FAKULTNÍ NEMOCNICE OSTRAVA

CyberKnife – fyzikálně technický pohled

L. Knybel

Bilancování 2010-2023

- Retrospektivní pohled
  - Nové výzvy, úkoly, diagnózy, metody- přístupy

- Technické a fyzikální úskalí
- Ozařovací čas
- Nehomogenní plánování
- Limity
- Nové diagnózy

Bilancování 2010-2023

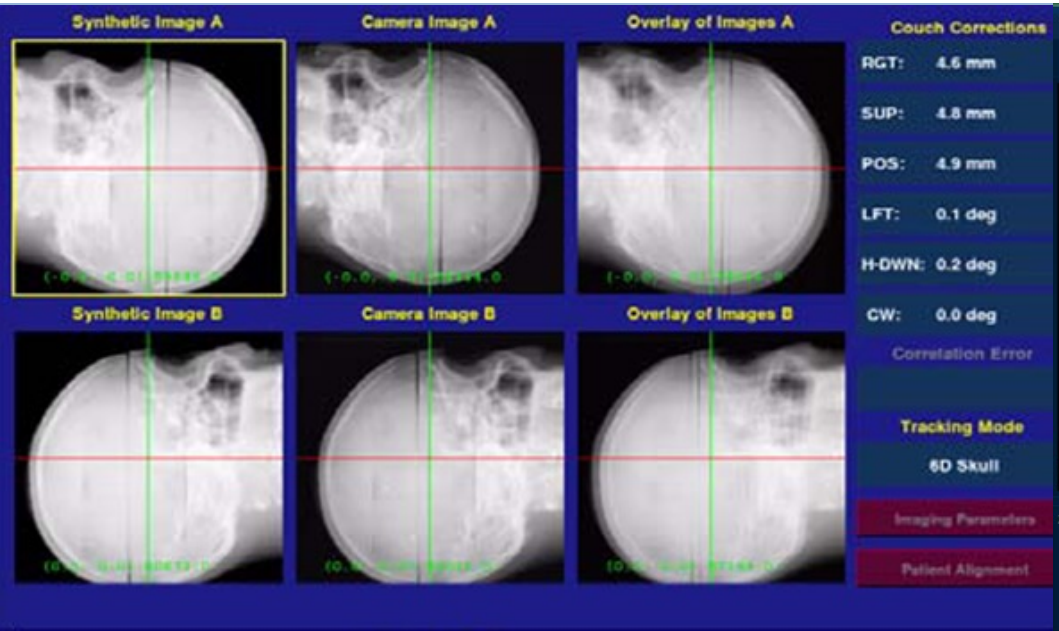
- CyberKnife Ostrava – 1. instalace ve střední Evropě

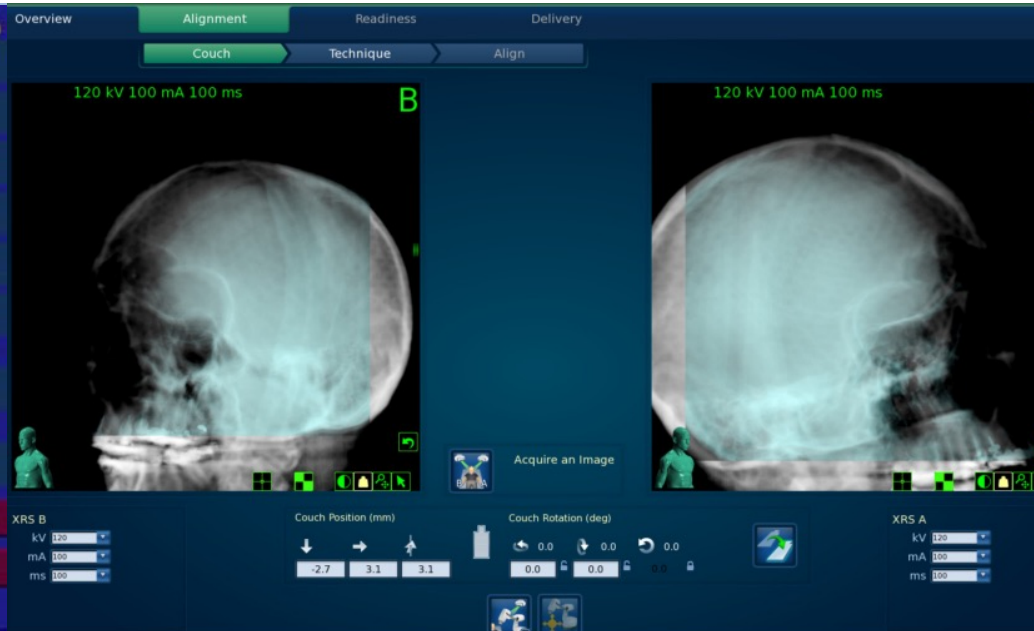
CyberKnife

TECHNICAL DATA	
Maximum reach	2496 mm
Rated payload	300 kg
Number of axes	6
Weight	Approx. 1120 kg
Pose repeatability (ISO 9283)	+/- 0.06 mm (60 microns)

CyberKnife Ostrava

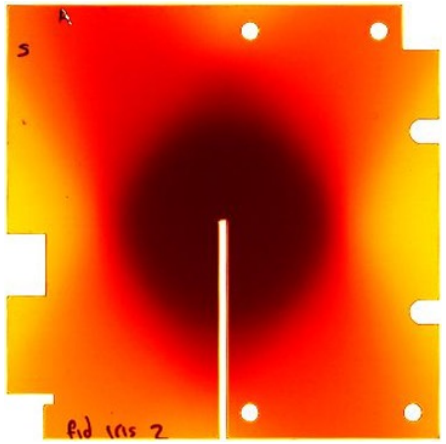
- 4/2023 8000 pacientů 9500 ložisek
- 1. pacient 8/2010
- 2015 upgrade na V10.5

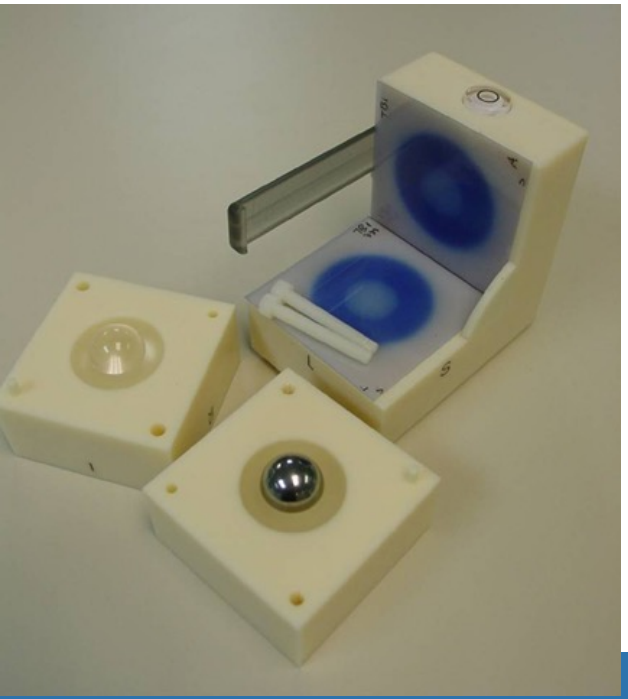


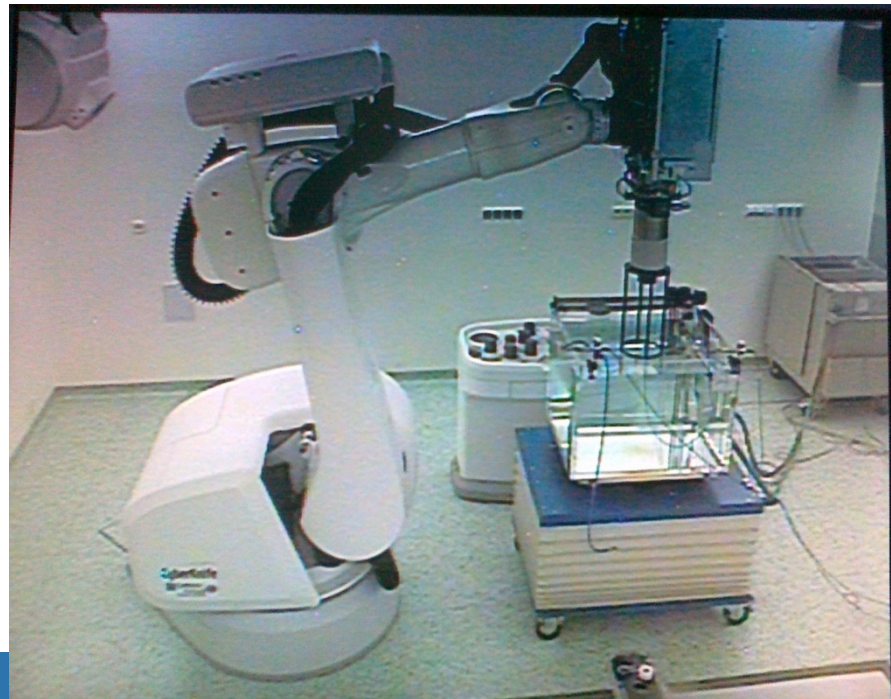


Technické a fyzikální úskalí

- Dozimetrie malých polí + kruhová pole
- Filmová dozimetrie
- Důraz na mechanickou přesnost robota
- Léčba pohyblivých lézí v pohybu
- Nové CT+ MR protokoly (Distorze MR obrazu)

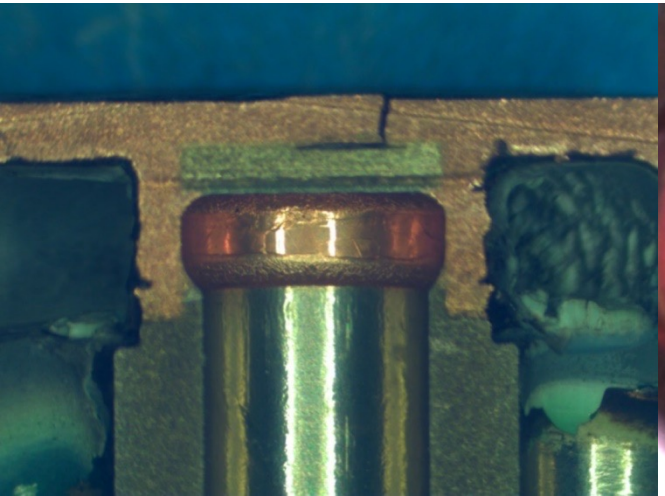


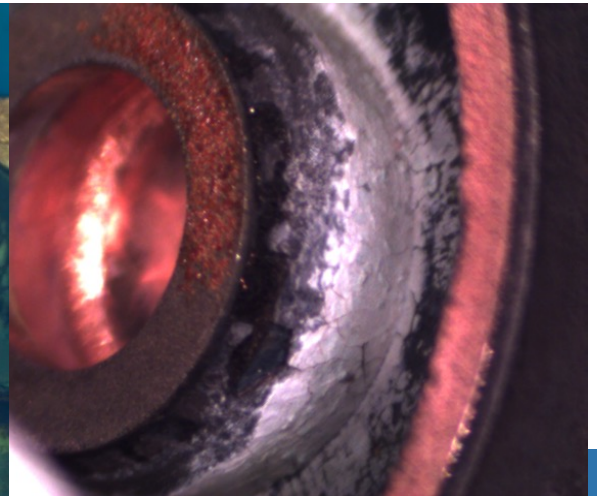




Technické a fyzikální úskalí

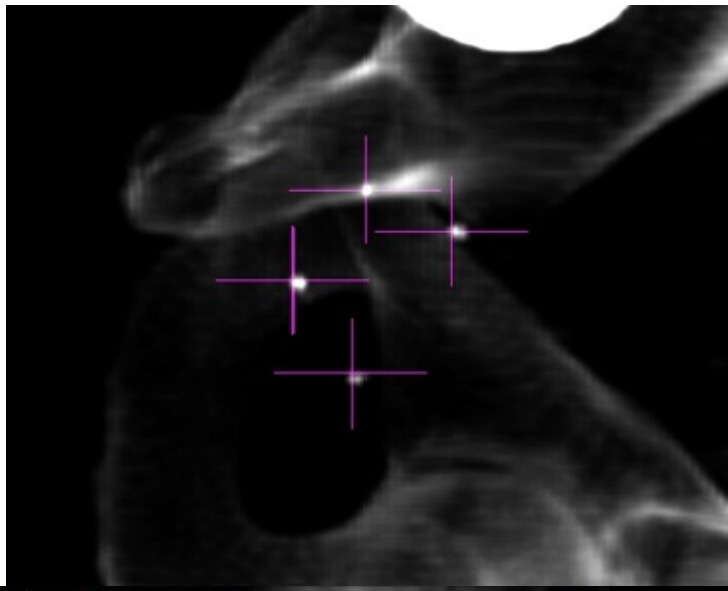
- 2013 – nejvíce extrakraniálních pacientů na světě
  - > pacientů > více poruch?
  - 4 měsíce do „zničení“ 1.kolimátoru Iris
  - Životnost RTG 2roky
    - 2015- po upgrade výměna 10ks RTG
  - 4x výměna LU – porucha vakua

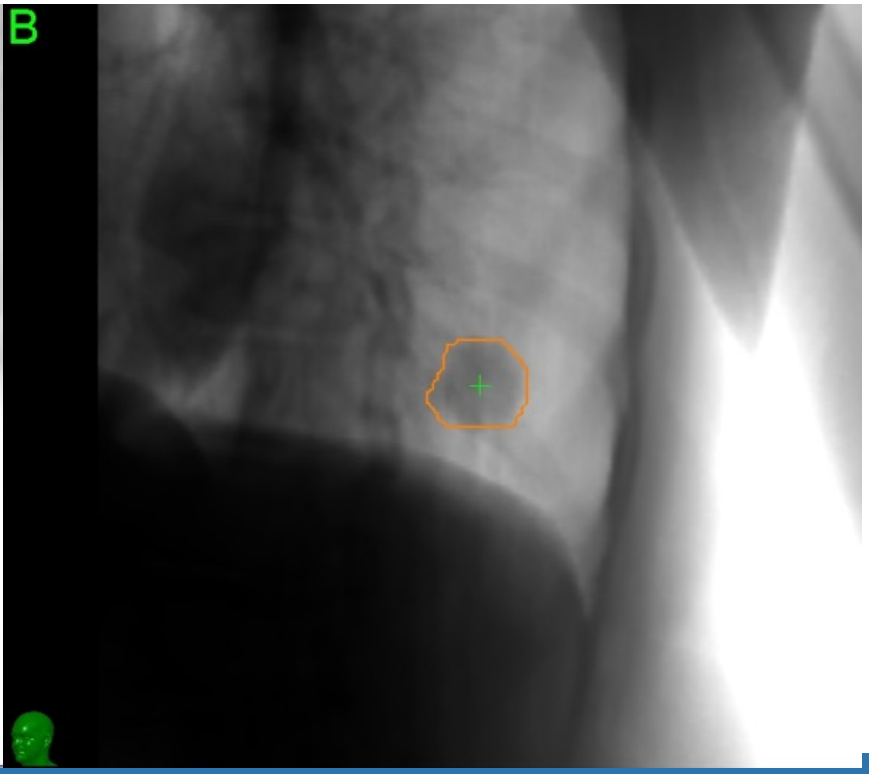




Technické a fyzikální úskalí

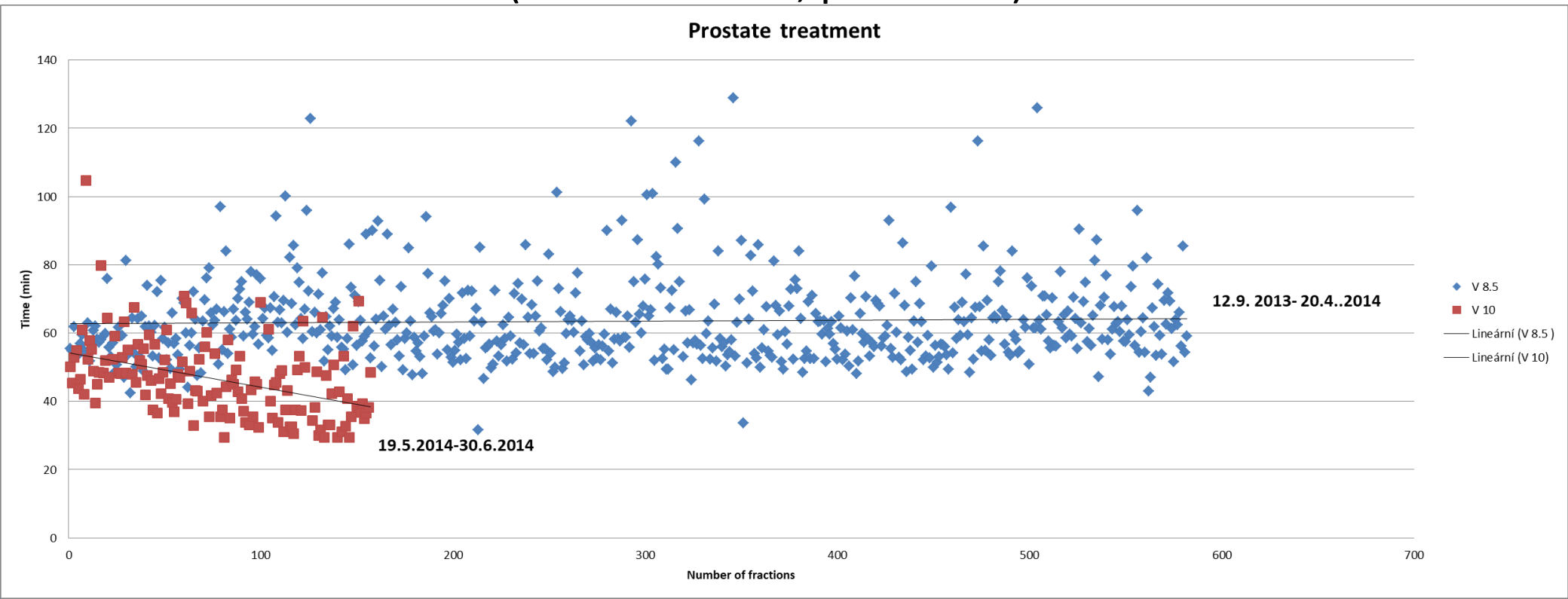
- Snímky 45°
- Implantace fiducials – správná geometrie
- Xsight Lung





Ozařovací čas

- Délka léčby na CyberKnife často kritizovaná
- Zkrácení ozařovacího času:
  - Zkušenosti (radiol.asistent, plánování)



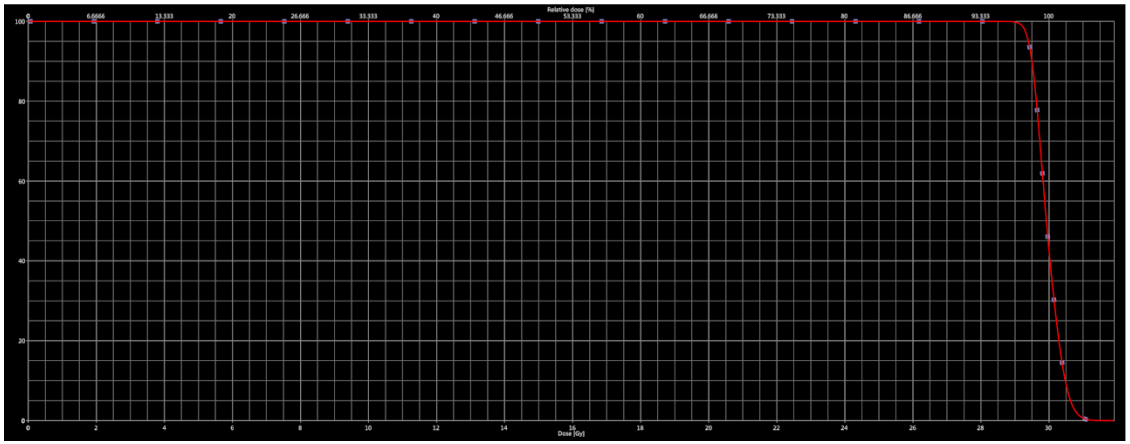
Ozařovací čas

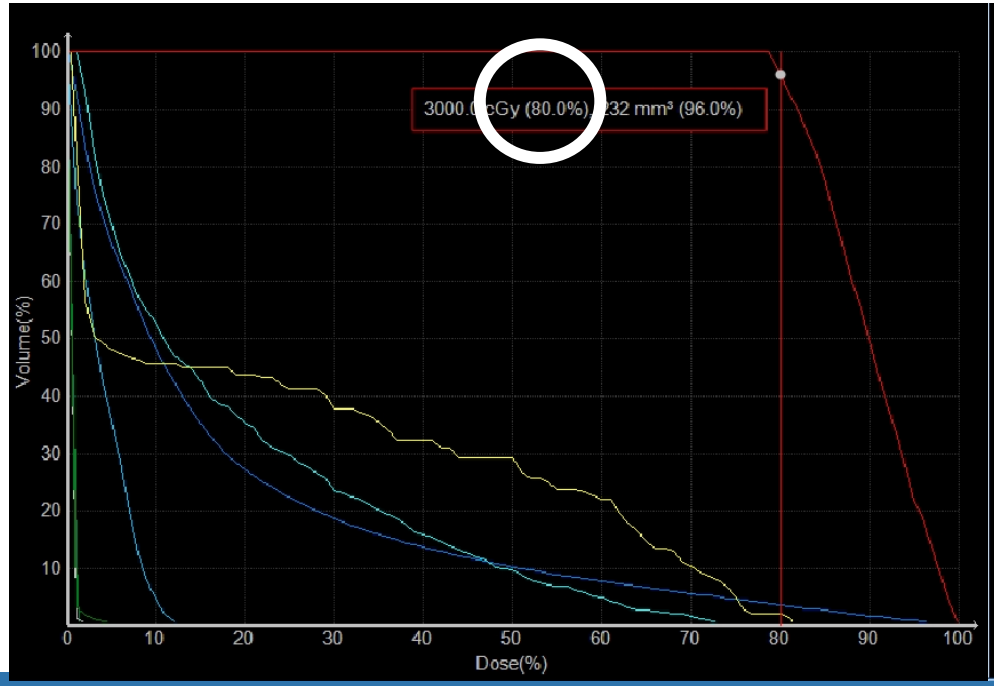
- Průměr prvních 100 – 51min
- Průměr posledních 100 – 36min

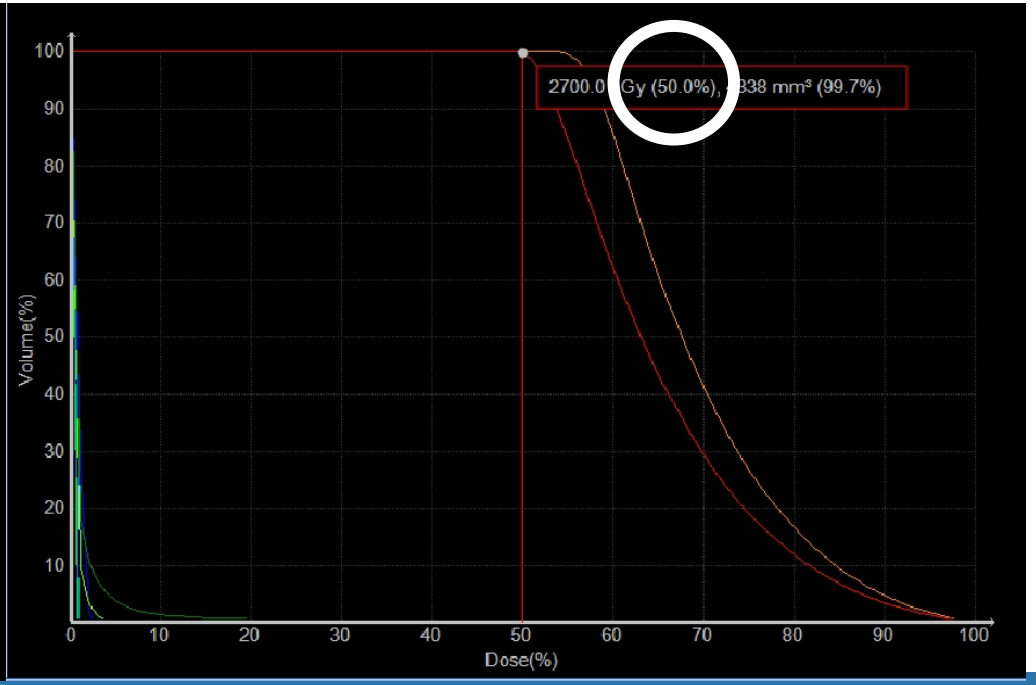
- Plicní ložiska 3x20Gy – 68min vs 41min (včetně 15min pro nastavení)

Nehomogenní plánování

- Standard 80% iso
- Intrakranialní meta – 50% iso







Nehomogenní plánování

- Nehomogenita – cesta eskalace dávky

Original research article

Dosimetric comparison of MRI-based HDR brachytherapy and stereotactic radiotherapy in patients with advanced cervical cancer: A virtual brachytherapy study

Bretislav Otahal[a,], Martin Dolezel[b], Jakub Cvek[a], Ondrej Simetka[c], Jaroslav Klat[c], Lukas Knybel[a], Lukas Molenda[a], Eva Skacelikova[a], Ales Hlavka[b], David Feltl[a]*

[a] *Department of Oncology, University Hospital Ostrava, Ostrava, Czech Republic*
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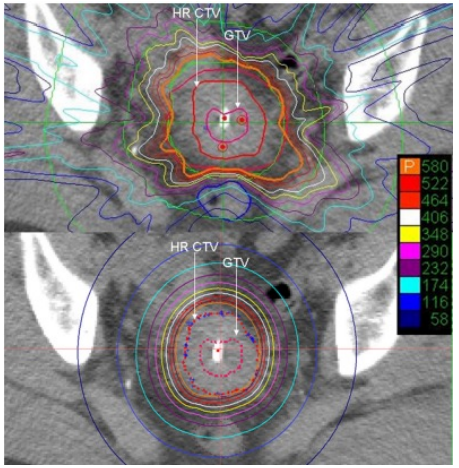
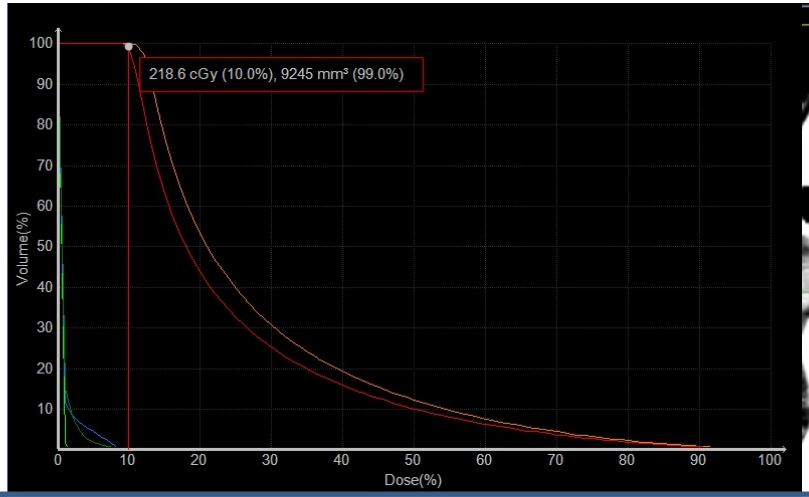
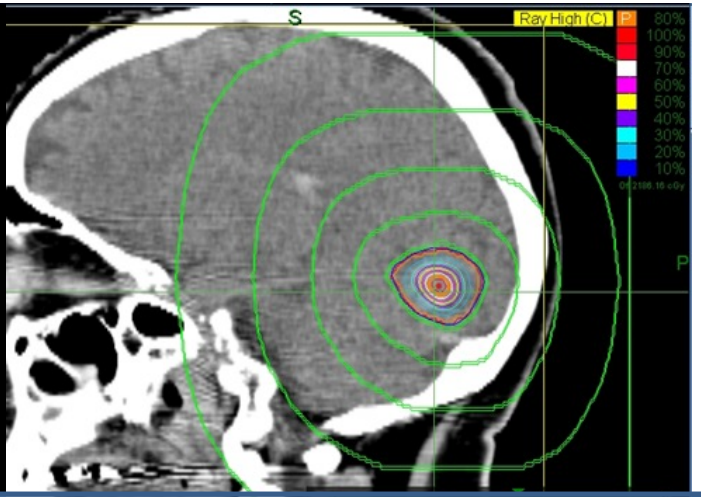
[c] *Department of Gynecology, University Hospital Ostrava, Ostrava, Czech Republic*

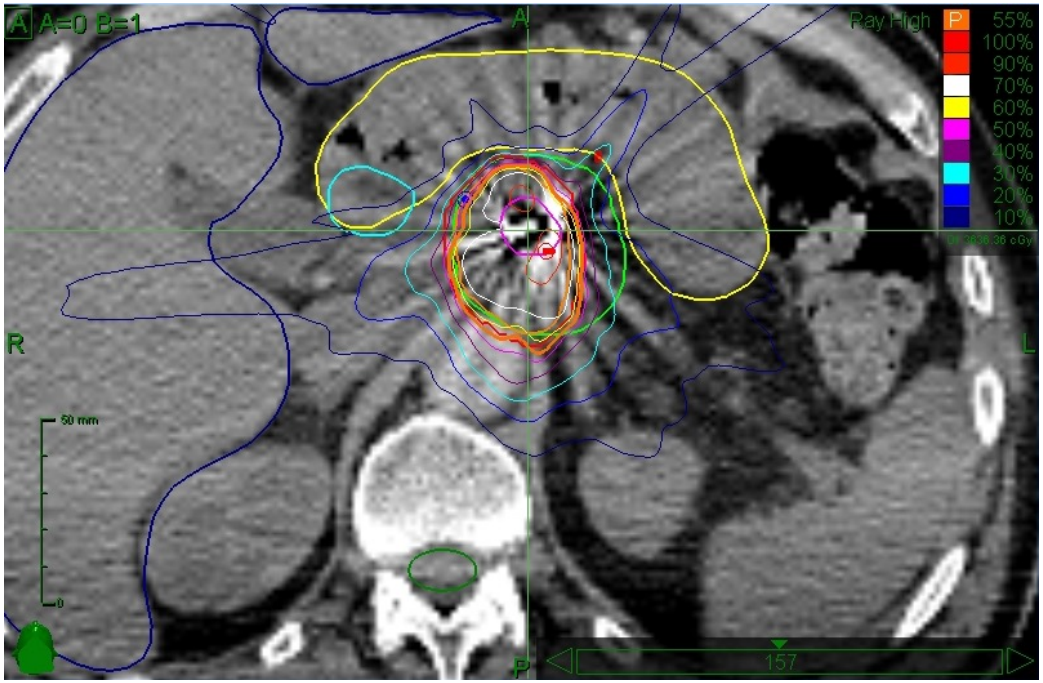






Nehomogenní plánování

- Nehomogenita – cesta eskalace dávky



Reiradiace 20Gy/5fr/55%iso

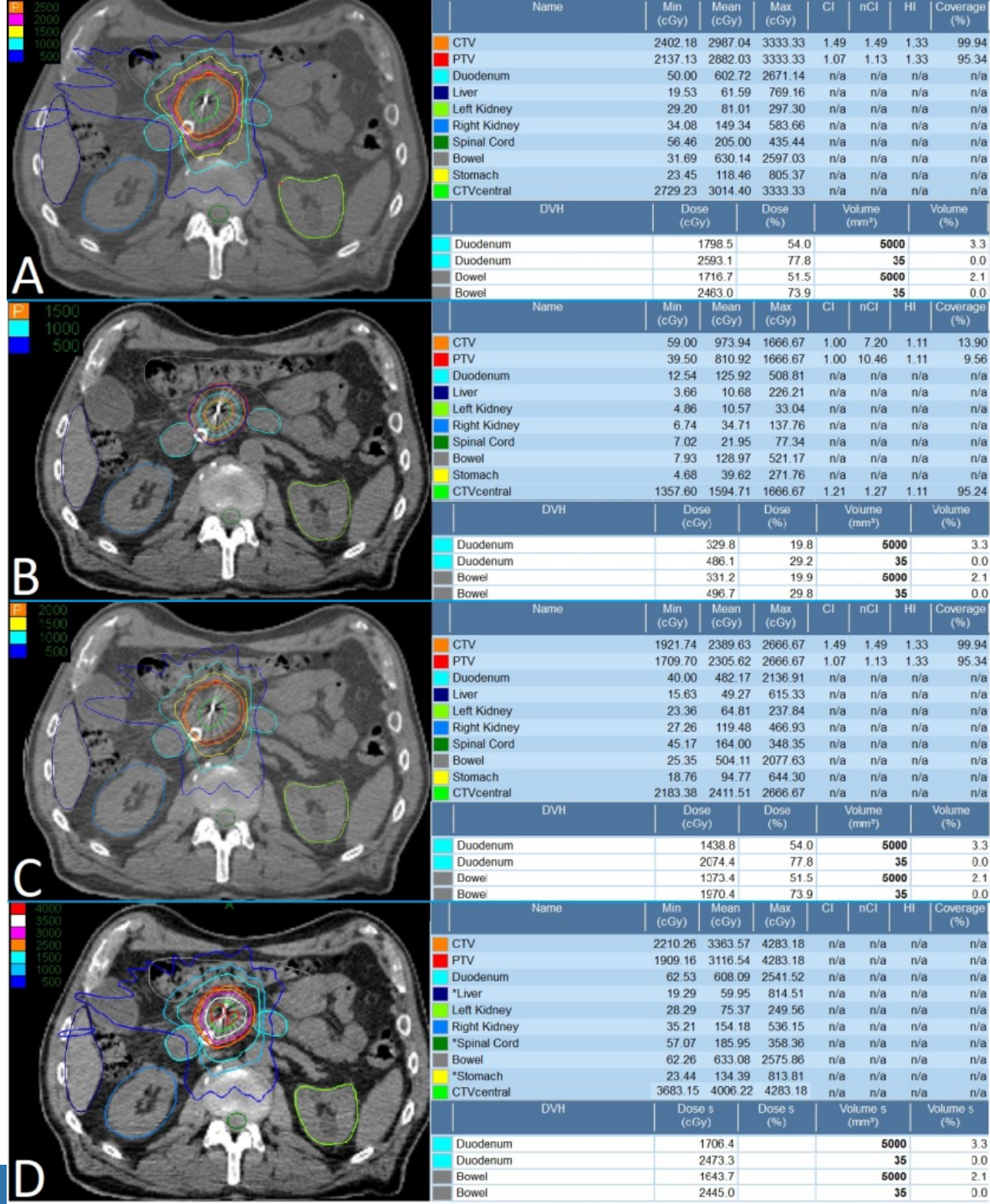
Knybel, L., Cvek, J., & Dvorak, P. (2023). Treatment Planning Study for Pancreatic Cancer-Dose Escalation using **Stereotactic Centralized Ablative Radiation Therapy** (SCART). *Cureus Journal of Medical Science*, *15*(4).

25Gy/fr vs SCART+ 20Gy/4fr

A) 25Gy/5fr
B) SCART
C) 20Gy/4fr
D) Sum B+C

BED_{10} z mean dose:
-nárůst z $48Gy_{10}$ na $80Gy_{10}$ pro CTVcentral
-nárůst z $47.7Gy_{10}$ na $57Gy_{10}$ pro CTV
-nárůst z $45Gy_{10}$ to $51Gy_{10}$ pro PTV

Dávky na OARs stejné či menší
BED_{10} CTVcentral >66%.



Name	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage (%)
CTV	2402.18	2987.04	3333.33	1.49	1.49	1.33	99.94
PTV	2137.13	2882.03	3333.33	1.07	1.13	1.33	95.34
Duodenum	50.00	602.72	2671.14	n/a	n/a	n/a	n/a
Liver	19.53	61.59	769.16	n/a	n/a	n/a	n/a
Left Kidney	29.20	81.01	297.30	n/a	n/a	n/a	n/a
Right Kidney	34.08	149.34	583.66	n/a	n/a	n/a	n/a
Spinal Cord	56.46	205.00	435.44	n/a	n/a	n/a	n/a
Bowel	31.69	630.14	2597.03	n/a	n/a	n/a	n/a
Stomach	23.45	118.46	805.37	n/a	n/a	n/a	n/a
CTVcentral	2729.23	3014.40	3333.33	n/a	n/a	n/a	n/a

DVH	Dose (cGy)	Dose (%)	Volume (mm³)	Volume (%)
Duodenum	1798.5	54.0	5000	3.3
Duodenum	2593.1	77.8	35	0.0
Bowel	1716.7	51.5	5000	2.1
Bowel	2463.0	73.9	35	0.0

Name	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage (%)
CTV	59.00	973.94	1666.67	1.00	7.20	1.11	13.90
PTV	39.50	810.92	1666.67	1.00	10.46	1.11	9.56
Duodenum	12.54	125.92	508.81	n/a	n/a	n/a	n/a
Liver	3.66	10.68	226.21	n/a	n/a	n/a	n/a
Left Kidney	4.86	10.57	33.04	n/a	n/a	n/a	n/a
Right Kidney	6.74	34.71	137.76	n/a	n/a	n/a	n/a
Spinal Cord	7.02	21.95	77.34	n/a	n/a	n/a	n/a
Bowel	7.93	128.97	521.17	n/a	n/a	n/a	n/a
Stomach	4.68	39.62	271.76	n/a	n/a	n/a	n/a
CTVcentral	1357.60	1594.71	1666.67	1.21	1.27	1.11	95.24

DVH	Dose (cGy)	Dose (%)	Volume (mm³)	Volume (%)
Duodenum	329.8	19.8	5000	3.3
Duodenum	486.1	29.2	35	0.0
Bowel	331.2	19.9	5000	2.1
Bowel	496.7	29.8	35	0.0

Name	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage (%)
CTV	1921.74	2389.63	2666.67	1.49	1.49	1.33	99.94
PTV	1709.70	2305.62	2666.67	1.07	1.13	1.33	95.34
Duodenum	40.00	482.17	2136.91	n/a	n/a	n/a	n/a
Liver	15.63	49.27	615.33	n/a	n/a	n/a	n/a
Left Kidney	23.36	64.81	237.84	n/a	n/a	n/a	n/a
Right Kidney	27.26	119.48	466.93	n/a	n/a	n/a	n/a
Spinal Cord	45.17	164.00	348.35	n/a	n/a	n/a	n/a
Bowel	25.35	504.11	2077.63	n/a	n/a	n/a	n/a
Stomach	18.76	94.77	644.30	n/a	n/a	n/a	n/a
CTVcentral	2183.38	2411.51	2666.67	n/a	n/a	n/a	n/a

DVH	Dose (cGy)	Dose (%)	Volume (mm³)	Volume (%)
Duodenum	1438.8	54.0	5000	3.3
Duodenum	2074.4	77.8	35	0.0
Bowel	1373.4	51.5	5000	2.1
Bowel	1970.4	73.9	35	0.0

Name	Min (cGy)	Mean (cGy)	Max (cGy)	CI	nCI	HI	Coverage (%)
CTV	2210.26	3363.57	4283.18	n/a	n/a	n/a	n/a
PTV	1909.16	3116.54	4283.18	n/a	n/a	n/a	n/a
Duodenum	62.53	608.09	2541.52	n/a	n/a	n/a	n/a
*Liver	19.29	59.95	814.51	n/a	n/a	n/a	n/a
Left Kidney	28.29	75.37	249.56	n/a	n/a	n/a	n/a
Right Kidney	35.21	154.18	536.15	n/a	n/a	n/a	n/a
*Spinal Cord	57.07	185.95	358.36	n/a	n/a	n/a	n/a
Bowel	62.26	633.08	2575.86	n/a	n/a	n/a	n/a
*Stomach	23.44	134.39	813.81	n/a	n/a	n/a	n/a
CTVcentral	3683.15	4006.22	4283.18	n/a	n/a	n/a	n/a

DVH	Dose s (cGy)	Dose s (%)	Volume s (mm³)	Volume s (%)
Duodenum	1706.4		5000	3.3
Duodenum	2473.3		35	0.0
Bowel	1643.7		5000	2.1
Bowel	2445.0		35	0.0

Dávkové limity

- 2010 – pro nás vše nové
  - Limity pro 1,3 a 5fr.
  - Neplatnost LQ modelu (dávky nad 10Gy/fr ?)
  - Sériové orgány- objemové dose constraints

ELSEVIER

Seminars in Radiation Oncology
Volume 18, Issue 4, October 2008, Pages 215-222

An Overview of Hypofractionation and Introduction to This Issue of *Seminars in Radiation Oncology*

Robert D. Timmerman MD (Guest Editor)

Serial Tissue	Volume (mL)	Volume Max (Gy)	Max Point Dose (Gy)	Endpoint (≥Grade 3)
SINGLE-FRACTION TREATMENT				
Optic pathway	<0.2	8	10	Neuritis
Cochlea			12	Hearing loss
Brainstem	<1	10	15	Cranial neuropathy
Spinal cord	<0.25	10	14	Myelitis
	<1.2	7		
Cauda equina	<5	14	16	Neuritis
Sacral plexus	<3	14.4	16	Neuropathy
Esophagus*	<5	14.5	19	Stenosis/fistula
Ipsilateral brachial plexus	<3	14.4	16	Neuropathy
Heart/pericardium	<15	16	22	Pericarditis
Great vessels	<10	31	37	Aneurysm
Trachea and ipsilateral bronchus*	<4	8.8	22	Stenosis/fistula
Skin	<10	14.4	16	Ulceration
Stomach	<10	13	16	Ulceration/fistula
Duodenum*	<5	8.8	16	Ulceration
Jejunum/ileum*	<5	9.8	19	Enteritis/obstruction
Colon*	<20	11	22	Colitis/fistula
Rectum*	<20	11	22	Proctitis/fistula
Bladder wall	<15	8.7	22	Cystitis/fistula
Penile bulb	<3	14	34	Impotence
Femoral heads (right and left)	<10	14		Necrosis
Renal hilum/vascular trunk	<2/3 volume	10.6		Malignant hypertension

Parallel Tissue	Critical Volume (mL)	Critical Volume Dose Max (Gy)	Endpoint (≥Grade 3)
Lung (right and left)	1,500	7	Basic lung function
Lung (right and left)	1,000	7.4	Pneumonitis
Liver	700	9.1	Basic liver function
Renal cortex (right and left)	200	8.4	Basic renal function

Serial Tissue	Volume (mL)	Volume Max (Gy)	Max Point Dose (Gy)	Endpoint (≥Grade 3)

Dávkové limity

- Zpřesnění /zpřísnění limitů →
- Tvorba „vlastních“ tabulek dle specifických diagnóz
- Doplnění tabulek o chybějící OAR

Task group report | Free Access

Stereotactic body radiation therapy: The report of AAPM Task Group 101

Correction(s) for this article

Stanley H. Benedict, Kamil M. Yenice, David Followill, James M. Galvin, William Hinson, Brian Kavanagh, Paul Keall, Michael Lovelock, Sanford Meeks, Lech Papiez, Thomas Purdie ... See all authors

First published: 14 July 2010 | https://doi.org/10.1118/1.3438081 | Citations: 1,315

0094-2405/2010/37(8)/4078/24/$30.00

HYTEC INTRODUCTION | VOLUME 110, ISSUE 1, P1-10, MAY 01, 2021

High Dose per Fraction, Hypofractionated Treatment Effects in the Clinic (HyTEC): An Overview

Jimm Grimm, PhD • Lawrence B. Marks, MD • Andrew Jackson, PhD • Brian D. Kavanagh, MD • Jinyu Xue, PhD • Ellen Yorke, PhD

DOI: https://doi.org/10.1016/j.ijrobp.2020.10.039 • Check for updates

- Nejnovější tabulky →

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A Story of Hypofractionation and the Table on the Wall

Robert Timmerman, MD

Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, Texas

Received Jul 29, 2021; Revised Sep 7, 2021; Accepted for publication Sep 14, 2021

Rectum[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Proctitis/fistula
Rectum[†]	<3.5 cm^3 <20 cm^3		50 37.5		55			Proctitis/fistula

Dávkové limity

- **Ukázka „evoluce“ limitů na rectum**

Rectum[b]	<20 cc	14.3	18.4	24 (8 Gy/fx)	28.2 (9.4 Gy/fx)	25 (5 Gy/fx)	38 (7.6 Gy/fx)	Proctitis/fistula
Rectum[†]	<3.5 cm^3 <20 cm^3		50 37.5		55			Proctitis/fistula

- 2010: 20cm3 < 25Gy (během let zůstává parametr konstantní)
- Interně zavedeno 20cm3 < 20Gy
- V18Gy < 50%
- V29Gy < 20%
- V32,6Gy < 10%
- V36,25Gy < 5%
- 2022: 20cm3 < 37,5Gy (nezavedeno do praxe)
- 2023:
- V20Gy < 30,2% + D19% < 24,8Gy

Nové diagnózy

- **Nové pro pracoviště:**
  - Léčba nenádorových dg. (neuralgie trigeminu)
  - Oligometastázy – 1-5 ložisek
  - Benigní + nízce maligní nádory mozku
  - Intramedulární ložiska
  - AVM

Nové diagnózy

- **Nové globálně:**
  - **STAR VT- Stereotactic Arrhythmia Radioablation**
  - Nový typ léčby
  - Neznámé dávkové limity

STAR VT- Stereotactic Arrhythmia Radioablation

- 2014 – 1.pacient (39.pac/2022)
  - NPO, IKEM
- Ektopická ložiska nedosažitelná katetrizační ablací

- Cyberknife
- 25Gy/1fr, výkon cca 60min
- „Tracking“ (sledování cíle) na základě hrotu elektrody ICD

- RVO-FNOs/2018
- grant project AZV NU20-000244 from the Ministry of Health of the Czech Republic
- European Union’s Horizon 2020 research and innovation-grant agreement 945119.


Cureus JOURNAL PUBLISHING CHANNELS COMPETITIONS NEWSROOM BLOG ABOUT COVID-19

Cardiac Radiosurgery for Malignant Ventricular Tachycardia

Abstract


ESC European Society of Cardiology

Europace (2019) 0, 1–8
doi:10.1093/europace/euz133

CLINICAL RE

Stereotactic radiosurgery for ablation of ventricular tachycardia

Radek Neuwirth[1], Jakub Cvek[2]*, Lukas Knybel[2], Otakar Jiravsky[3], Lukas Molenda[2], Michal Kodaj[3], Martin Fiala[1], Petr Peichl[4], David Feltl[5], Jaroslav Januška[3], Ian Hecko[3], and Josef Kautzner[4]


frontiers in Cardiovascular Medicine

CASE REPOR

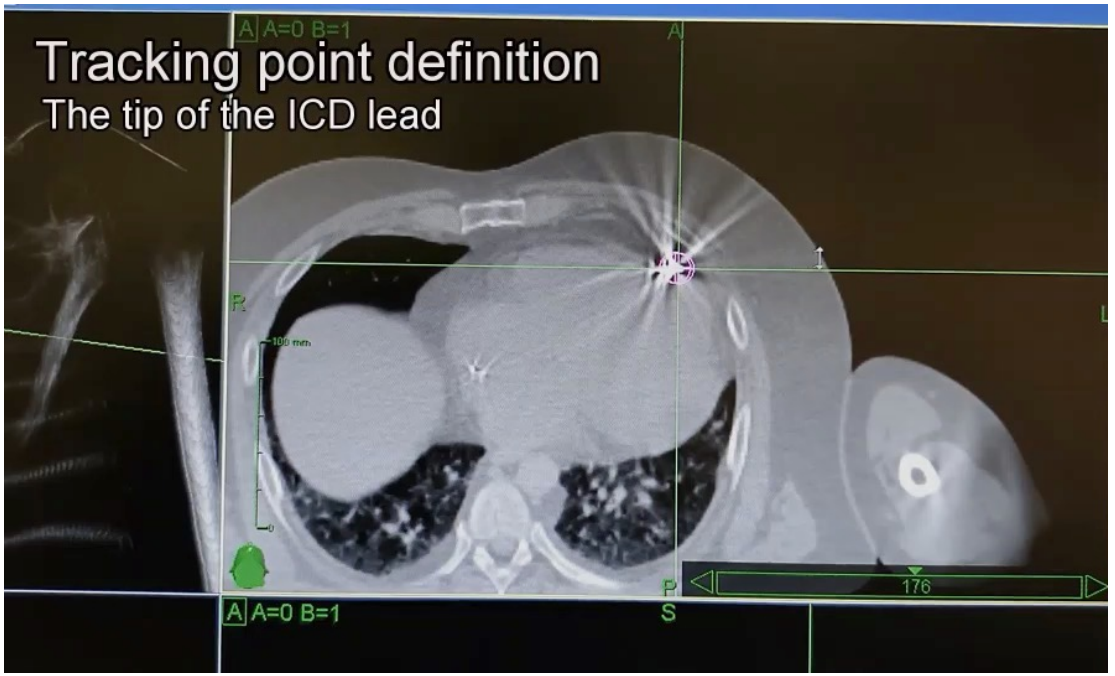
Case Report: Repeated Stereotactic Radiotherapy of Recurrent Ventricular Tachycardia: Reasons, Feasibility, and Safety

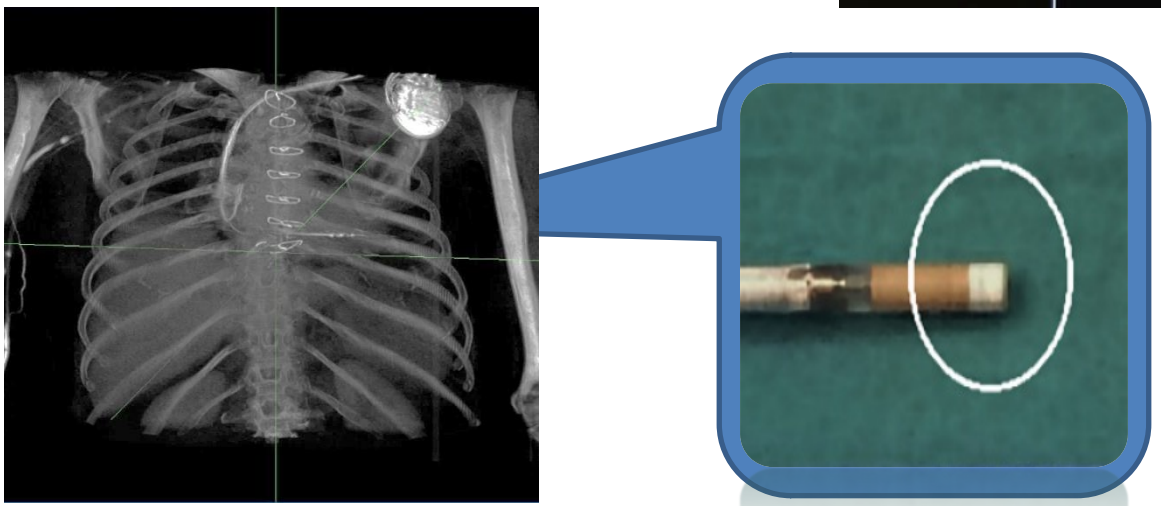
Jana Haskova[1]*, Petr Peichl[1], Marek Šramko[1], Jakub Cvek[2,3], Lukáš Knybel[2], Otakar Jiravský[4], Radek Neuwirth[4,5] and Josef Kautzner[1]

[1] Department of Cardiology, Institute for Clinical and Experimental Medicine (IKEM), Prague, Czechia, [2] Department of Oncology, University Hospital Ostrava, Ostrava, Czechia, [3] Department of Oncology, Ostrava University Medical School, Ostrava, Czechia, [4] Department of Cardiology, Podlesí Hospital Trinec, Trinec, Czechia, [5] Department of Cardiology, Masary University Medical School, Brno, Czechia

STAR VT- Kompenzace respiračních pohybů

- Marker = elektroda ICD
  - Bez další invazivní procedury
  - Sledování pohybu během léčby
- Ověřena detekční schopnost
  - Boston Scientific
  - St. Jude Medical
  - Medtronic





STAR VT- Kompenzace respiračních pohybů

Nové diagnózy

- **Nové globálně:**
  - **Ablace ganglion stellatum**

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GRAND ROUND
Coronary heart disease

Chronic refractory angina pectoris treated by bilateral stereotactic radiosurgical stellate ganglion ablation: first-in-man case report

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Background Refractory angina pectoris (AP) significantly impairs quality of life in patients with chronic coronary syndrome. Several minimally invasive methods (coronary sinus reducer, cell therapy, laser or shockwave revascularization, and spinal cord stimulation) or non-invasive methods (external counterpulzation) have been studied. However, their routine clinical use has not been widely implemented. Surgical or endoscopic sympathectomy is feasible for permanently relieving angina, but is often contraindicated due to the extent of complications associated with it. Neuromodulation by anaesthetic blockade of the left-sided stellate ganglion (SG) has been shown to relieve angina for days or weeks. To provide a long-term anti-anginal effect, novel pharmacological (phenol-based) or radiofrequency ablation techniques have been individually used to permanently destroy sympathetic pathways.

Case summary We describe a first-in-man use of stereotactic radiosurgical SG ablation using a linear accelerator (CyberKnife) in a heart failure patient after myocardial infarction with chronic refractory AP. Repeated anaesthetic SG blockade in this patient resulted in a significant, but only short-term, clinical improvement. The left, and subsequently the right, SG was ablated by targeted irradiation. During the 1-year follow-up, the patient remained without angina. We did not observe any clinically relevant early or late complications. Atrial fibrillation that developed 2 months after the second procedure was deemed to be associated with a natural progression of co-existing heart failure.

- **Pacient 1**
  - 100% závislost na kardiostimulátoru
  - Sympatektomie kontraindikována
  - Nitráty 20-40x denně
  - Anestetiská blokáda GS – účinnost 5 dní, pak návrat příznaků AP
  - Revaskularizace koronárních tepen nemožná

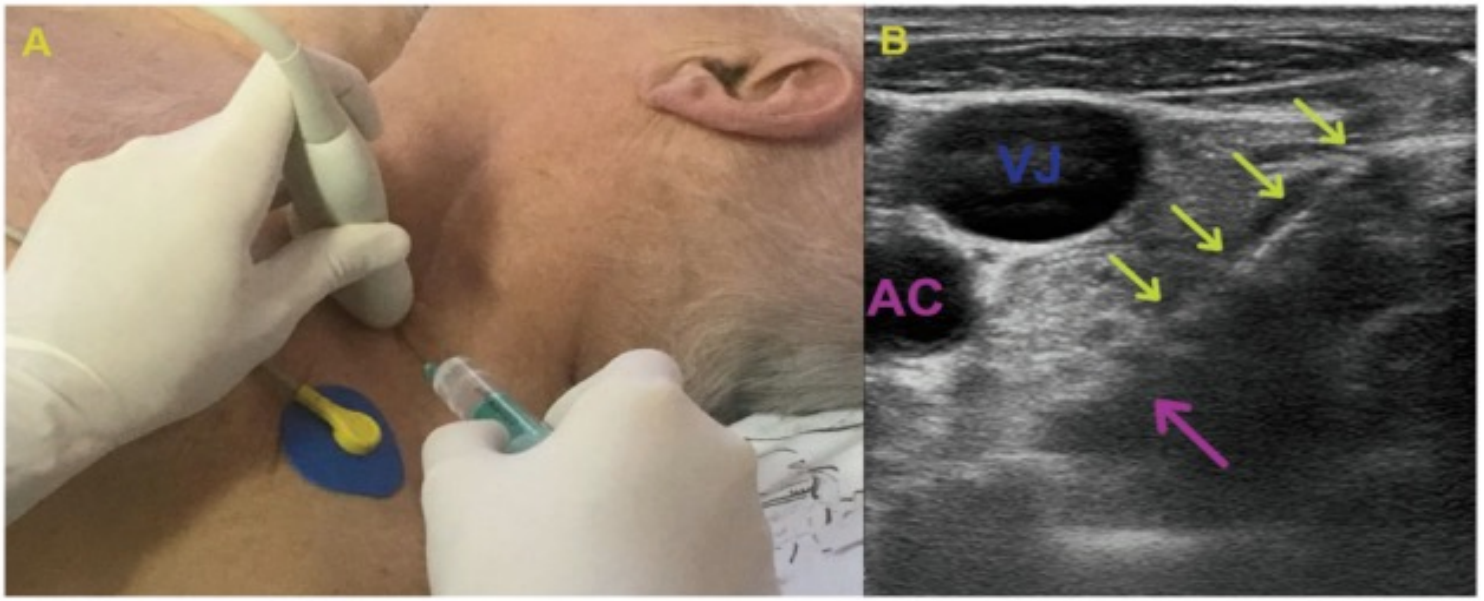


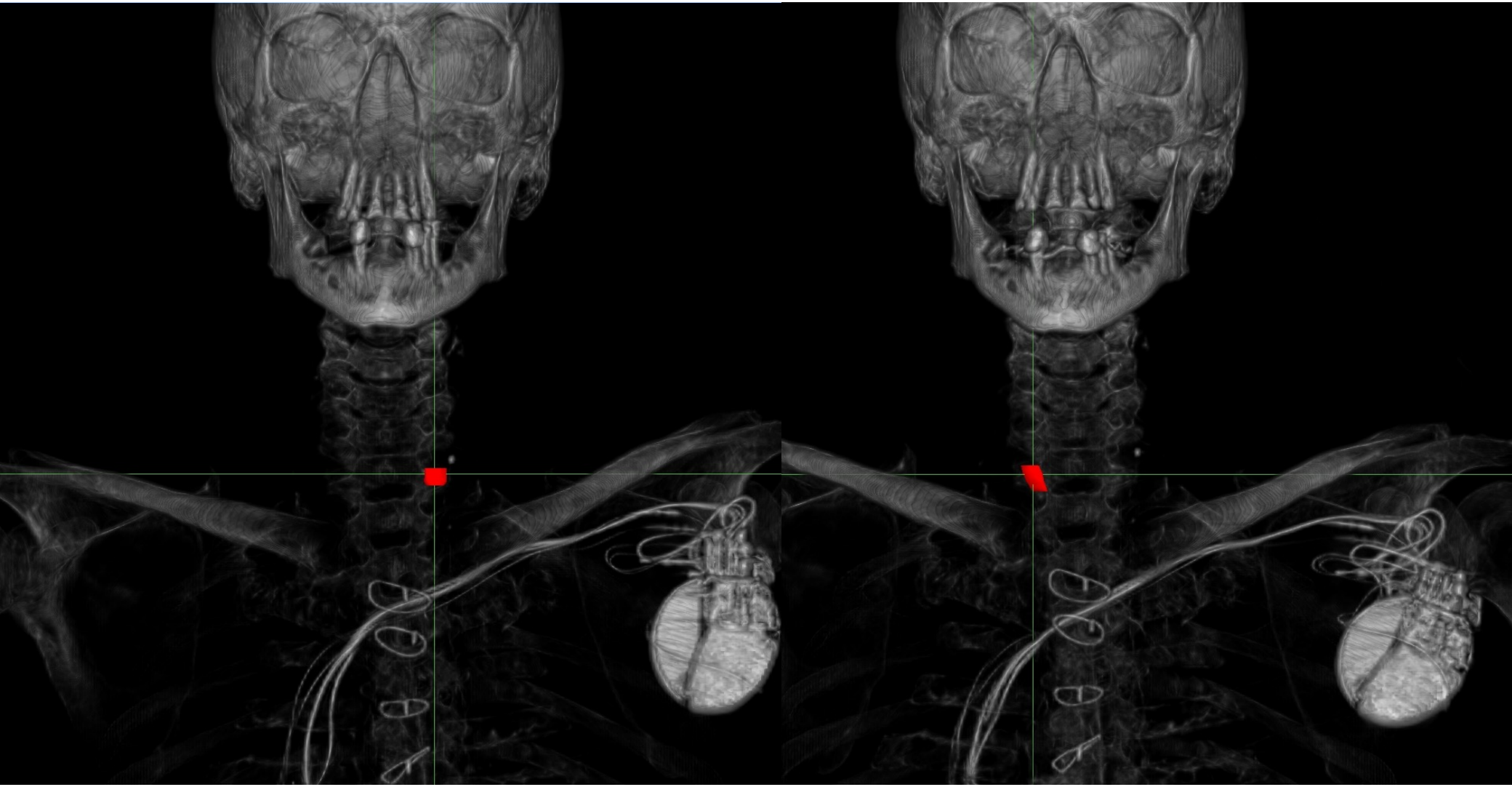
Figure 2 Ultrasound-guided left stellate ganglion anaesthetic blockade. (*A*) Patient positioning and introduction of puncture needle. (*B*) Ultrasound image of landmark structures and needle approaching left stellate ganglion. AC, internal carotid artery; VJ, internal jugular vein; yellow arrows—puncture needle reaching left stellate ganglion; pink arrow—left stellate ganglion.

Ablace ganglion stellatum

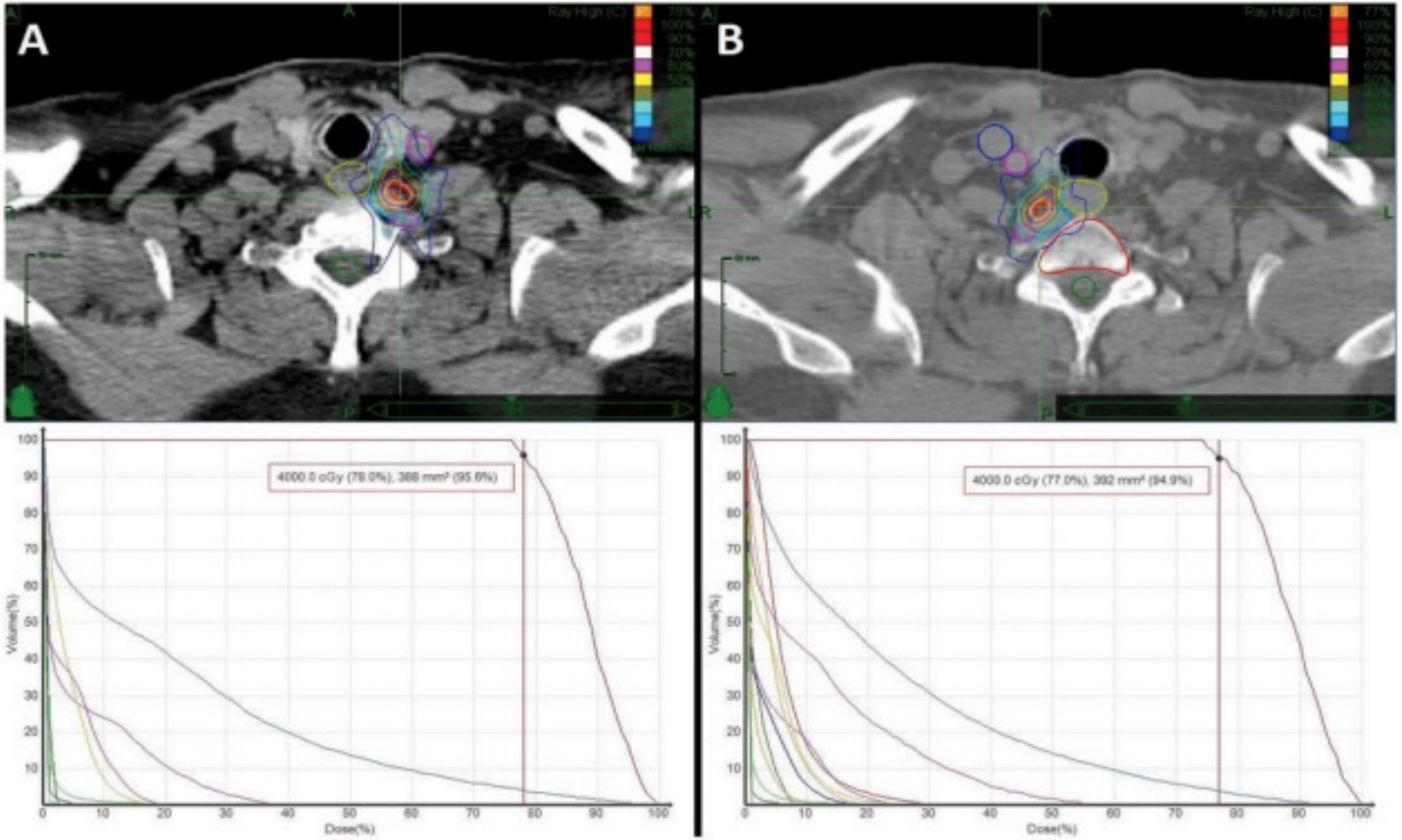
- 12/2018 levostranný GS (1.léčba na světě)
- 11/2019 pravostranný GS
- 1x40Gy
- Uložení ložiska vhodné pro „Xsight Spine tracking“

2018

2019



- 2023 – 3 pacienti v klinické studii



Závěr

- Osobní
  - Obrovská výzva, která (myslím) dopadla dobře
- Obecný
  - Podařilo se vytvořit kvalitní, úzce spolupracující tým
  - „OSTRAVSKÉ“ pojetí (kvantita vs kvalita)
  - Propagace regionu
- Výhled do budoucna
  - Obměna???
  - Nelze usnout na vavřínech, jelikož i po 13letech **se stále učíme!**

FAKULTNÍ NEMOCNICE OSTRAVA

Děkuji za pozornost