade?
- Demonstração prática de:
 - OSMS
 - Calypso
 - Monitoramento intrafação
 - Triggered imaging

Hospital
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