WP3 Clinical networking

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

WP3: Clinical networking

WP NA3	**Start Date**	Month 1		**End Date**	Month 48	
WP Title:	**Clinical Networking**					
Participant no.						
Participant	**MEDA**	HIT	CNAO	MIT		
Person months	19	25	33	17		
Objectives						

Task 3.1: Trial design for innovative use of heavy ion therapy

- Review preclinical data to identify promising novel approaches to exploit heavy ion therapy advantage
- Design one trial as a template for bringing innovative heavy ion therapy approaches in the clinics

Task 3.2: European registry of heavy ion therapy patients

- Set up a European registry to collect data on rare cancers treated with heavy ion therapy

Task 3.3: European agreement for OARs dose constraints with heavy ion therapy

- Review existing data on OARs dose constraints in use in the clinical facilities
- Perform pooled data analysis to validate constraints on critical OARs

Task 3.1

1: Hypoxia and reoxygenation
2: Synergistic effect of CIRT and immunotherapy
3: LET based optimization

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LETd evaluation for targets

No	Citation	Purpose	Population	Tumor Volume (TV) (cc)	RBE Model	Dose prescription	Results	Drawback / limitations
1	Matsumoto et al [26]	Role of LET in Chondrosarcomas recurrence	N = 45, Unresectable chondrosarcoma June 2000 -February 2012 at NIRS-QST	PTV= 50- 1750cc (median 400 cc)	Non - LEM RBE model (RBE profile was taken from measurements in HSG cells- Kanai et al 1999)	70.4 Gy (RBE) / 16 fractions	LETdmax (PTV) = 124 keV/µm, LETdmin (PTV) = 37 keV/µm (@ isocenter, LETd50% (w. r)= 37.8 to 46.8 keV/µm, LETd50% (wo r.) = 38.5 to 70.6 keV/µm, LETd50% (No recurrence) > 46.8 keV/µm, $LETd_{mean}$ (w. r)= 38.7 to 52.2 keV/µm, $LETd_{mean}$ (wo r.) = 41.4 to 72.3 keV/µm, $PTV_{(L1\ ml)}$ (w. r)= 24.7 to 54.9 keV/µm, $PTV_{(L1\ ml)}$ (wo r.) = 22.4 to 36.3 keV/µm, $PTV_{(L1\ ml)}$ (No recurrence) > 36.3 keV/µm, correlation - PTV(L1 ml) vs TV (r=–0.90, p<0.01), $V_{50\ keV/\mu m}$ (w. r)= 0.56-0.92, V50 keV/µm (wo r.) = 0 - 0.85, correlation - V50 keV/µm vs TV (r=0.86, p<0.01)	LETd evaluation only
2	Molineli et al [28]	To D_{RBE} and LETd parameters of CIRT for sacral chordomas	N = 52, Sacral Chordoma March 2013 -August 2018 at CNAO	Relapsed: GTV = 337 (2–1738) cc, HD-CTV = 844 (104–2397) cc, LD-CTV = 1621 (286–3411) cc, Controlled: GTV = 466 (22–2678) cc, HD-CTV = 1145 (89–4351) cc, LD-CTV = 1883 (182–4714) cc	LEM-I optimization, mMKM recomputation	70.4 -73.6 Gy (RBE) / 16 fractions	D_{RBE} : Delta [$D_{mMKM\|50\%]}$ = 10% (wrt mMKM PD), Delta [$_{DmMKM\|95\%]}$ = 18% (wrt mMKM PD) LETd: GTV LETd50% (w. r.)= 25.0 ± 2.3 keV/µm LETd50% (wo r.) = 28.6 ± 4.0 keV/µm, PTV(L1 ml) (w. r)= 18.7 ± 2.1 keV/µm, PTV(L1 ml) (wo r.) = 20.2 ± 6.0 keV/µm, LETd50 keV/µm (w. r)= 0.7 ± 1.0 (%), LETd50 keV/µm (wo r.) = 2.7 ± 2.8 (%), HD-CTV LETd50% (w. r)= 27.4 ± 2.1 keV/µm LETd50% (wo r.) = 30.2 ± 3.3 keV/µm, PTV(L1 ml) (w. r)= 18.5 ± 1.9 keV/µm, PTV(L1 ml) (wo r.) = 19.0 ± 5.6 keV/µm, LETd50 keV/µm (w. r)= 2.2 ± 2.6 (%), LETd50 keV/µm (wo r.) = 7.6 ± 5.4 (%)	Severely compromised D_{mMKM} and LETd distribution in the nominal CIRT plans compared to other series . Limitations with dose and LETd computation with Syngo TPS

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LETd evaluation for targets

3	Hagiwara et al [27]	Evaluation of how LET contributes to a therapeutic effect in pancreatic cancers	N = 18, Pancreatic adenocarcinoma April 2013 -November 2013 at NIRS-QST	GTV = 28.7 (5.9–62.8) cc	Non - LEM RBE model	55.2 Gy (RBE) / 12 fractions	GTV DMKM|98%, GTV $D_{MKM\|min}$ = No difference those with or without local relapse LETdmin (w. r)= 40.1 keV/µm (median), LETdmin (wo r.) = 45 keV/µm (median), LETd98% < 45 keV/µm 18 m LC = 43.8 mo, >/= 45 keV/µm, 18 m LC = 100 mo (p< 0.05), LETdmin < 44 keV/µm 18 m LC = 34.3 mo, >/= 44 keV/µm, 18 m LC = 100 mo (p< 0.05)	LETd50 keV/µm lower in spite of low tumor volumes
4	Moreli et al [50]	To investigate prognostic biomarkers : survival models fed with Dosiomics features and conventional DVH metrics (D_{RBE}) and (LETd) maps	N = 50 Sacral Chordoma March 2013 -August 2018 at CNAO		LEM-I optimization, mMKM recomputation	70.4 -73.6 Gy (RBE) / 16 fractions		

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LETd optimization for targets

No	Citation	Population	Tumor Volume (TV) (cc)	RBE Model	Dose prescription	LETd optimization goals	Results	Drawback / limitations
1	Kohno et al [30]	N = 13 Head and neck cancer March 2013 - August 2018 at NIRS-QST	GTV = 5.9 - 143.1 cc, PTV= 29.41 - 287.97 cc	mMKM	60.8 - 70.4 Gy (RBE) / 16 fractions	LP beam design similar to nominal IMIT plans. LETd constraints GTV: LETdmin= L-5, LETd goal = L, LETdmax= L + 10 [here L = L= 45, 55, 65, 75, 85, 95, and 105 keV/µm for PTV $D_{mMKM\|90\%}$, $D_{mMKM\|50\%}$	PTV $D_{MKM\|90\%}$ deteriorated for L = > 75 keV/µm, GTV LETdmin = 45.9 ± 6.0 keV/µm (IMIT), LETdmin = 59.2 ± 7.9 keV/µm [LP --> increased mean 13.2 (8 - 24) keV/µm], LETdmean = 69.2 ± 7.0 keV/µm (LP), LETdmean = 58.5 ± 5.7 keV/µm (IMIT), LETdmax = 90.0 ± 6.1 keV/µm (LP), LETdmax = 94.9 ± 14.5 keV/µm (IMIT)	Total optimization time for the LP took 1.5 times longer than that for the IMIT Planning comparison with IMIT and LETd painting (No clinical evaluation)
2	Nachankar et al [33]	N = 22 Pelvic sarcomas/ Chordoma September 2020 - June 2022 at MedAustron	small : GTV = 55.9 ± 39.8 cc, HD-CTV = 116.3 ± 52.6 cc, LD-CTV = 195.1 ± 76.8 cc, Large: GTV = 301 ± 243.5 cc, HD-CTV = 551.7 ± 211.3 cc, LD-CTV = 776.7 ± 257.7 cc	LEM-I optimization, mMKM recomputation	70.4-73.6 Gy (RBE) / 16 fractions	1. LETd optimization using 'distal patching': Distal-patching structures were created to stop beams 1–2 cm beyond the HD-PTV-midplane. 2. LETd goals for evaluation only (LETd goals for evaluation a. HD-CTV: V−27 cm^3 ≥ 33 - 39 keV/µm, b. GTV: V−9 cm3 ≥ 33 - 39 keV/µm, c. HD-PTV: V−56 cm3 ≥ 33 -42 keV/µm d. GTV: $V_{[LETd50keV/\mu m]}$ > 50%	1. $D_{RBE\|LEM-I}$, $D_{RBE\|mMKM}$ statistics (D98%, D95%, D50%, and D2%) for distally patched plans for HD-CTV and for HD-PTV and GTV were (goal ±3%, compared to unpatched plans) Distal patching increased LETd50% in HD-CTV (from 38 ± 3.4 keV/µm to 47 ± 8.1 keV/µm) (24% increase), 2. LETdmean in low-LETd regions of the HD-CTV (from 40.1 ± 3.5 keV/µm to 48.6± 8 keV/µm) (21% increase), 3. LETdmin in low-LETd regions of the HD-CTV (from 32 ± 2.3 keV/µm to 36.2 ± 3.6 keV/µm), LETdmean in GTV fraction receiving LETd of > 50 keV/µm, (from <10% to >50%) high-LETd component in the central region of the GTV. by 7.1 ± 6.5 keV/µm, HD-CTV by 8.5 ± 7.3 keV/µm, GTV by 10 ± 8.8 keV/µm.	Distal patching is sensitive to setup/range uncertainties, there is a always a tradeoff between target coverage with D_{RBE} and LETd and CIRT plan robustness. Retrospective evaluation and LETd optimization planning study (No clinical evaluation)

LETd optimization for targets

3	Schafasand et al. [51]	N = 10 Pelvic sarcomas/ Chordoma at MedAustron		LEM-I optimization, mMKM recomputation	73.6 Gy (RBE) / 16 fractions	LETd goals HD-CTV: V−27 cm3 ≥ 40 keV/µm GTV V−9 cm3 ≥ 42 keV/µm	LETd optimization method with LETdmin = 60 keV/µm HD-CTV, LETd98% increased by 8.9±1.5 keV/µm (27%) HD-CTV, LETd50% increased by 6.9±1.3 keV/µm (17%) By compromising target prescription by ±5% HD-CTV, LETd98% increased by 11.3±1.2 keV/µm (34%) HD-CTV, LETd50% increased by 11.7±3.4 keV/µm(29%) robustness evaluation, the pass rate of the LETdmin = 60 keV/µm optimized plans in achieving the OAR goals was in the same level as the reference plans in all scenarios	With mixed field CIRT LETd optimization (Single ion) LETdmin ≥ 80-100 keV/µm goal cannot be reached without compromising target coverage and homogeneity. LETd optimization planning study (No clinical evaluation)
4	Koto et al. [2024]	N = 12 Head and neck cancer October 2021-October 2023 at NIRS-QST	SCC, ACC, AD,DC, ME	mMKM, LEM-I optimization	64 Gy (RBE) / 16 fractions	LETd goals GTV: LETdmin ≤ 70 keV/µm	GTV LETdmin = increased from 52 keV/µm (No LETd optimization) to 63 keV/µm (LETd optimization) LETdmean = increased from 64 keV/µm (No LETd optimization) to 73 keV/µm (LETd optimization) Clinical result: No acute / late toxicity ≥ G3 at 180 days except G4 optic nerve toxicity. Treatment response rate (CR + PR) 67% (Koto et al IJROBP 2024) vs 56% (previously reported by Mizoe et al Radiother Oncol 2012) at 180 days.	Longer follow up period is required for validation of clinical benefits. Dosimetric correlation with G4 optic nerve toxicity is not reported.

LETd evaluation for OARs

No	Citation	Aim	Population	Tumor Volume (TV)	RBE Model	Dose prescription	Results	Drawback / limitations
1	Okonogi et al [42]	To assess predictive factors for late morbidities in the rectum and bladder after carbon-ion C-ion RT for uterus carcinomas	N = 134 uterus carcinomas June 1995 - January 2010, at NIRS-QST		Non - LEM RBE model (RBE profile was taken from measurements in HSG cells- Kanai et al 1999)	52.8 Gy (RBE)–74.4 Gy (RBE) / 20-24 fractions	1. D2cc > 60.2 Gy (RBE) grade 3 late rectal complications ($p = 0.012$). 2. No trends between grading of late rectal complications and these LETd histograms	Studies LETd as a sole parameter without studying the dose in in same voxel
2	Mori et al [43]	To investigate the effects of LETd and dose on pelvic insufficiency fractures after CIRT	N = 134 uterus carcinomas June 1995 and January 2010 - NIRS-QST		mMKM model	52.8 Gy (RBE)–74.4 Gy (RBE) / 20-24 fractions	1. D50% RBE-weighted dose was a valuable predictor of SIF. 2. patients over 50 years of age validated that current smoking habit were risk factors for SIF	Studies LETd as a sole parameter without studying the dose in in same voxel
3	Nachankar et al [48]	To evaluate results of sacral nerve sparing strategy (SNSo-CIRT) and investigate the effects of LETd and D_{RBE} on Radiation induced lumbosacral neuropathy after CIRT	N = 35 Pelvic sarcomas/ Chordoma August 2019 - August 2022 at MedAustron	HD-CTV: 503.3 ± 402.1 cc	LEM-I optimization, mMKM recomputation	70.4 Gy (RBE)-73.6 Gy (RBE) / 16 fractions	1. No difference in sole D_{RBE} or LETd distribution on sacral nerves in patient with or without neuropathy. 2. RILSN-free survival at $D_{RBE\|LEM-I}$ cutoff = 65 Gy (RBE) and LETd < 55 keV/µm for sacral-nerves-to-spare was 100% and those with LETd ≥ 55 keV/µm was 70% (CI, 47-100) ($p = 0.03$).	

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LETd evaluation for OARs

4	Nachankar et al [49]	To evaluate results of mucosa-sparing-strategy (MSS-CIRT) and investigate the effects of LETd and D_{RBE} on G3 late mucosal toxicity after CIRT	N = 55 Non-squamous Head and neck cancer August 2019 - October 2023 at MedAustron		LEM-I optimization, mMKM recomputation	65.6 Gy (RBE)-73.6 Gy (RBE)/16 fractions	1. Average D_{RBE} LETd after filtering-out RBE-weighted doses (D_{RBE}-filtered LETd) for mucosa were higher in patients with LMT3 (without MSS-CIRT) compared to those treated with MSS-CIRT, [$_{DRBE\|LEM\text{-}I\|0.1\ cc}$ =73.2 vs 66.8 Gy (RBE) and $D_{RBE\|mMKM\|0.1\ cc}$ =74.2 vs 64.4 Gy (RBE) (Figure 2, n: MSS-CIRT=25, LMT3=2)] respectively. 2. Limiting D_{RBE}-filtered LETd for MTS substructure receiving $D_{RBE\|mMKM\|0.1cc}$ >69 and >70 Gy (RBE) appears critically important.	……?

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Two possible strategy for LET painting

- Blocking
- Let optimization in TPS

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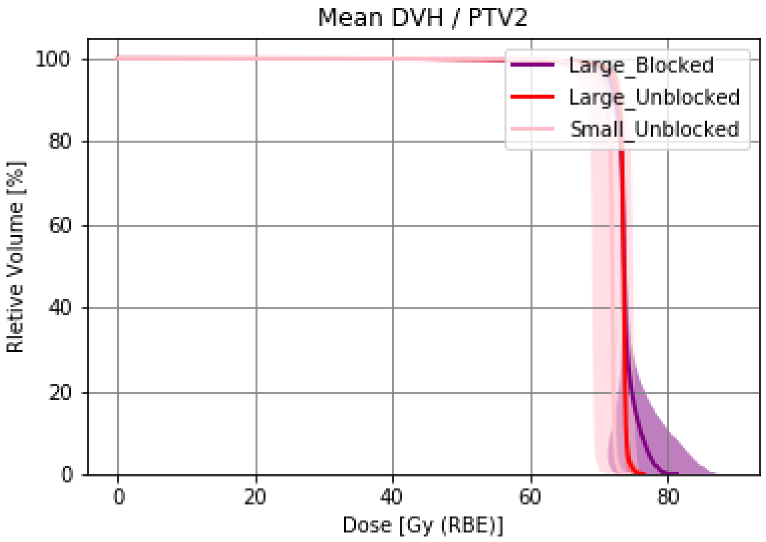
DVH | LEM | Small vs Large vs Large Blocked

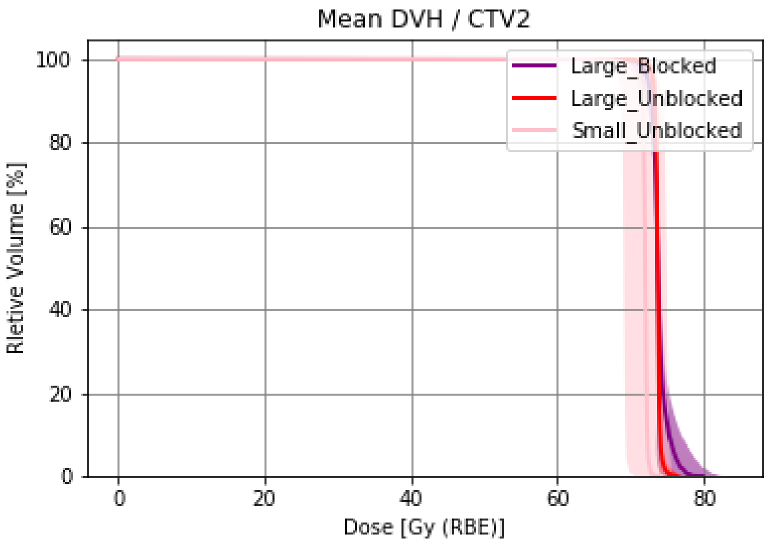
PTV2

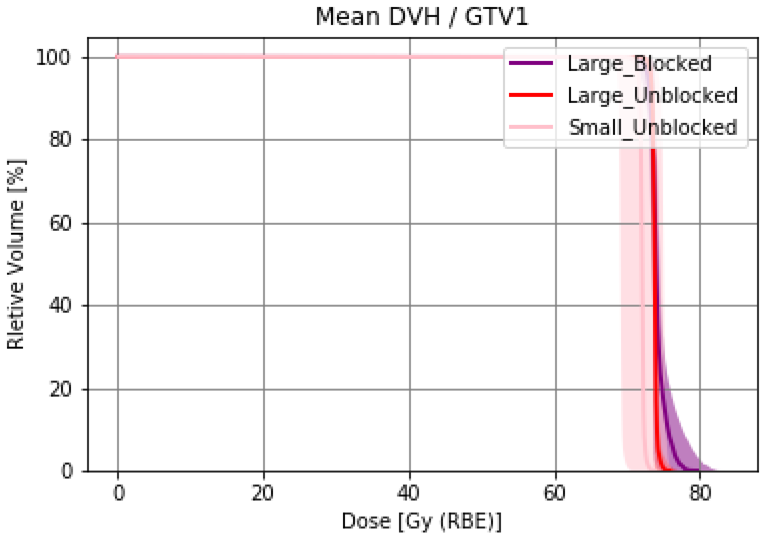
CTV2

GTV

n= 20,
Small = 10
Large = 10
Large_Blocked = 10





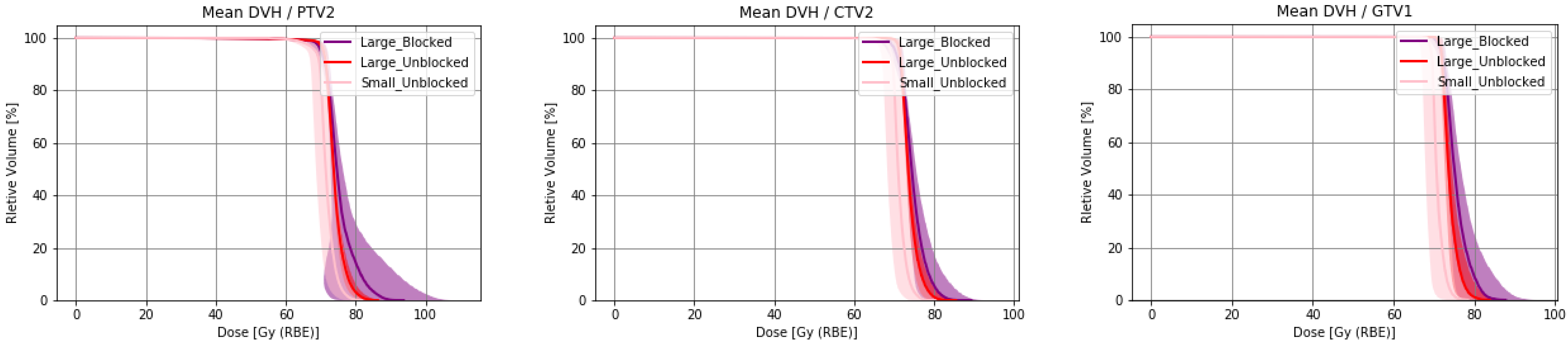


Satisfactory LEM: For blocked cases: Satisfactory coverage in terms of LEM RBE weighted dose

DVH | MKM | Small vs Large vs Large Blocked

PTV2 CTV2 GTV

n= 20,
Small = 10
Large = 10
Large_Blocked = 10



MKM: FOR BLOCKED CASES: SATISFACTORY COVERAGE, BUT HOTSPOT ESPECIALLY FOR PTV2

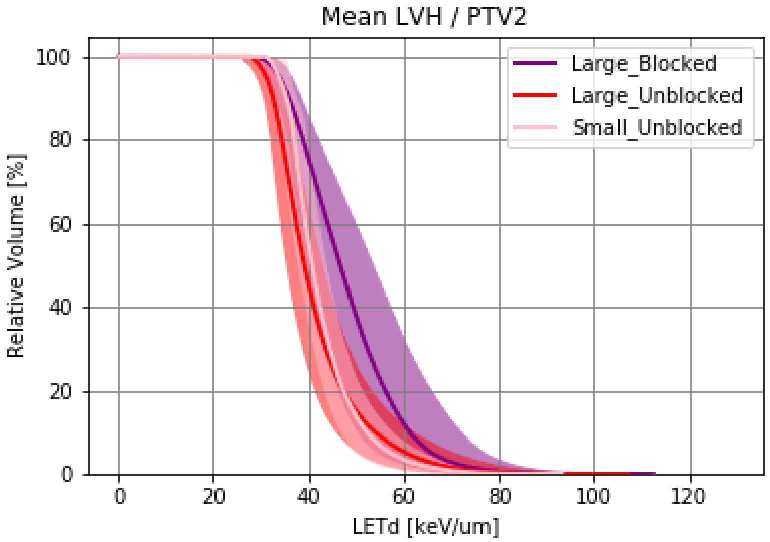
LVH | LET | Small vs Large vs Large Blocked

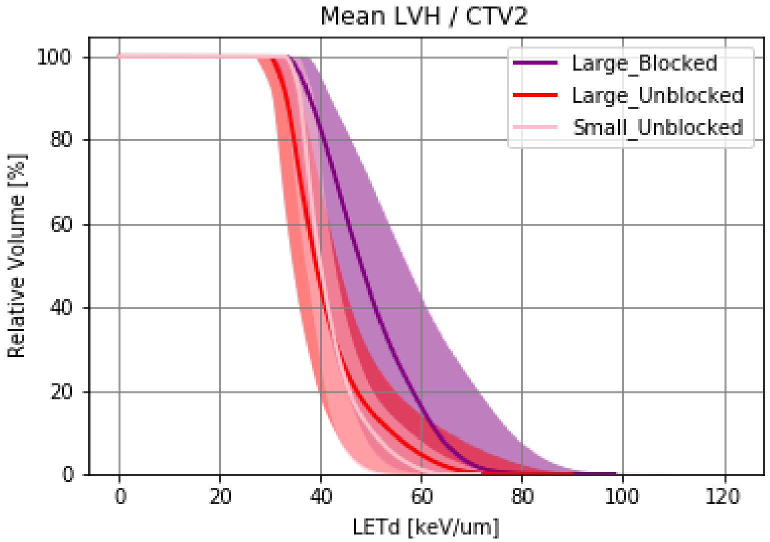
PTV2

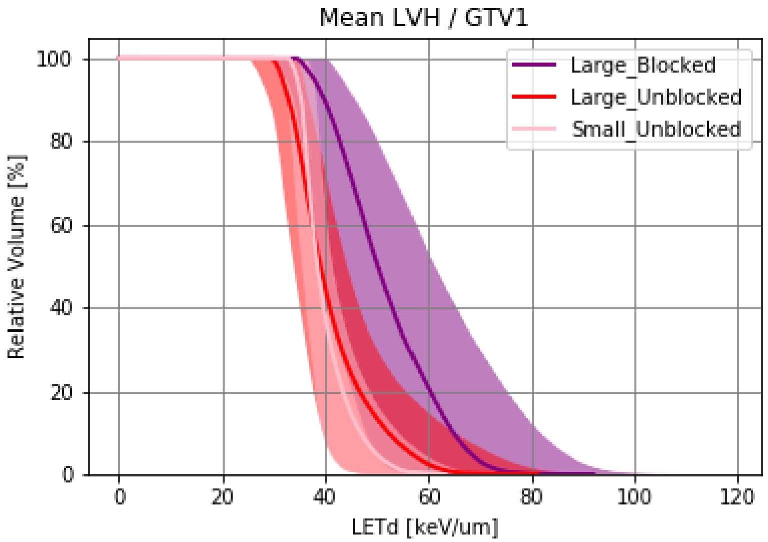
CTV2

GTV

n= 20,
Small = 10
Large = 10
Large_Blocked = 10

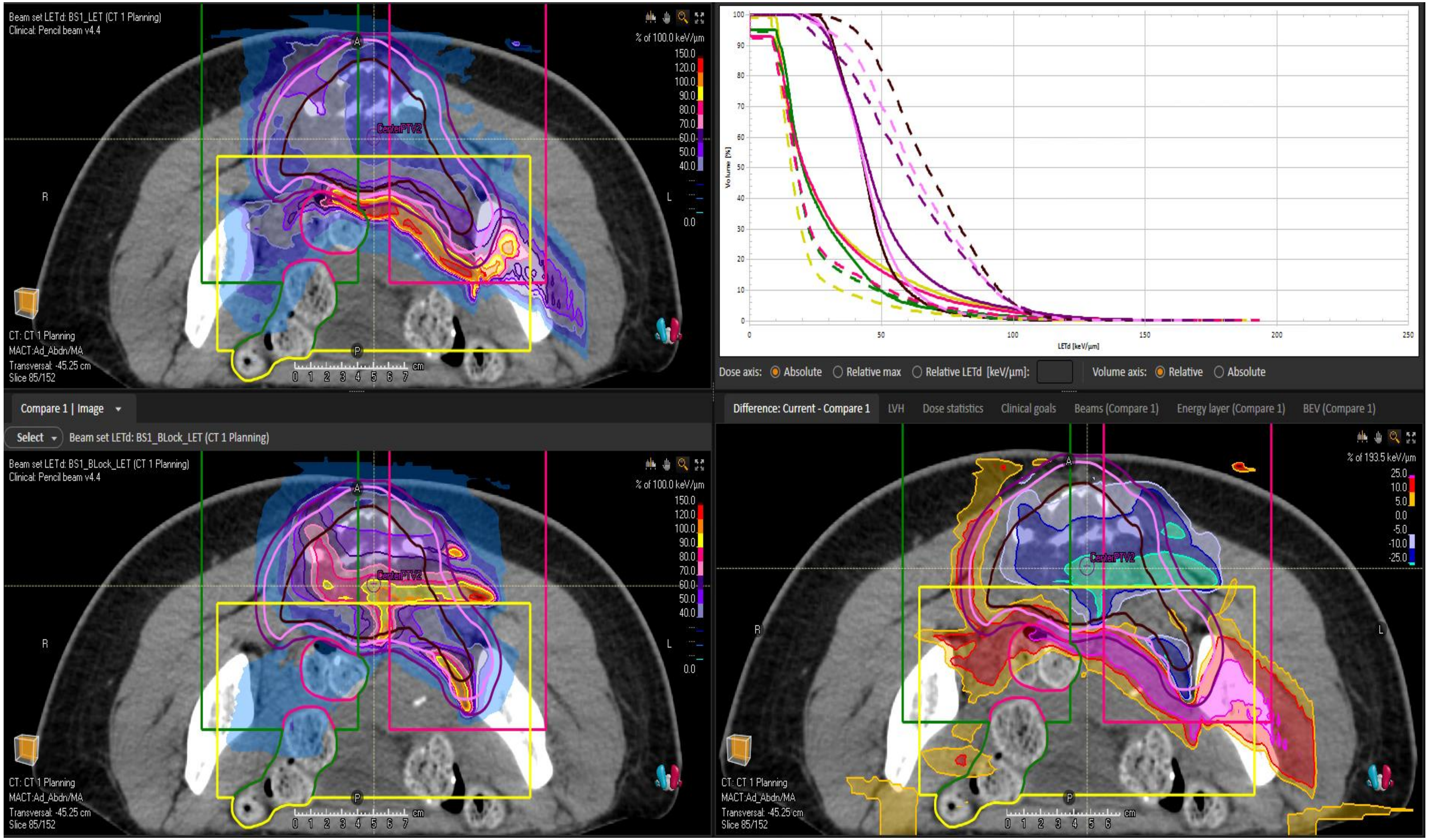






Satisfactory LET: For blocked cases: Significantly better LET Distribution most benefit with GTVc

LET in central portion of GTV | Small vs Large vs Large Blocked



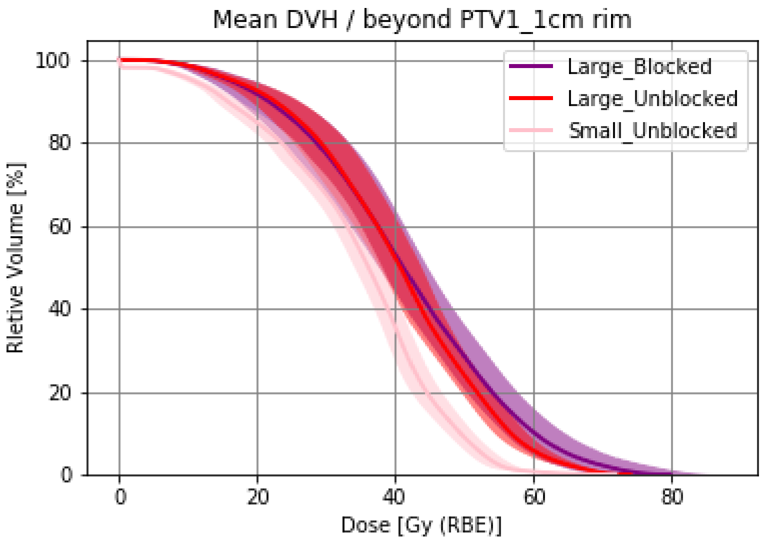
Dose, LET outside PTV | Small vs Large vs Large Blocked

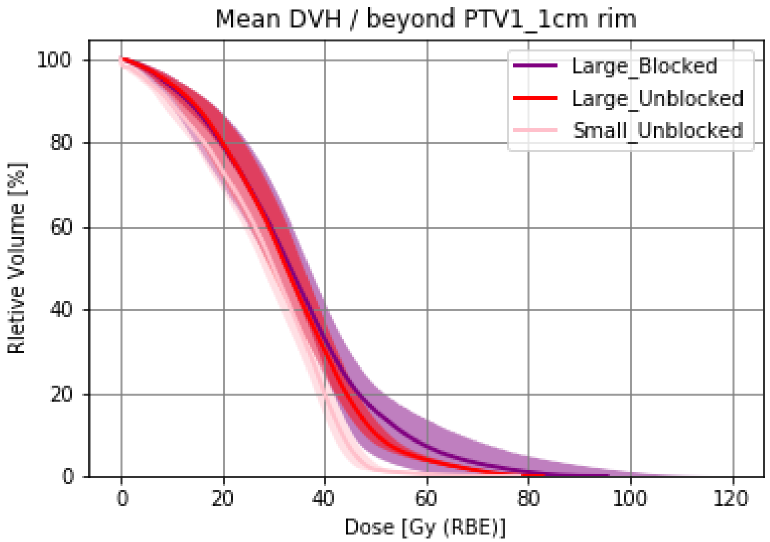
LEM

MKM

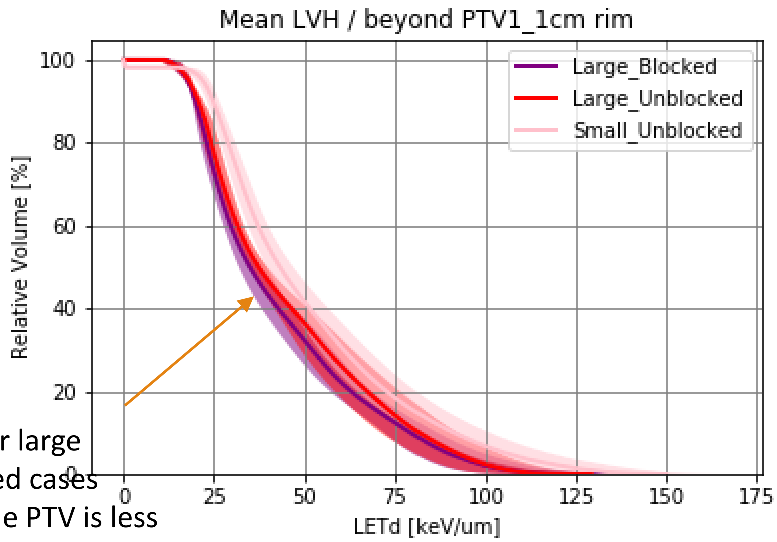
LET

n= 20,
Small = 10
Large = 10
Large_Blocked = 10



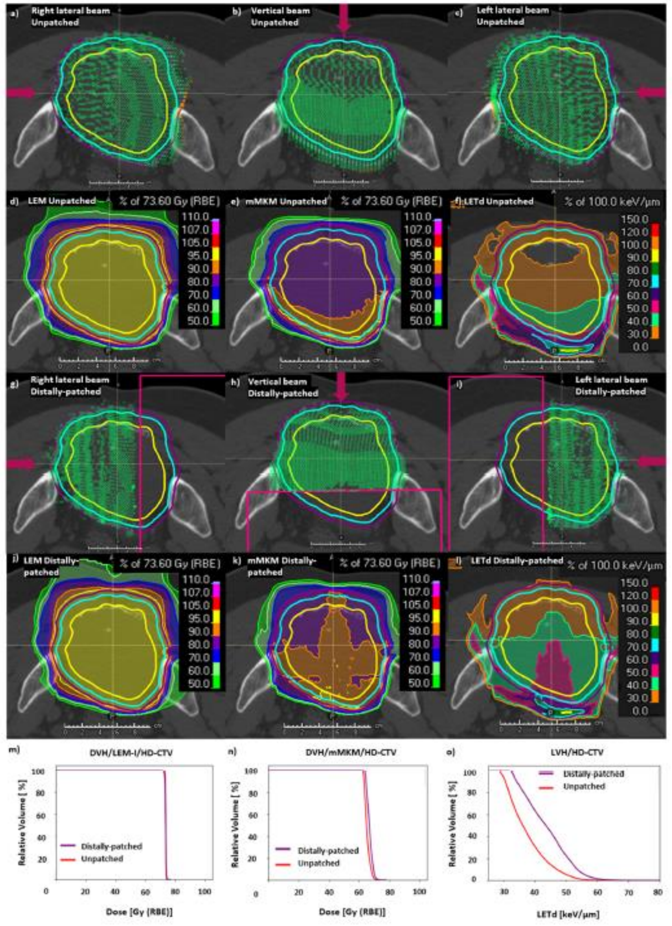


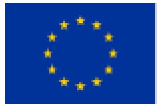
LET for large blocked cases outside PTV is less than small tumors



LET LET: For blocked cases: LET DISTRIBUTION OUTSIDE PTV1 IS ALSO IMPROVED DUE TO SPATIAL REDISTRIBUTION OF LET IN THE CENTER OF GTV/PTV

First Patient experience sin MedAustron





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Parameters used in clinical cases in MA

Acceptable clinical goals for targets

Target	Internally (MedAustron) validated LETd Constraints	Constraints extrapolated form other series	Priority
HD-CTV	CTV - 27 cc > 40 keV/µm (Chordomas/sarcomas)		Moderate
GTV	GTV - 9 cc > 40 keV/µm (Chordomas/sarcomas)		High
	V[LETd50 keV/µm] > 50% (Chordomas/sarcomas)		High
		LETdmin > 59 keV/µm (Bulky, non-squamous Head and neck cancers)	High
		LETdmin > 80 keV/µm (Pancreatic cancers, renal cell carcinoma)	High
HD-PTV	PTV - 56 cc > 42 keV/µm		Moderate to low
Sacral-nerves (outside HD-CTV)	at $D_{RBE\|LEM-I}$ cutoff = 64 Gy (RBE), <12% of volume should receive > LETd < 55 keV/µm (Dose filtered LETd)		Moderate
Cauda equina	at $D_{RBE\|LEM-I}$ cutoff = 63 Gy (RBE), <10% of volume should receive > LETd < 50 keV/µm (Dose filtered LETd)		Moderate

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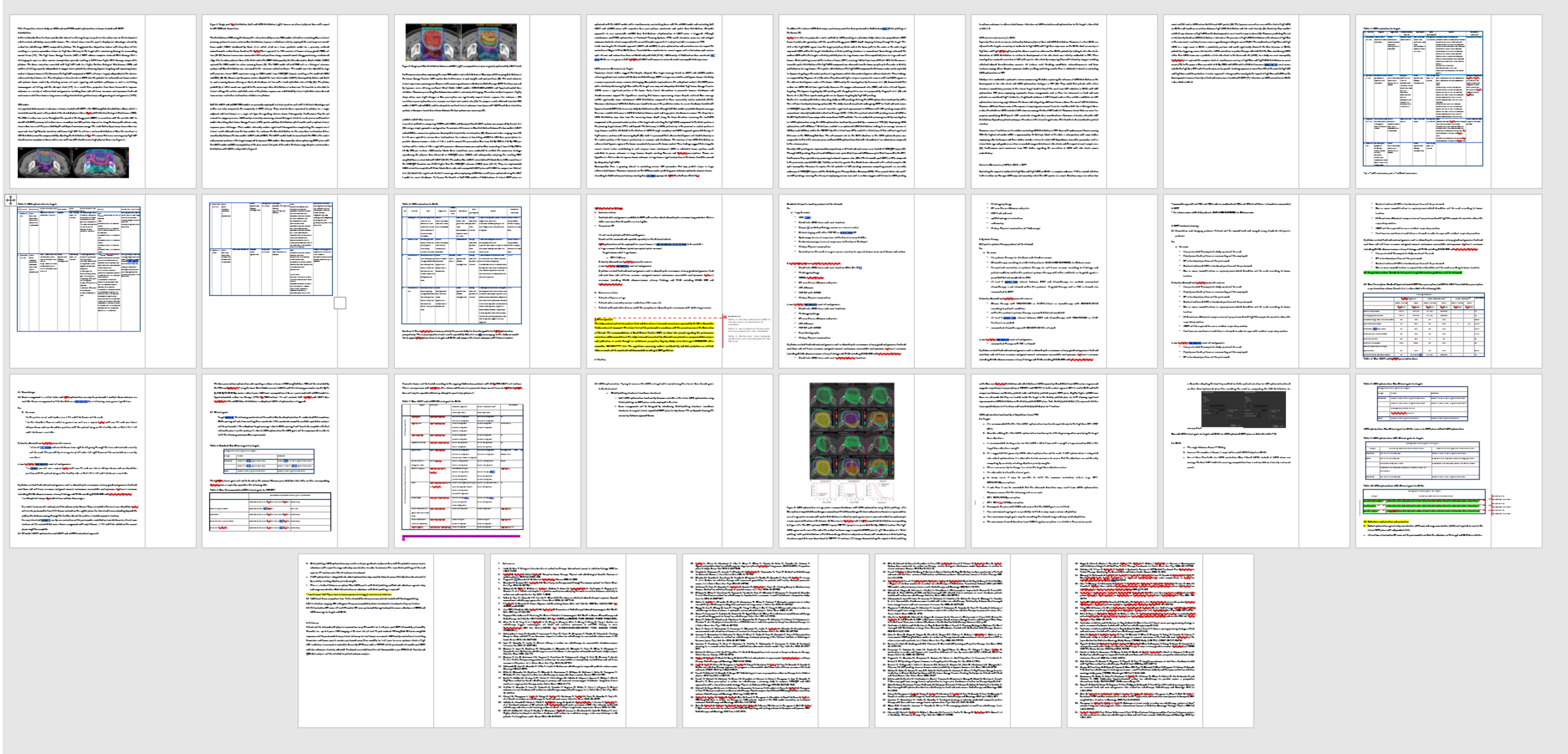
Draft of the protocol is being finalised



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Task 3.2

						Previous cancer								
Patient ID	Sex	Date of birth	Age	Type of diagnosis	Comorbidity	Previous cancer	Specify cancer	Year of diagnosis	Radiotherapy treatment	Year of radiotherapy	Specify energy	Total dose	Chemotherapy treatment?	Year

Type of diagnosis — **Campo Chiara:**
- Primary Tumor
- Relapsed Tumor - Local (T)
- Relapsed Tumor - Regional (N)
- Relapsed Tumor - Metastatic (M)
- Radiation-induced Tumor

Comorbidity — **Campo Chiara:**
According to MedDRA

Previous cancer — **Campo Chiara:**
- Yes
- No
- Unknown

Radiotherapy treatment — **Campo Chiara:**
- Yes
- No
- Unknown

Specify energy — **Campo Chiara:**
- Carbon ions
- Protons
- Photons
- Unknown

Chemotherapy treatment? — **Campo Chiara:**
- Yes
- No
- Unknown

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The database has so far been used only by CNAO

In the last phase of the project the database will be used to support the activity of task 3.3.

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Task 3.3

A	B	C	D	E	F	G
	MedAustron * red constraints must be respected in the LEM optimized plan and in the MKM recalculated plan					
	japanese fractionation (> 4 Gy RBE LEM per fraction)			german fractionation (3 Gy RBE LEM per fraction)		
	optimal	acceptable	high risk (to be used only on one side)	optimal	acceptable	high risk (to be used only on one side)
optic nerve	**D1% < 45 Gy RBE LEM D20%< 40 Gy RBE LEM D1%< 40 Gy RBE MKM D20%< 30 Gy RBE MKM**	**D1% < 50Gy RBE LEM D20%< 40 Gy RBE LEM D1%< 40 Gy RBE MKM D20%<**	**D1% < 54 Gy RBE LEM D20%< 40 Gy RBE LEM D1%< 40 Gy RBE**	D (RBE, 2%) < 50 Gy RBE	D (RBE, 2%) < 54 Gy RBE	D (RBE, 2%) < 56 Gy RBE
optic chiasm	**D1% < 45 Gy RBE LEM D20%< 40 Gy RBE LEM D1%< 40 Gy RBE MKM**	na	na	D (RBE, 2%) < 50 Gy RBE	D (RBE, 2%) < 54 Gy RBE	na
brainstem	**D0.1cc < 46 Gy RBE LEM D0.7cc< 38 Gy RBE LEM D0.1cc < 40 Gy RBE MKM D0.7cc< 30 Gy RBE MKM**	na	na	D (RBE, 0,01 ccm) < 54 Gy (RBE), D (RBE, 2%) < 50 Gy RBE	na	na
spinal cord	**D0.1cc < 46 Gy RBE LEM D0.7cc< 38 Gy RBE LEM D0.1cc < 40 Gy RBE**	na	na	D (RBE, 0,01 ccm) < 54 Gy (RBE), D (RBE, 2%) < 50 Gy RBE	na	na
brain parenchyma	D1cc < 60 Gy RBE D5cc < 54 Gy RBE L	D1cc < 64 Gy RBE D5cc < 60 Gy RBE L	na	D1cc < 65 Gy RBE	D1cc < 69 Gy RBE	na
parotid gland	Dmean < 20 Gy RBE	na	Dmean < 26 Gy RBE	Dmean < 20 Gy RBE	na	Dmean < 26 Gy RBE
mandible (teeth bearing)				D (RBE, 2%) < 50 Gy RBE	na	na
mandible (ramus)	D (RBE,1cc) < 53 Gy RBE, D (RBE,3cc) < 50 Gy RBE , D (RBE,5cc) < 38 Gy RBE	D (RBE,3cc) < 60 Gy RBE, D (RBE,5cc) < 50 Gy RBE, D (RBE 8cc) < 38 Gy RBE	na	D (RBE, 2%) < 50 Gy RBE	na	na
cornea	D2% < 30 Gy RBE	D2% < 40 Gy (RBE), D10% < 30 Gy RBE	na	D2% < 30 Gy RBE	D2% < 40 Gy (RBE), D10% < 30 Gy RBE	na
retina	D (RBE, 2%) < 40 Gy (RBE)	D (RBE, 2%) < 45 Gy	na	D (RBE, 2%) < 40 Gy (RBE)	D (RBE, 2%) < 45 Gy (RBE)	na
cochlea	Dmean < 30 Gy RBE	Dmean < 43 Gy RBE	na	Dmean < 30 Gy RBE	Dmean < 43 Gy RBE	na
skin	D5sqcm < 60 Gy RBE	na	na	none	none	none
duodenum	D (RBE, 0.1 ccm) < 46 Gy RBE, D (RBE, 5 ccm) < 36 Gy RBE, D (RBE, 25 ccm) < 25 Gy RBE	D (RBE, 0.1 ccm) < 48 Gy RBE	na	not used	not used	not used
Stomach	D (RBE, 0.1 ccm) < 46 Gy RBE, D (RBE, 5 ccm) < 36 Gy RBE, D (RBE, 25 ccm) < 25 Gy RBE	D (RBE, 0.1 ccm) < 48 Gy RBE	na	not used	not used	not used
small bowel	D (RBE, 0.1 ccm) < 45 Gy RBE, D (RBE, 2 ccm) < 40 Gy RBE	D (RBE, 0.1 ccm) < 50 Gy RBE, D (RBE, 2	na	not used	not used	not used
rectum/sigmoid colon	D (RBE, 1 ccm) < 66 Gy RBE, D (RBE, 5 ccm) < 60 Gy RBE, D (RBE, 10 ccm) < 47 Gy RBE	D (RBE, 1 ccm) < 66 Gy RBE, D (RBE, 5 ccm) < 63 Gy RBE, D (RBE, 10 ccm) < 55 Gy	na	not used	not used	not used
urinary bowel	D (RBE, 1 ccm) < 66 Gy RBE, D (RBE, 50 ccm) < 50 Gy RBE	na	na	not used	not used	not used
kidney	D (RBE, mean) < 10 Gy RBE;	D (RBE, mean) < 18 Gy	na	D (RBE, mean) < 10 Gy RBE;	D (RBE, mean) < 18 Gy	na
cauda equina	D (RBE, 0.1%) < 66 Gy RBE	D (RBE, 0.1%) < 70 Gy RBE	na	not used	not used	not used
nerveroots outside high dose CTV	D1% < 69 Gy RBE	D1% < 71 Gy RBE	na	not used	not used	not used
nerveroots inside high dose CTV	D1% < 71 Gy RBE	D1% < 73 Gy RBE	na	not used	not used	not used

Brain has been selected as organ at risk for pooled analysis

Heavy Ion Therapy Research Integration

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CLINICAL INVESTIGATION

Prospective Analysis of Radiation-Induced Contrast Enhancement and Health-Related Quality of Life After Proton Therapy for Central Nervous System and Skull Base Tumors

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Radiation-induced contrast enhancement following proton radiotherapy for low-grade glioma depends on tumor characteristics and is rarer in children than adults

Tanja Eichkorn • Julia Bauer • Emanuel Bahn • ... Jürgen Debus • Laila König [1] •
Semi Harrabi [1] • Show all authors • Show footnotes

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Original Article

Radiation induced contrast enhancement after proton beam therapy in patients with low grade glioma – How safe are protons?

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cancers

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Article

Patterns of Temporal Lobe Reaction and Radiation Necrosis after Particle Radiotherapy in Patients with Skull Base Chordoma and Chondrosarcoma—A Single-Center Experience

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Happy to answer your questions

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