HITRI plus

Heavy Ion Therapy Research Integration



DR. MED. SEMI B. HARRABI

*HIT*

*HEIDELBERG ION-BEAM THERAPY CENTER*

HIT Heidelberger Ionenstrahl-Therapiezentrum



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

# Pediatric cancer particle therapy

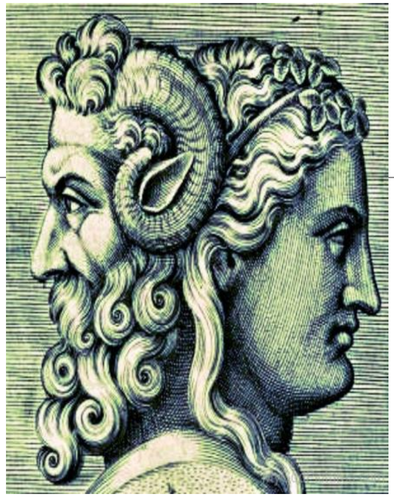
- Individual therapy
- very time consuming (sedation, anesthesia)
- Interdisciplinary team
- Mostly in trial protocols

# Challenges in pediatric RadioOncology

Complex tumor volumes

Proximity to neighboring organs, e.g.:

- optical nerves
- bone marrow
- tendon crossings
- brain stem



Aim: local tumor control

High risk for therapy induced adverse effects:

- Impaired vision, blindness
- Neurological deficits
- Xerostomia (mouth dryness)
- Impaiment of growth, deformations
- Hormonal deficits
- Secondary malignancies
- etc.

# Indications for particle therapy in pediatric RadiationOncology

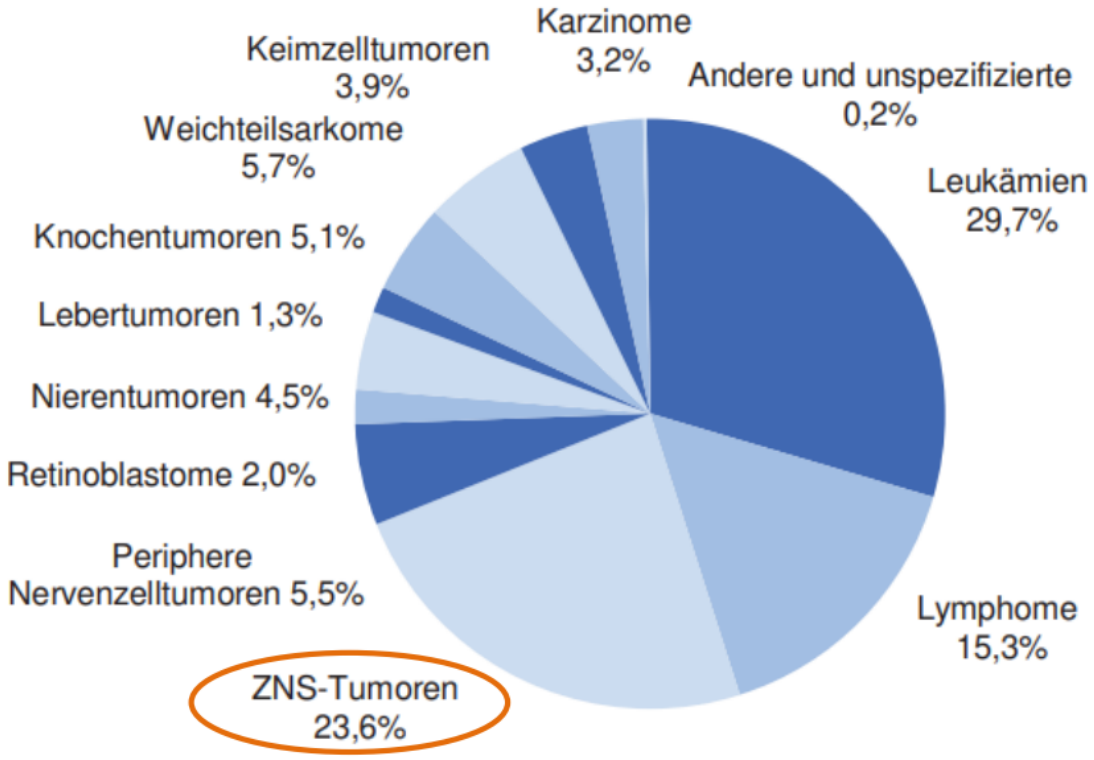
**Protons**

- Chordoma / low grade chondrosarkoma
- Glioma, Ependymoma, boost-irradiations
- RMS, EWS, (head&neck, orbita, parameningeal etc.)
- Paraspinal tumors, e.g. sarkoma
- *(irradiation of craniospinal axis in medulloblastoma, pineoblastoma etc.)*

**Carbon ions**

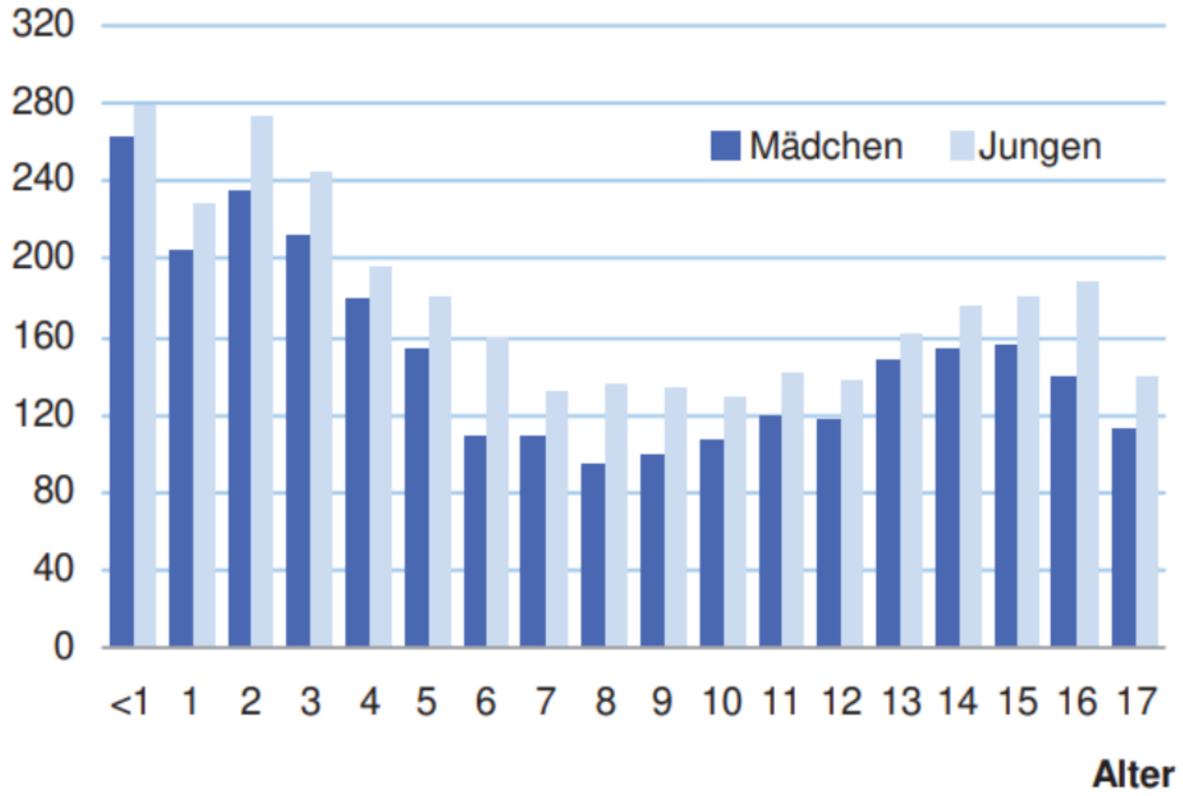
- Chordoma / low grade chondrosarkoma
- Osteosarkoma
- Rare tumors, e.g. adenoid cystic carcinoma (ACC)

**Relative Häufigkeiten der an das Deutsche Kinderkrebsregister gemeldeten Erkrankungsfälle nach Diagnose-Hauptgruppen***




ZNS: Zentrales Nervensystem

**Alters- und geschlechtsspezifische Erkrankungsraten pro 1 Million***




*2009-2018, basierend auf insgesamt 21831 unter 18-jährigen Patienten

Quelle: deutsches Kinderkrebsregister, Jahresbericht 2019

HITRIplus Heavy Ion Therapy Research Integration

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

Selected characteristics under 18 years Germany 2009-2018

| | |
|---|---|
| **Relative frequency:** | 5142 / 21831 = 23.6 % |
| **Relative frequency of trial patients:** | 93.5 % |

| **Incidence rates per million:** | **Girls** | **Boys** | **Total** |
|---|---|---|---|
| Number of cases: | 2348 | 2794 | 5142 |
| Standardized rate *: | 37.3 | 41.9 | 39.6 |
| Cumulative incidence: | 659 | 742 | 702 |
| **Sex ratio (m/f):** | | | 1.2 |

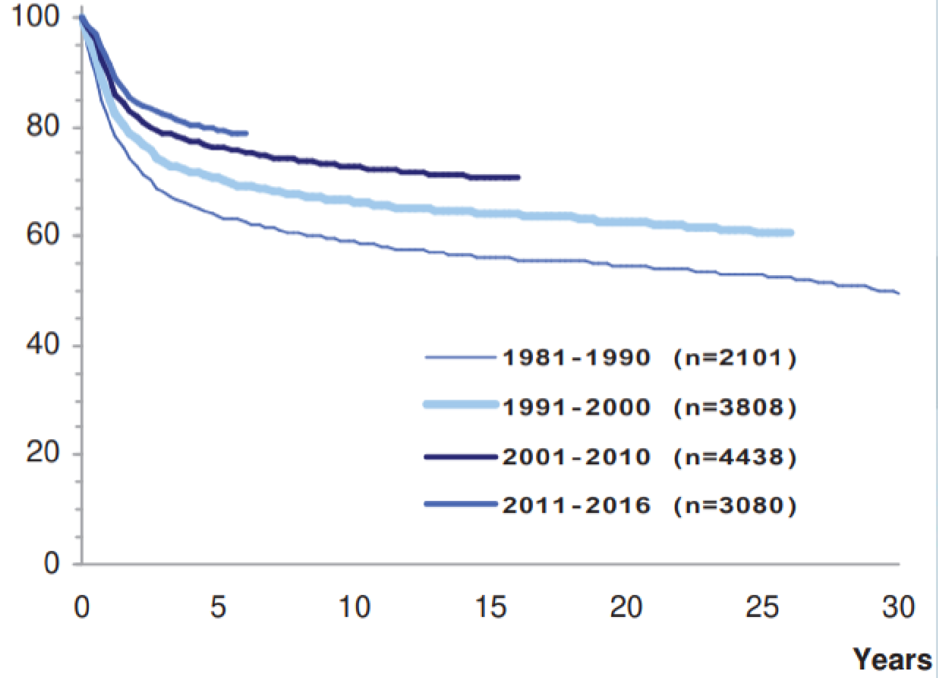
**Second neoplasms (SN) within 30 yrs. of diagnosis (1981-2016):**
III CNS and miscellaneous intracranial and intraspinal neoplasms

| SN after III | | | III as SN after any primary | | |
|---|---|---|---|---|---|
| N | % of all 1540 SN | Cumulative incidence | N | % of all 1540 SN | Cumulative incidence |
| 288 | 18.7 % | 7.6 % | 344 | 22.3 % | 1.7 % |

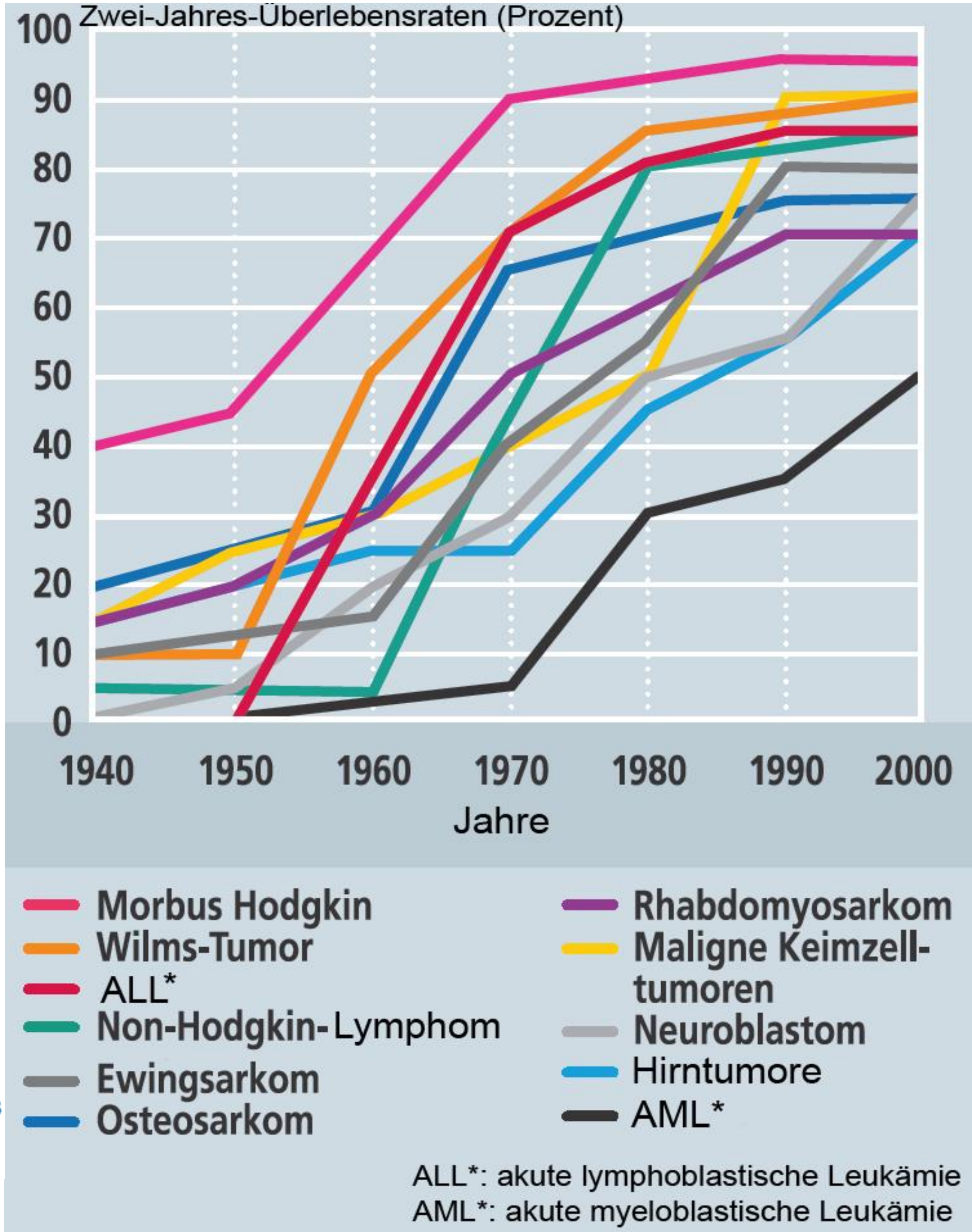
* Standard: Segi world standard population

# The prognosis for overall survival for pediatric cancer patients has improved over the decades

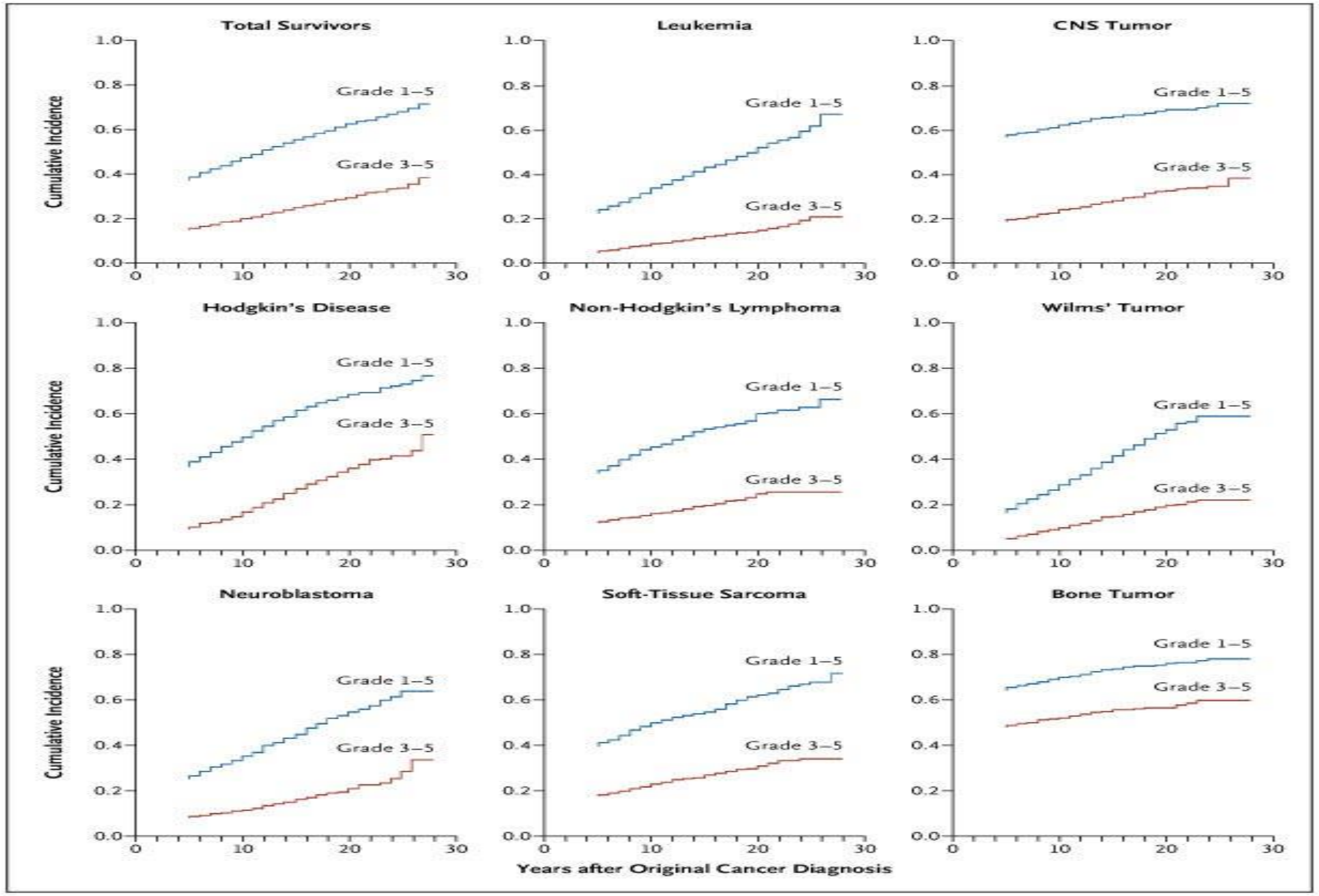
**Survival probabilities by year of diagnosis Germany 1981-2016**




Quelle: deutsches Kinderkrebsregister, Jahresbericht 2019



# Price of survival: the childhood cancer survival study




Cumulative incidence of chronic health conditions among 10,397 adult survivors of pediatric cancer

HITRI plus
Heavy Ion Therapy Research Integration



Oeffinger et al, NEJM 2006

# Price of survival: the childhood cancer survival study

**Table 3.** Relative Risk of Selected Severe (Grade 3) or Life-Threatening or Disabling (Grade 4) Health Conditions among Cancer Survivors, as Compared with Siblings.

| Condition | Survivors (N=10,397) | Siblings (N=3034) | Relative Risk (95% CI) |
|---|---|---|---|
| | *percent* | | |
| Major joint replacement* | 1.61 | 0.03 | 54.0 (7.6–386.3) |
| Congestive heart failure | 1.24 | 0.10 | 15.1 (4.8–47.9) |
| Second malignant neoplasm† | 2.38 | 0.33 | 14.8 (7.2–30.4) |
| Cognitive dysfunction, severe | 0.65 | 0.10 | 10.5 (2.6–43.0) |
| Coronary artery disease | 1.11 | 0.20 | 10.4 (4.1–25.9) |
| Cerebrovascular accident | 1.56 | 0.20 | 9.3 (4.1–21.2) |
| Renal failure or dialysis | 0.52 | 0.07 | 8.9 (2.2–36.6) |
| Hearing loss not corrected by aid | 1.96 | 0.36 | 6.3 (3.3–11.8) |
| Legally blind or loss of an eye | 2.92 | 0.69 | 5.8 (3.5–9.5) |
| Ovarian failure‡ | 2.79 | 0.99 | 3.5 (2.7–5.2) |

* For survivors, major joint replacement was not included if it was part of cancer therapy.

62% affected,
25% vital,
25% >3 conditions

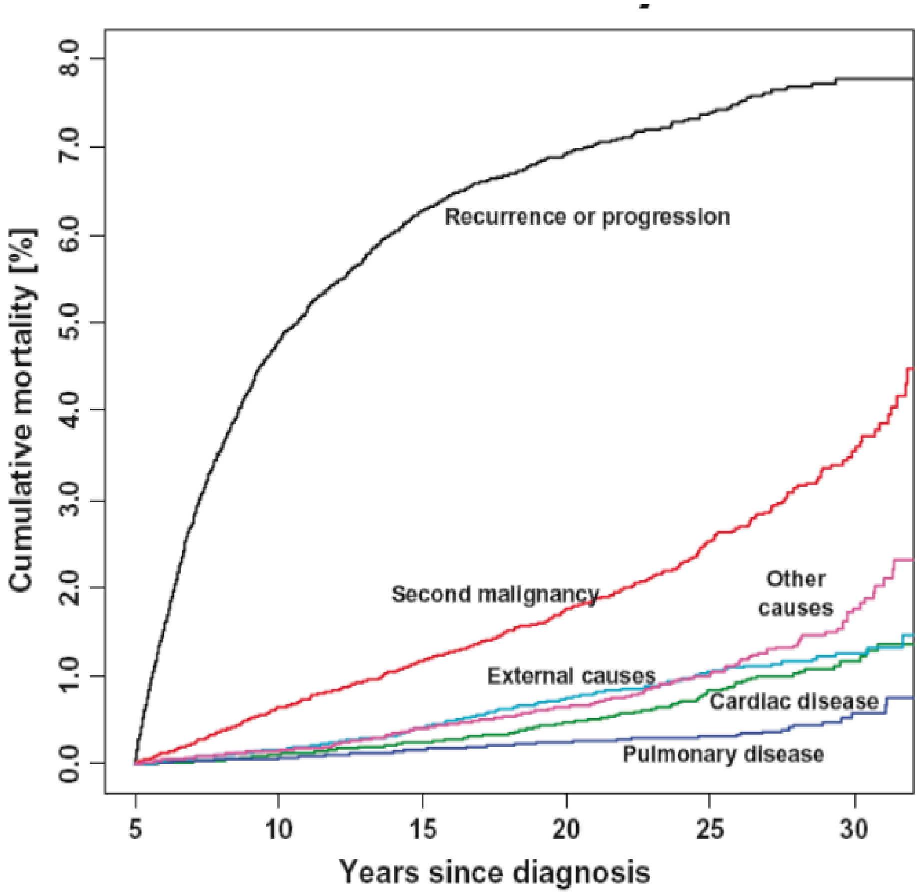
HI
Heavy Ion Therapy Research Integration

ding from the European Union's Horizon 2020
gramme under grant agreement No 101008548

Oeffinger et al, NEJM 2006

# Price of survival: late mortality

Cause-specific late mortality among long term survivors of childhood cancer




HITRI plus
Heavy Ion Therapy Research Integration

uropean Union's Horizon 2020
ɪrant agreement No 101008548

# Price of survival: late mortality

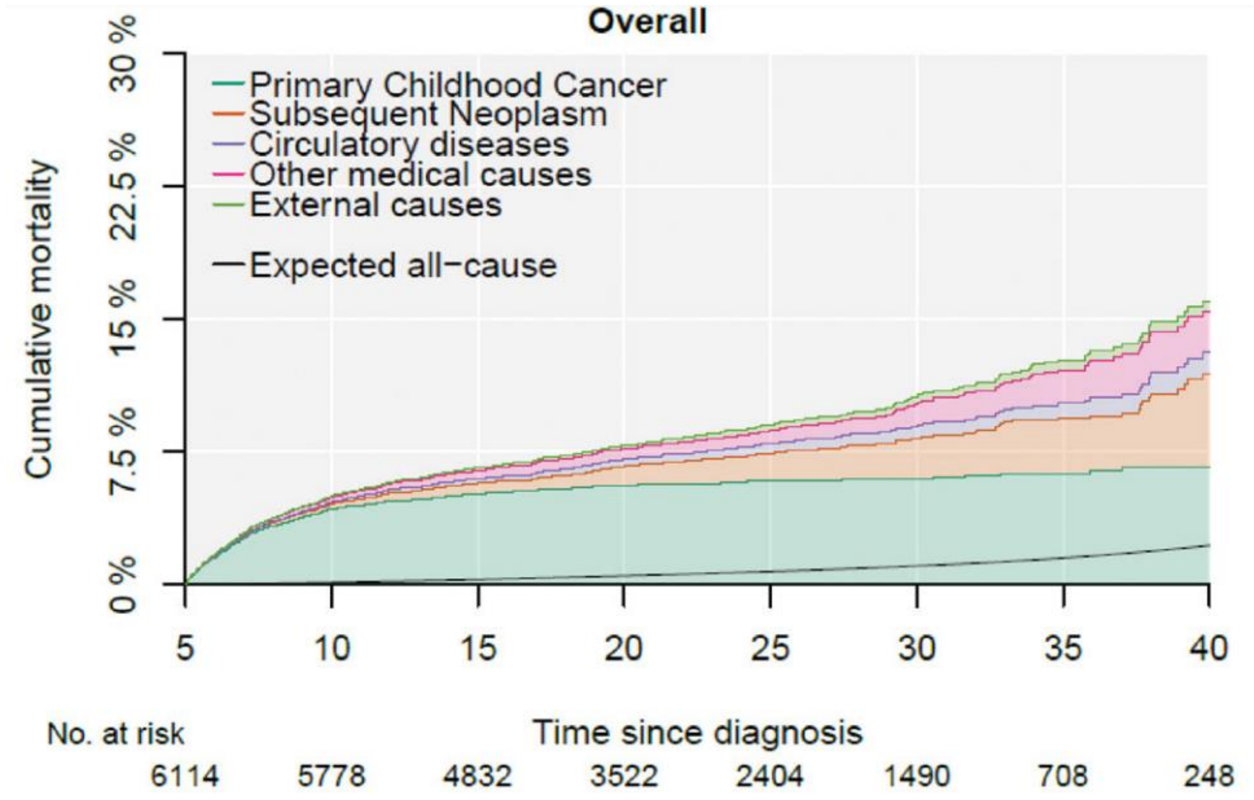



**Figure 1.** Cumulative mortality (%) by time since diagnosis for various COD categories in the DUTCH LATER cohort. *Corrected for sex, age and calendar year.

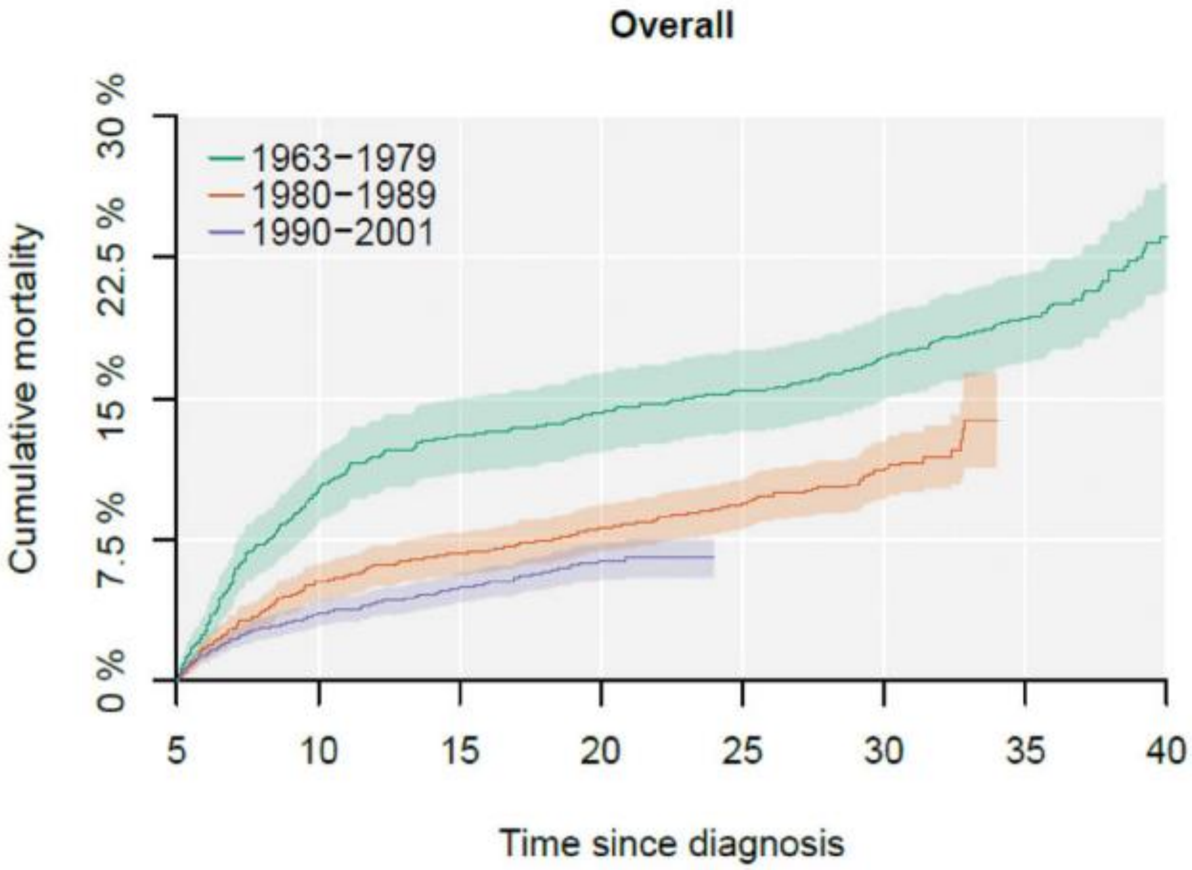



**Figure 3.** Cumulative late mortality (%) of CCSs by time since diagnosis for different periods of diagnosis.



Kilsdonk et. al, Cancer Investigation, 2022

# physical rationale for ion beam therapy

**potential aims of ion beam therapy**

- Dose escalation -> improving outcome
- Sparing of normal tissue -> reduction of late sequelae
- Reduction of irradiated volume -> reduction of 2nd malignancies

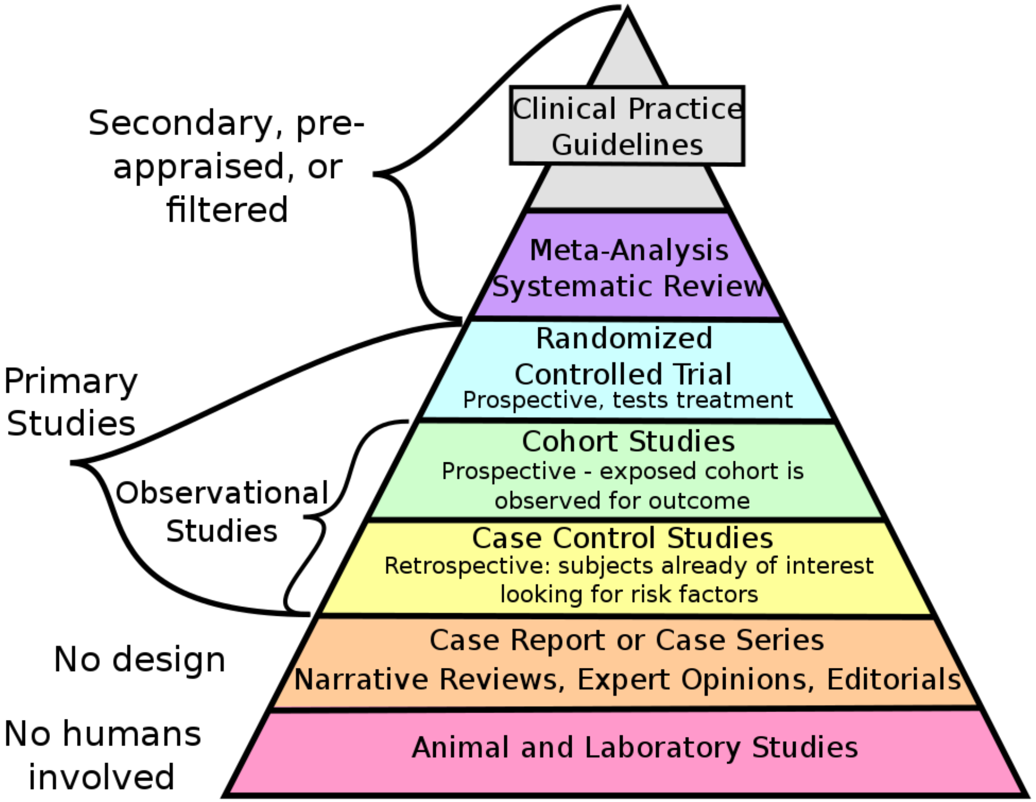
**particularly relevant if**

- Very high radiation dose is needed
- Very sensitive patients/structures are involved

HITRIplus
Heavy Ion Therapy Research Integration

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

# Level of evidence




Randomized trials on proton beam therapy in children internationally considered unethical

HITRI plus
Heavy Ion Therapy Research Integration

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

# German society of radiation oncology

## Proton beam therapy

- is **NOT** considered being **experimental**
- is considered to be a **proven radiation technique**
- can be performed according to photon standards
- does not need special approval (radiation safety board) if dose/ volume concepts are alike photon concepts
- may help to reduce dose to normal tissue

HITRI plus
Heavy Ion Therapy Research Integration

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

# medulloblastoma

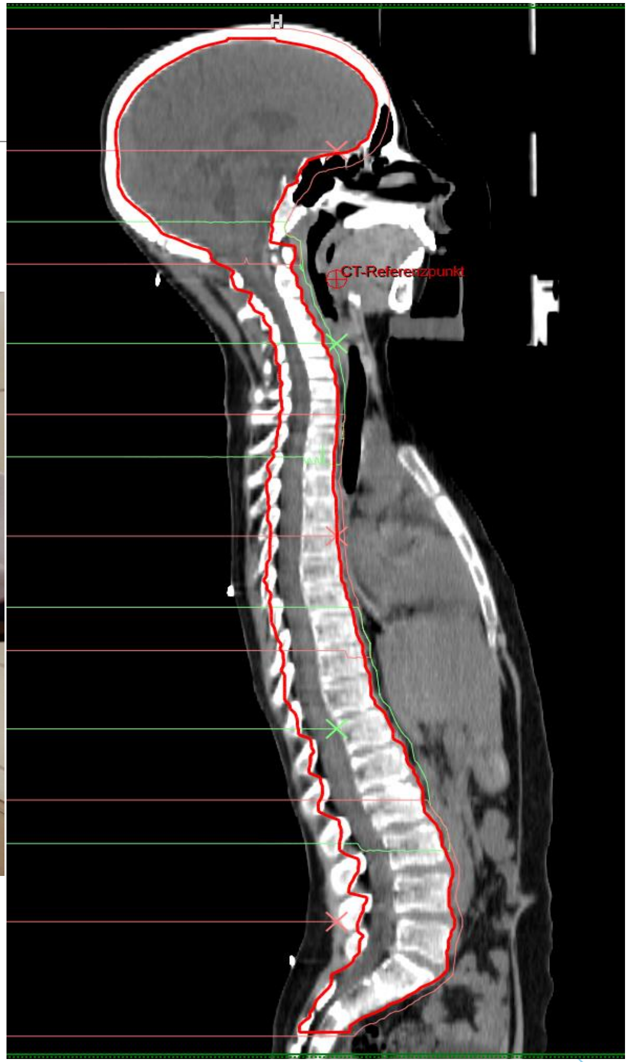
- Large irradiation field

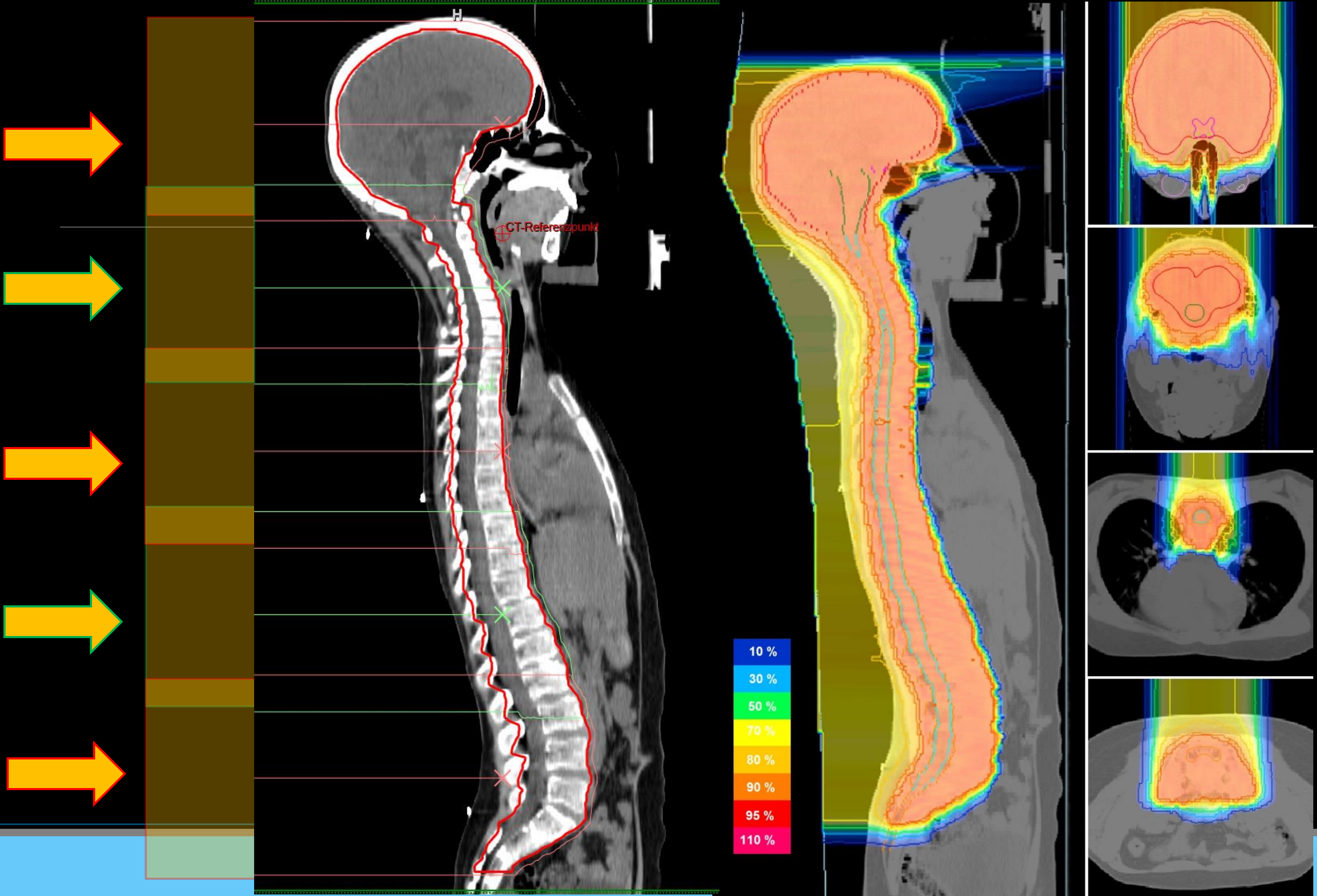
---

- Vertebral bodies might need to be included in PTV
  - Growth impairment
  - Blood production disorders

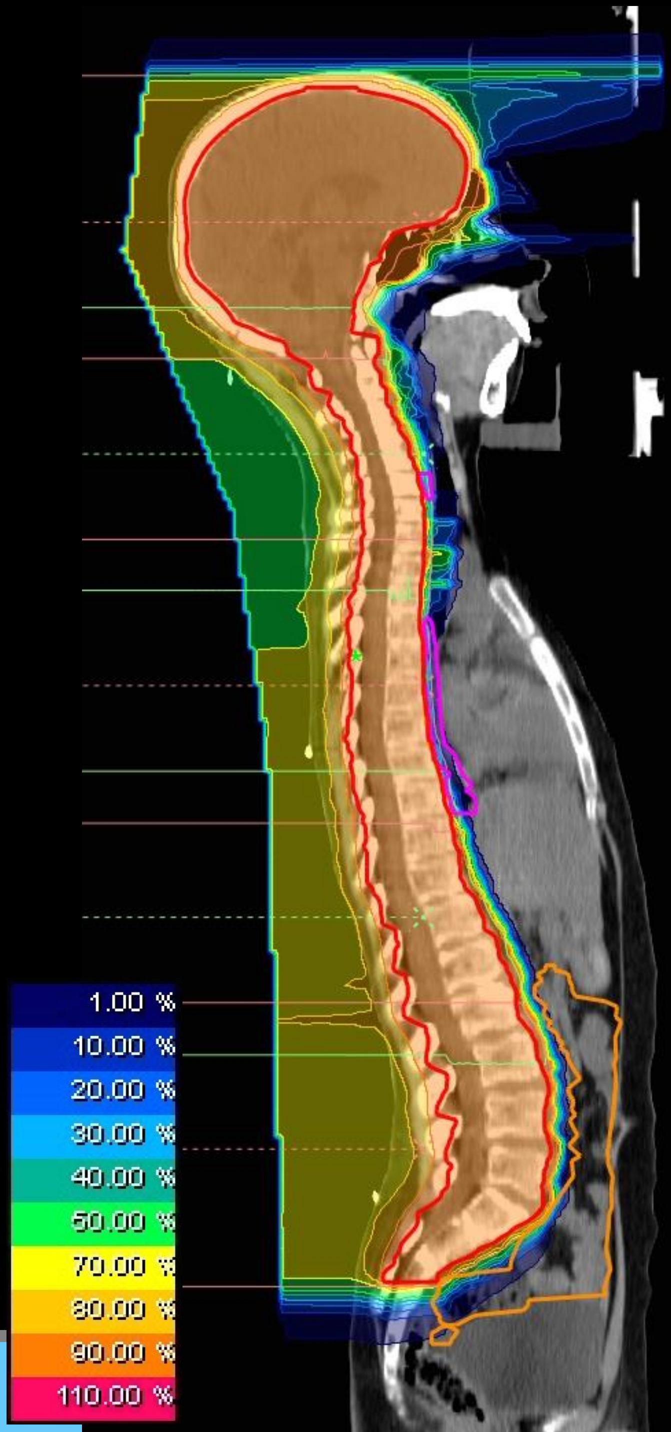
- So many citical OAR:
  thyroid gland, heart, lungs, kidneys, bowel, …

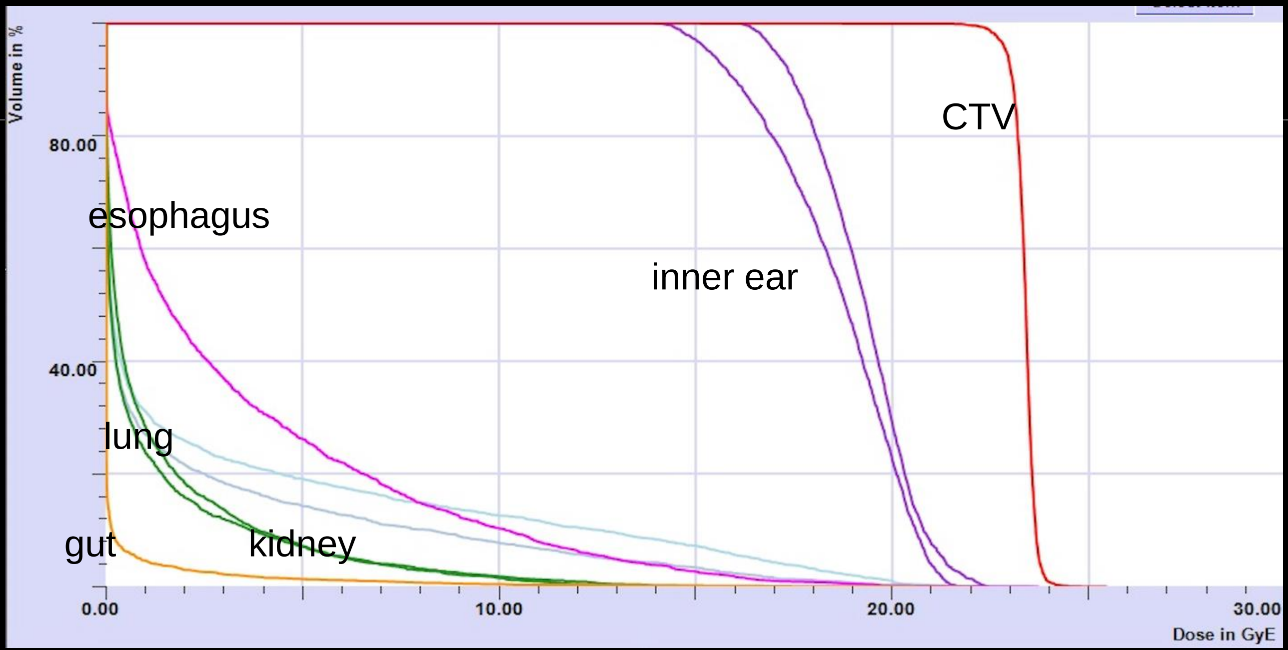
→ challenging situation necessitating special radiation techniques

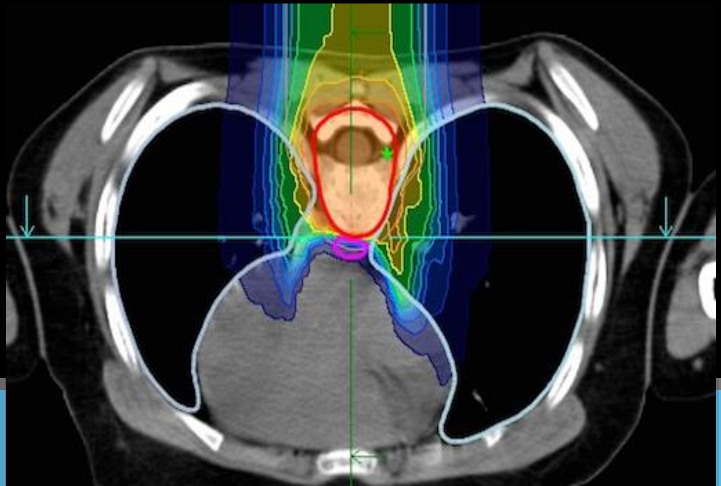


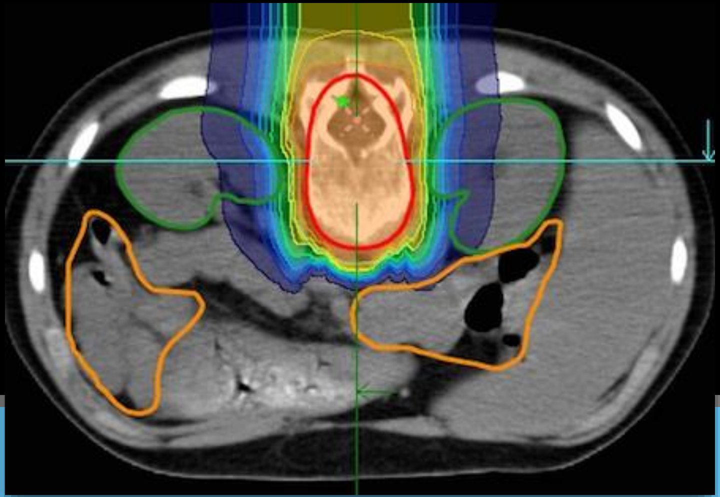

H
CT-Referenzpunkt
10 %
30 %
50 %
70 %
80 %
90 %
95 %
110 %

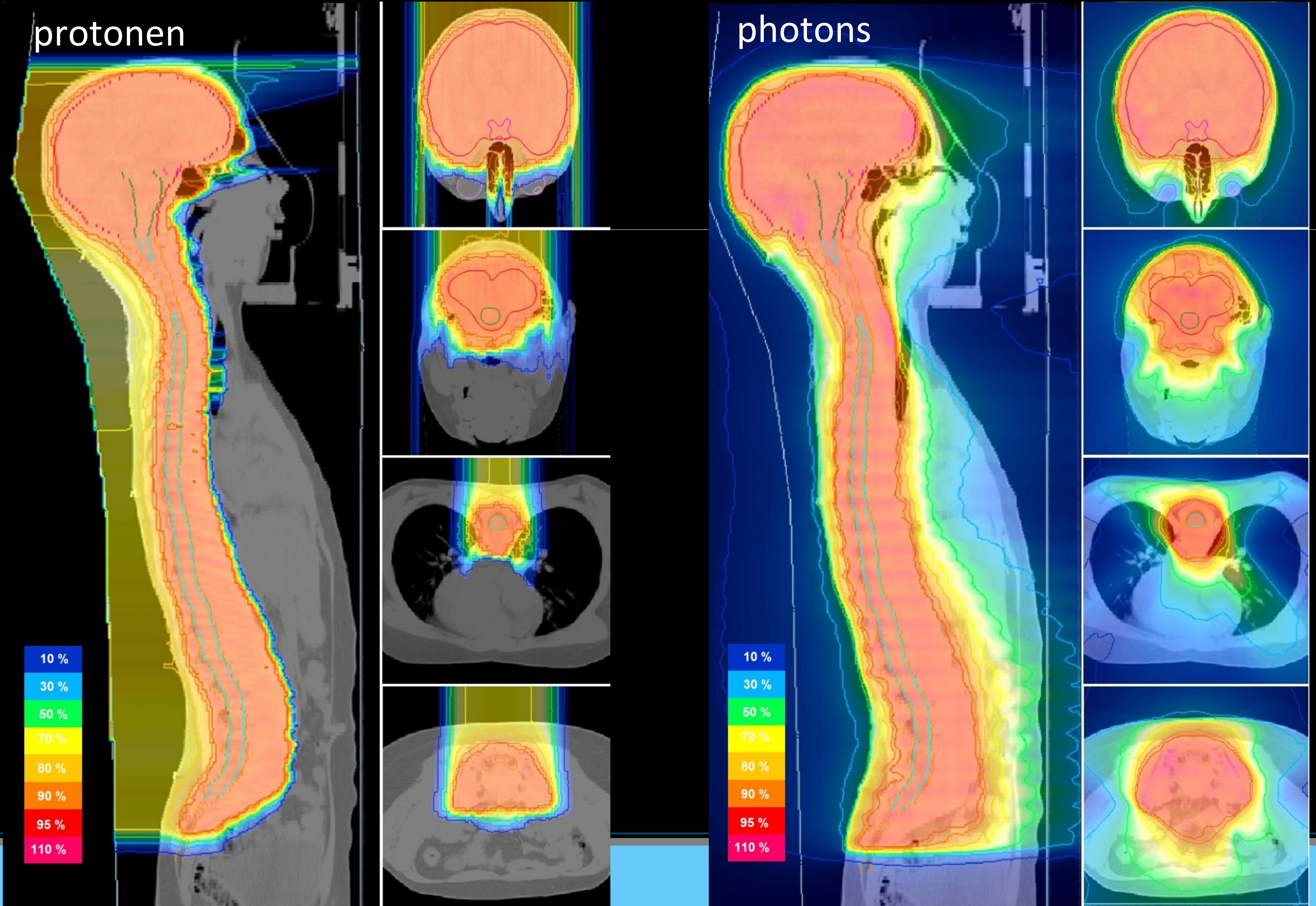
# cranio spinal irradiation



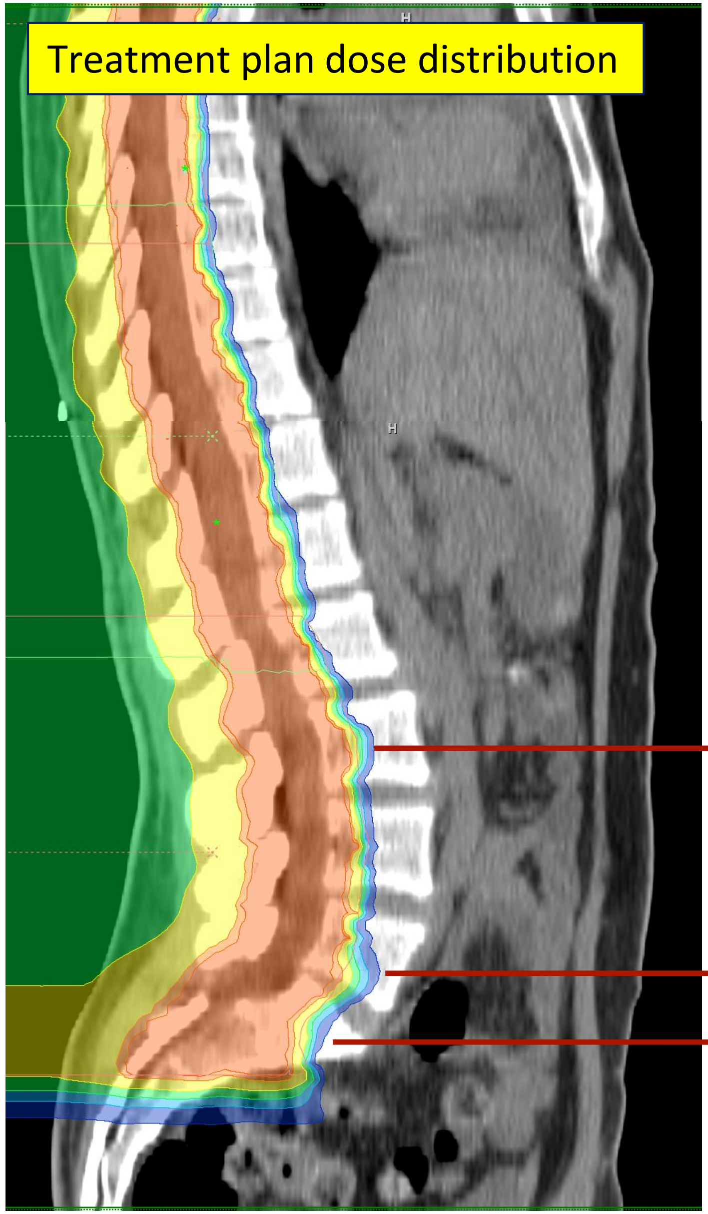






protonen
10 %
30 %
50 %
70 %
80 %
90 %
95 %
110 %
photons
10 %
30 %
50 %
70 %
80 %
90 %
95 %
110 %

# *In vivo* range verification

Heidelberger Ionenstrahl-Therapiezentrum



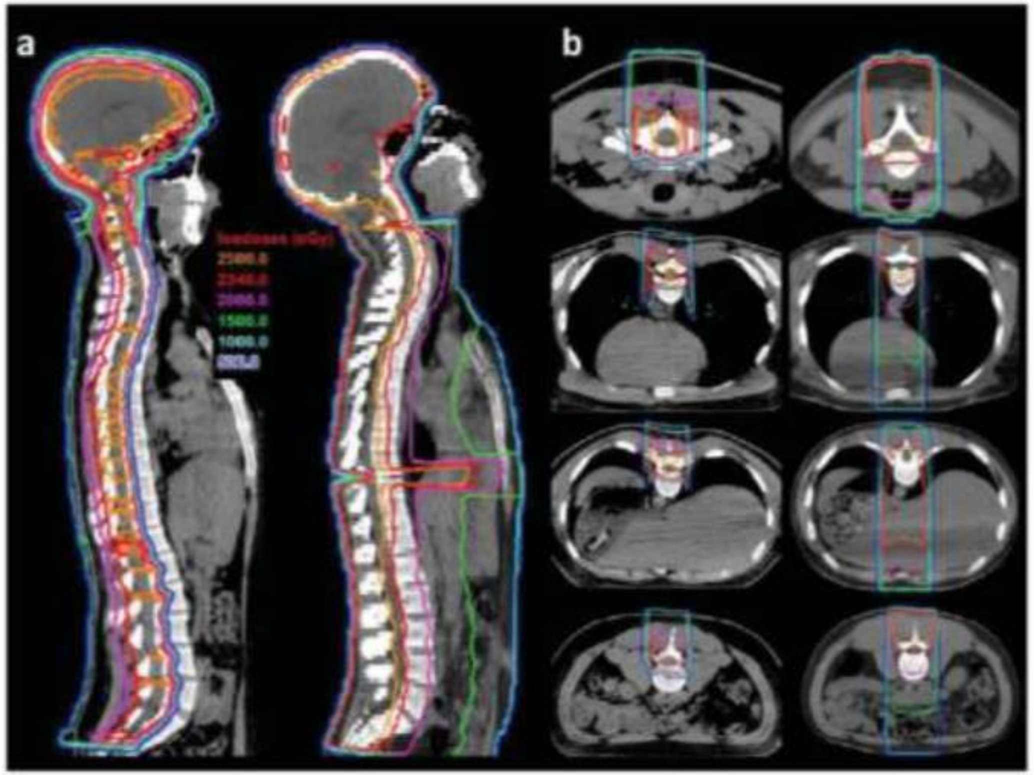

Fatty changes
in irradiated part
of vertebral bodies

~6 month
after
Proton RT

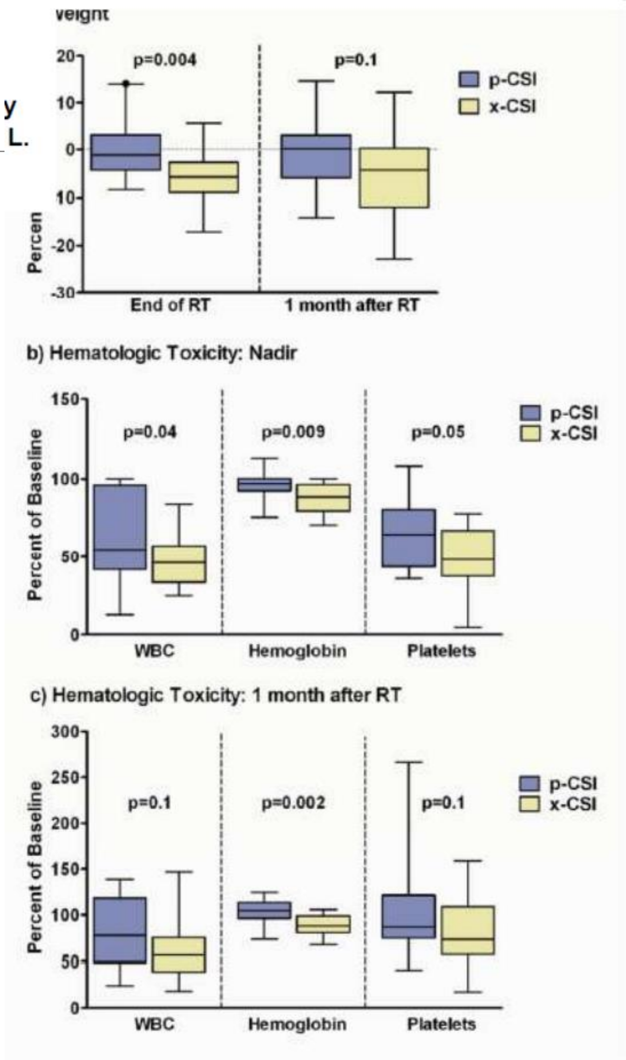

Proves entire treatment chain, incl. patient positioning, beam application

# Proton Beam Craniospinal Irradiation Reduces Acute Toxicity for Adults with Medulloblastoma

Aaron P. Brown, M.D.[a], Christian L. Barney, B.S.[e], David R. Grosshans, M.D., Ph.D.[a], Mary Frances McAleer, M.D., Ph.D.[a], John F. de Groot, M.D.[b], Vinay K. Puduvalli, M.D.[b], Susan L. Tucker, Ph.D.[d], Cody N. Crawford, C.M.D.[a], Meena Khan, C.M.D.[a], Soumen Khatua, M.D.[c], Mark R. Gilbert, M.D.[b], Paul D. Brown, M.D.[a], and Anita Mahajan, M.D.[a]




## PT & Acute Toxicity




*Int J Radiat Oncol Biol Phys*. 2013 June 1; 86(2): 277–284. doi:10.1016/j.ijrobp.2013.01.014.

Neuro-Oncology
Neuro-Oncology 18(6), 881–887, 2016
doi:10.1093/neuonc/nov302
Advance Access date 19 December 2015

## Endocrine outcomes with proton and photo[...] standard risk medulloblastoma

Bree R. Eaton, Natia Esiashvili, Sungjin Kim, Briana Patterson, Eliza[...] Claire Mazewski, Tobey J. MacDonald, David Ebb, Shannon M. Mac[...]

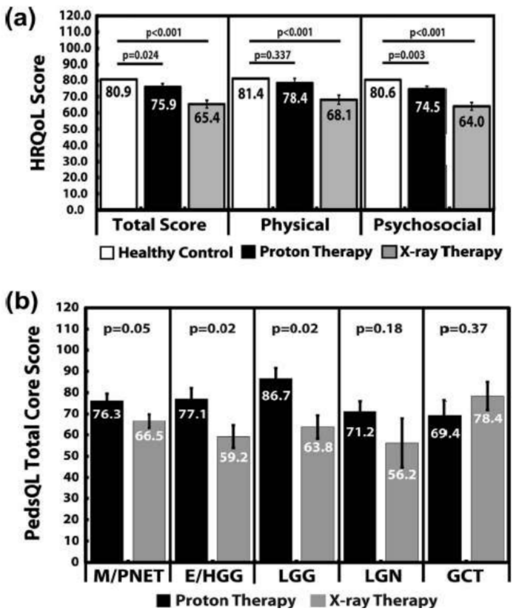
original reports

## Superior Intellectual Outcomes After Proton Radiotherapy Compared With Photon Radiotherapy for Pediatric Medulloblastoma

Lisa S. Kahalley, PhD[1,2]; Rachel Peterson, PhD[3]; M. Douglas Ris, PhD[1,2]; Laura Janzen, PhD[3]; M. Fatih Okcu, MPH, MD[1,2]; David R. Grosshans, MD, PhD[4]; Vijay Ramaswamy, MD, PhD[3,5]; Arnold C. Paulino, MD[4]; David Hodgson, MD[6]; Anita Mahajan, MD[7]; Derek S. Tsang, MD, PhD[6]; Normand Laperriere, MD[6]; William E. Whitehead, MPH, MD[1,2]; Robert C. Dauser, MD[1,2]; Michael D. Taylor, MD, PhD[3,5]; Heather M. Conklin, PhD[8]; Murali Chintagumpala, MD[1,2]; Eric Bouffet, MD[3,5]; and Donald Mabbott, PhD[3,5]

Yock TI et al.
***Quality of life outcomes in proton and photon treated pediatric brain tumor survivors.***
Radiother Oncol. 2014 Oct; 113 (1):89-94

- **57 PT vs. 63 XRT**
- **Ped. Brain tumours**
- **PedsQL Tests after 3 years**




*Article*

## Neurocognitive Outcomes in Pediatric Patients Following Brain Irradiation

Katharina Weusthof [1,2], Peggy Lüttich [3], Sebastian Regnery [1,2], Laila König [1,2,4,5], Denise Bernhardt [6,7], Olaf Witt [3,8], Klaus Herfarth [1,2,4,5,9,10], Andreas Unterberg [11], Christine Jungk [11], Benjamin Farnia [12], Stephanie E. Combs [6,7], Jürgen Debus [1,2,4,5,9,10], Stefan Rieken [13], Semi Harrabi [1,2,4,5,9,10,†] and Sebastian Adeberg [1,2,4,5,9,10,*,†]

Clinical Investigation

## Cognitive and Adaptive Outcomes After Proton Radiation for Pediatric Patients With Brain Tumors

Margaret B. Pulsifer, PhD,[*,†] Haley Duncanson, PhD,[*,†] Julie Grieco, PsyD,[*,†] Casey Evans, MS,[*] Irene Delgado Tseretopoulos, PhD,[*] Shannon MacDonald, MD,[†,‡] Nancy J. Tarbell, MD,[†,‡] and Torunn I. Yock, MD[†,‡]

UKHD

Evidenz for Cost effectiveness!

Cancer

Original Article | Free Access

## Cost-effectiveness of proton radiation in the treatment of childhood medulloblastoma

Jonas Lundkvist M.Sc., Mattias Ekman Ph.D., Suzanne Rehn Ericsson Ph.D., Bengt Jönsson Ph.D., Bengt Glimelius Ph.D.

First published: 03 February 2005 | https://doi.org/10.1002/cncr.20844 | Citations: 93

**able 1.** Cost and Clinical Outcome per Patient for the Base-Case Assumptions

| Variable | Proton radiation | Conventional radiation | Difference |
|---|---|---|---|
| Radiation cost (€) | 10217.9 | 4239.1 | 5978.8 |
| Cost from adverse events (€) | 4231.8 | 33857.1 | −29625.3 |
| Total cost (€) | 14449.7 | 38096.2 | −23646.5 |
| LYG | 13.866 | 13.600 | 0.266 |
| QALY | 12.778 | 12.095 | 0.683 |

LYG: life years gained; QALY: quality-adjusted life-years.

**Table 2.** Radiation-Induced Events per 100 Patients

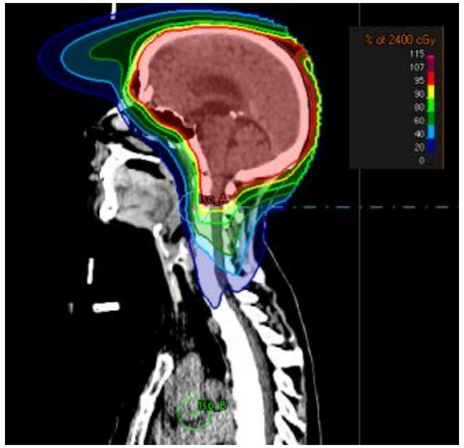
| Variable | Hearing loss | Hypothyroidism | Osteoporosis | GHD | Nonfatal secondary malignancies | Fatal events |
|---|---|---|---|---|---|---|
| Conventional radiation | 11.9 | 16.3 | 0.4 | 17.1 | 1.2 | 1.91 |
| Proton radiation | 1.4 | 2.7 | 0.1 | 2.0 | 0.7 | 0.38 |
| Difference | 10.5 | 13.6 | 0.3 | 15.1 | 0.5 | 1.53 |

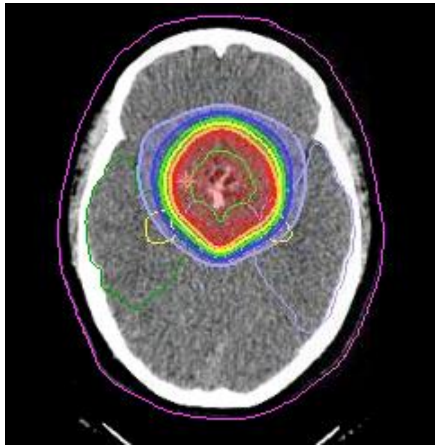
GHD: growth hormone deficiency.

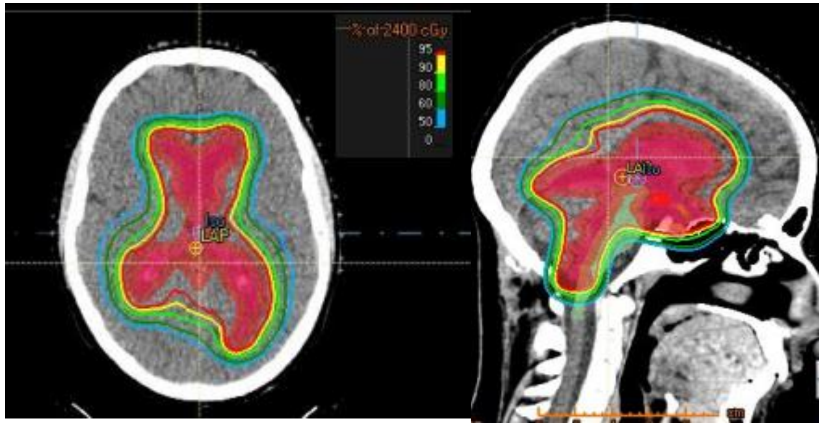
The current analyses indicated that **proton therapy had both lower total cost and better effect than conventional radiation**. In the base-case analysis, **proton therapy was associated with €23,600 cost savings, 0.27 additional life years, and 0.68 additional QALYs per patient** compared with conventional radiation. Thus, the additional costs for radiation therapy were offset by reduced costs for adverse events.

# Proton beam therapy for CNS

1. Craniospinal ( „CSI“)
2. Whole ventricular system
3. Focal irradiation
4. Tumor bed
5. …

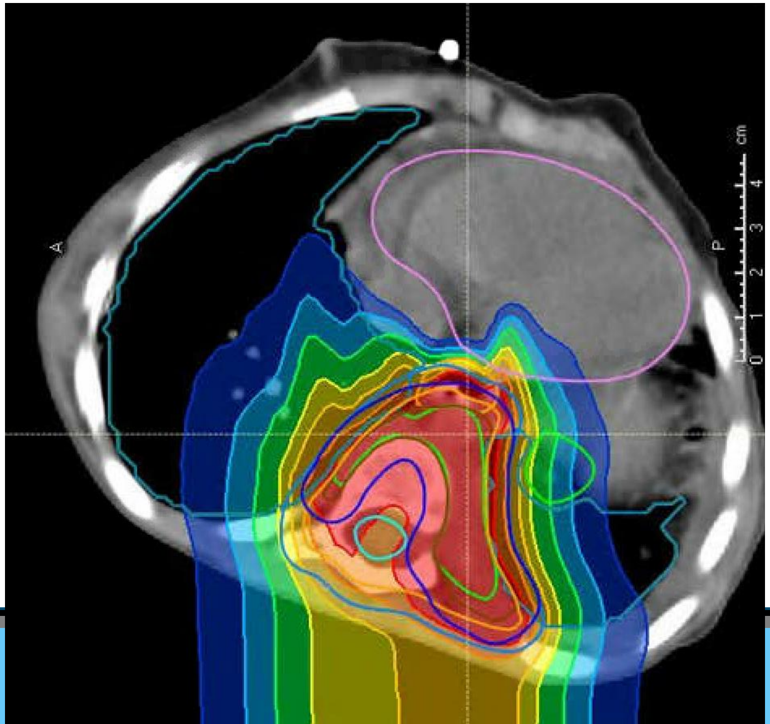


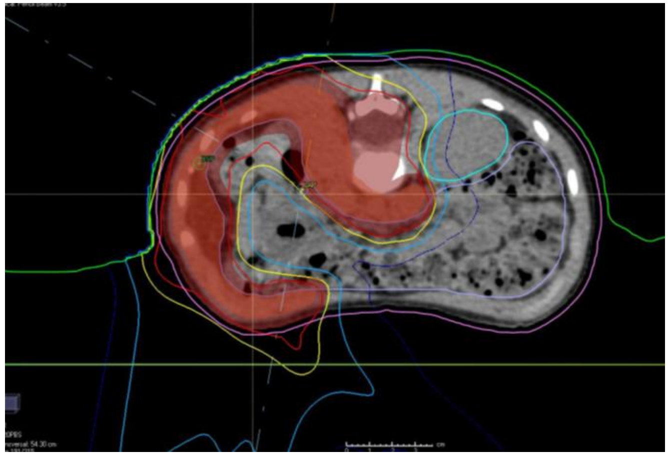


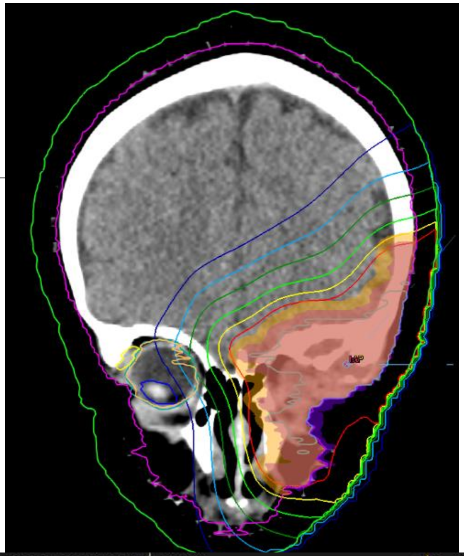


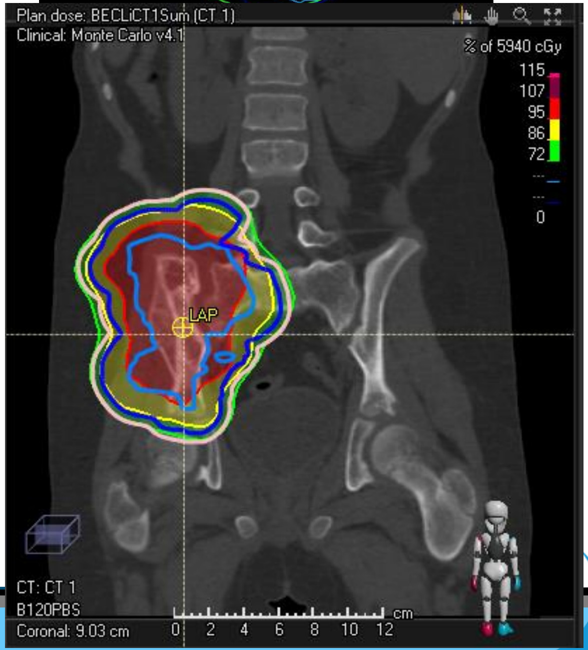

# Proton beam therapy for non-CNS

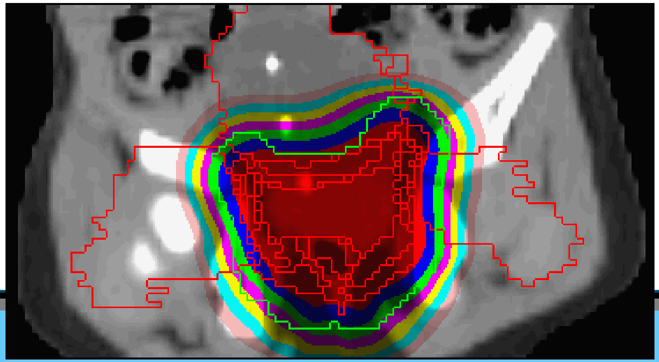
1. Osteo-, Rhabdomyo- or Ewing-Sarcoma
2. lymphoma
3. neuroblastoma
4. retinoblastoma









> Cancer. 2020 Aug 1;126(15):3560-3568. doi: 10.1002/cncr.32938. Epub 2020 May 19.

# Second cancer risk after primary cancer treatment with three-dimensional conformal, intensity-modulated, or proton beam radiation therapy

Michael Xiang [1, 2], Daniel T Chang [1], Erqi L Pollom [1, 2]

Evidence for reduction of SPC

**TABLE 2.** Overall Second Cancer Risk for Intensity-Modulated Radiation Relative to Three-Dimensional Conformal Radiation and Proton Beam Radiation Relative to Intensity-Modulated Radiation[a]

| Cohort and Adjustment Method(s) | Adjusted OR (95% CI) | *P* |
|---|---|---|
| IMRT relative to 3DCRT | | |
| Nonmatched, multivariable | 1.00 (0.97-1.02) | .75 |
| Matched, univariable | 1.03 (1.00-1.06) | .04 |
| Matched, multivariable | 1.00 (0.98-1.03) | .75 |
| PBRT relative to IMRT | | |
| Nonmatched, multivariable | 0.31 (0.26-0.36) | <.0001 |
| Matched, univariable | 0.30 (0.26-0.36) | <.0001 |
| Matched, multivariable | 0.29 (0.24-0.35) | <.0001 |

Abbreviations: 3DCRT, 3-dimensional conformal radiation, IMRT, intensity-modulated radiation; OR, odds ratio; PBRT, proton beam radiation; CI, confidence interval.

[a]Values were estimated using multivariable adjustment, matching, or both (with the same covariates used in Table 1).

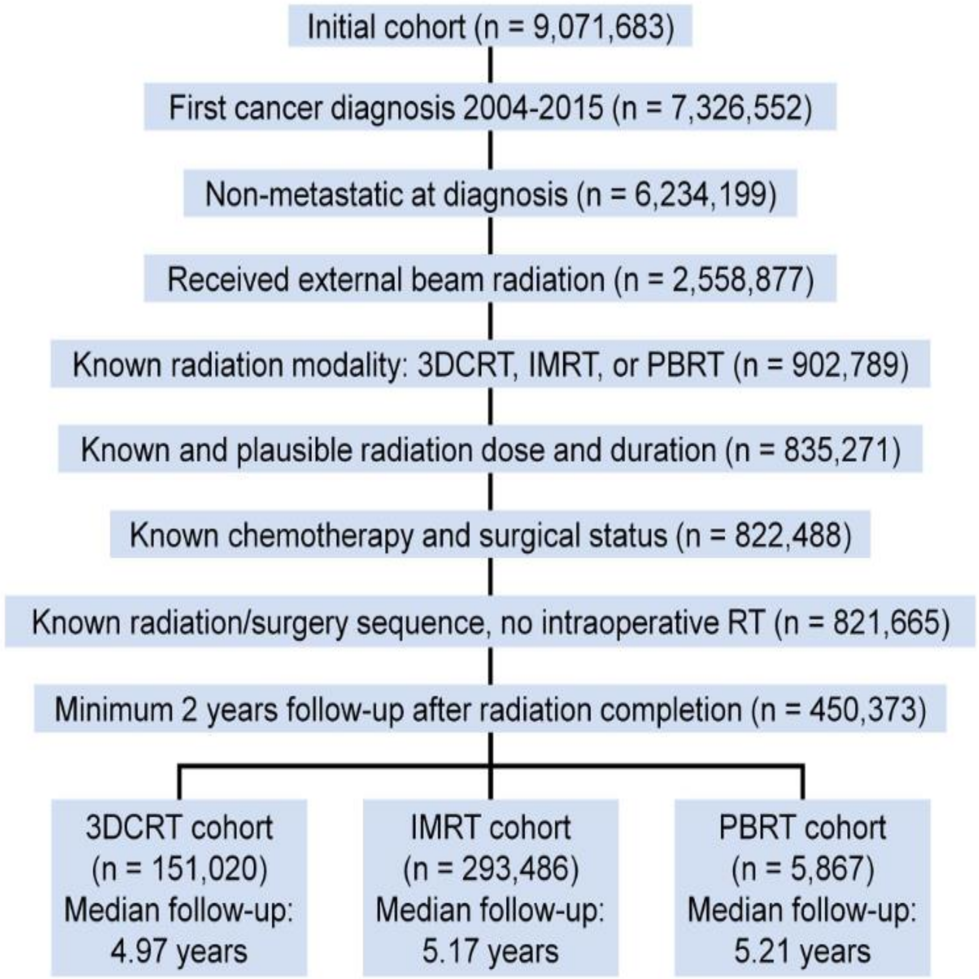



**FIGURE 1.** This is a Consolidated Standards for Reporting Trials (CONSORT)-style diagram for cohort identification. 3DCRT indicates 3-dimensional conformal radiation therapy; IMRT, intensity-modulated radiation therapy; PBRT, proton beam radiation therapy.

# A (Strong) Case

**2008:** Dx: **Bilateral RB**
TX: Enucleation left eye
Chemotherapy
EBRT right eye (50Gy)

**2015:** ♀ 7.5 y.
Swelling left paraocular
**Dx: undiff. Sarcoma**

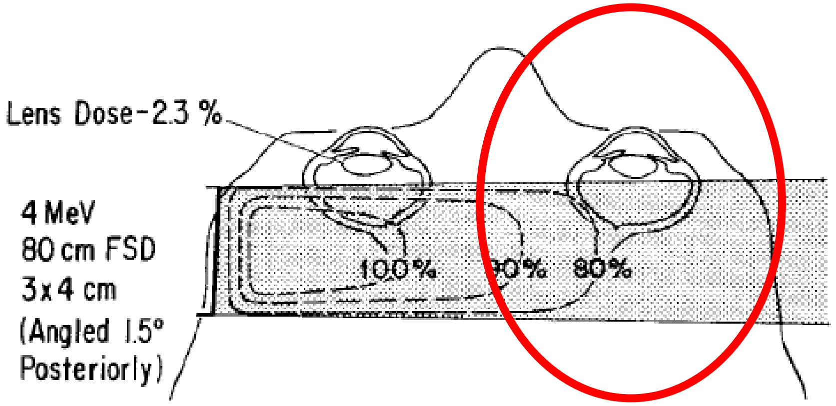
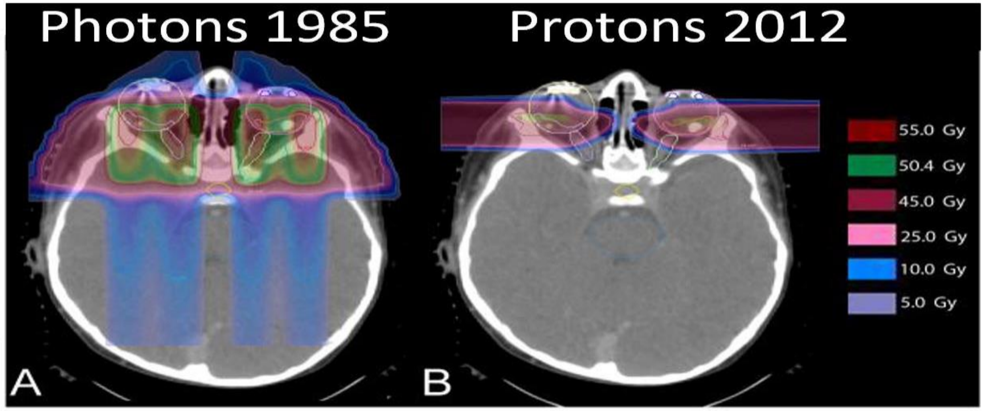



Fig. 2. Computer-calculated isodose distribution for a single 3 × 4-cm lateral field using a 4 MeV Varian linear accelerator. The anterior beam edge is placed at the bony canthus and the beam angled 1.5° posteriorly if the contralateral eye remains in place. Ipsilateral lens dose is estimated using a $Li_2BO_4$ thermal luminescent dosimeter.

**Today: Proton Beam Therapy**

# Second non-ocular tumors among survivors of retinoblastoma treated with contemporary photon and proton radiotherapy.

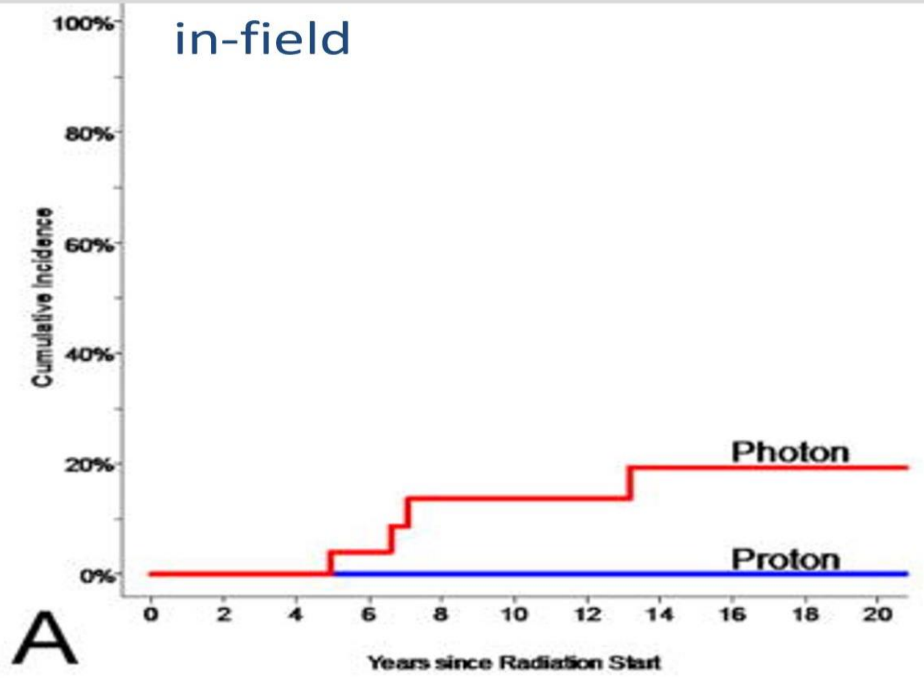


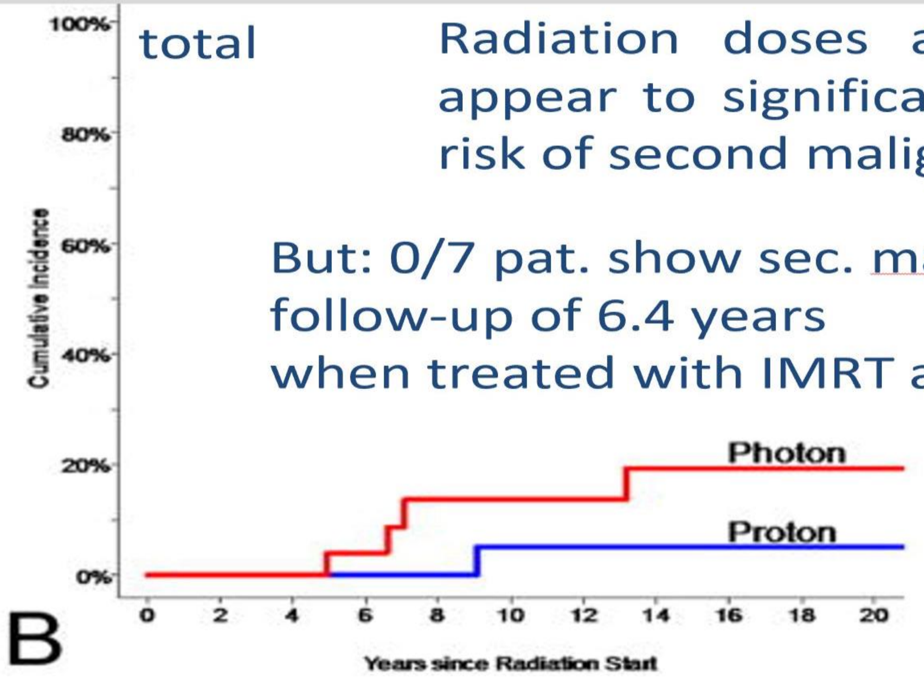

Sethi et al. Cancer. 2014; 120(1):126-33.

protons 55 patients
f/u median 6.9 years

photons 31 patients
f/u median 13.1 years

## Secondary malignancy




Radiation doses as low as 5 Gy appear to significantly increase the risk of second malignancy.

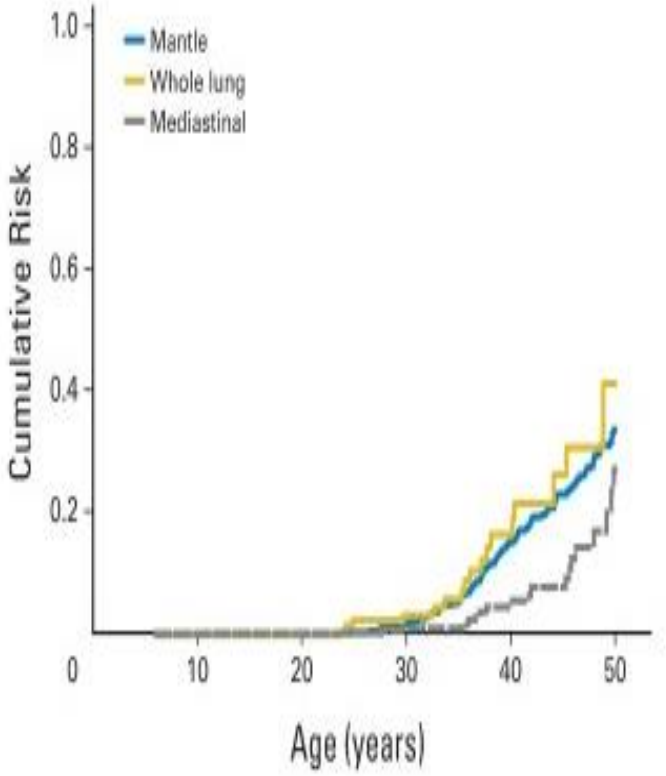
But: 0/7 pat. show sec. malig. at median follow-up of 6.4 years
when treated with IMRT and SRT

# Breast Cancer After Chest Radiation Therapy for Childhood Cancer

*Moskowitz CS, Wolden SL, Oeffinger KC for Childhood Cancer Survivor Study J Clin Oncol. 2014 Apr 21.*

Assessed cumulative breast cancer risk in 1,230 female childhood cancer survivors treated with chest irradiation. Whole lung irradiation versus Mantle field.

- **Lower** delivered doses of radiation (**median, 14 Gy**; range, 2 to 20 Gy) to a **large volume** (whole-lung field) had a high risk of breast cancer (standardized incidence ratio [SIR], 43.6), as did survivors treated with high doses of delivered radiation (median, 40 Gy) to the mantle field (SIR, 24.2).
- The **cumulative incidence of breast cancer by age 50 years was 30%** (95% CI, 25 to 34), with a 35% incidence among Hodgkin lymphoma survivors (95% CI, 29 to 40).
- Breast cancer mortality at 5 and 10 years: 12% and 19%, respectively.




**CONCLUSION:**
Among women treated for childhood cancer with chest radiation therapy, those treated with **whole-lung irradiation have a greater risk of breast cancer than previously recognized**, demonstrating the importance of radiation dose and volume. **Importantly, mortality associated with breast cancer after childhood cancer is substantial.**

# Background - Toxicity

**Long-term side effects after mediastinal RT/RChT:**

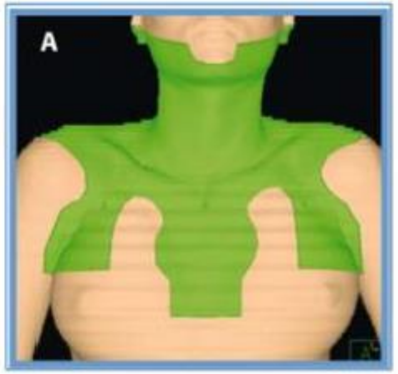
- Secondary malignancies (breast):
  - 734 patients with HL after 20-y: Mantle field RT (7.5%) is associated with increased risk of breast cancer compared to small volume RT (3.1%) or ChT alone (2.2%) [2]
  - 3905 HL patients after 40 y: cumulative incidence for secondary cancers 49% and breast cancer 17% [3]
  - 1230 childhood HL survivors with chest RT: cumulative incidence of breast cancer by age 50 y 35% [4]

[2] Conway et al., Secondary Breast Cancer Risk by Radiation Volume in Women with Hodgkin Lymphoma, IJROB, in press
[3] Schaapveld et al., Second Cancer Risk Up to 40 Years after Treatment for Hodgkin's Lymphoma. N Engl J Med. 2015 Dec 24;373(26):2499-511.
[4] Moskowitz et al., Breast cancer after chest radiation therapy for childhood cancer. J Clin Oncol. 2014 Jul 20;32(21):2217-23.

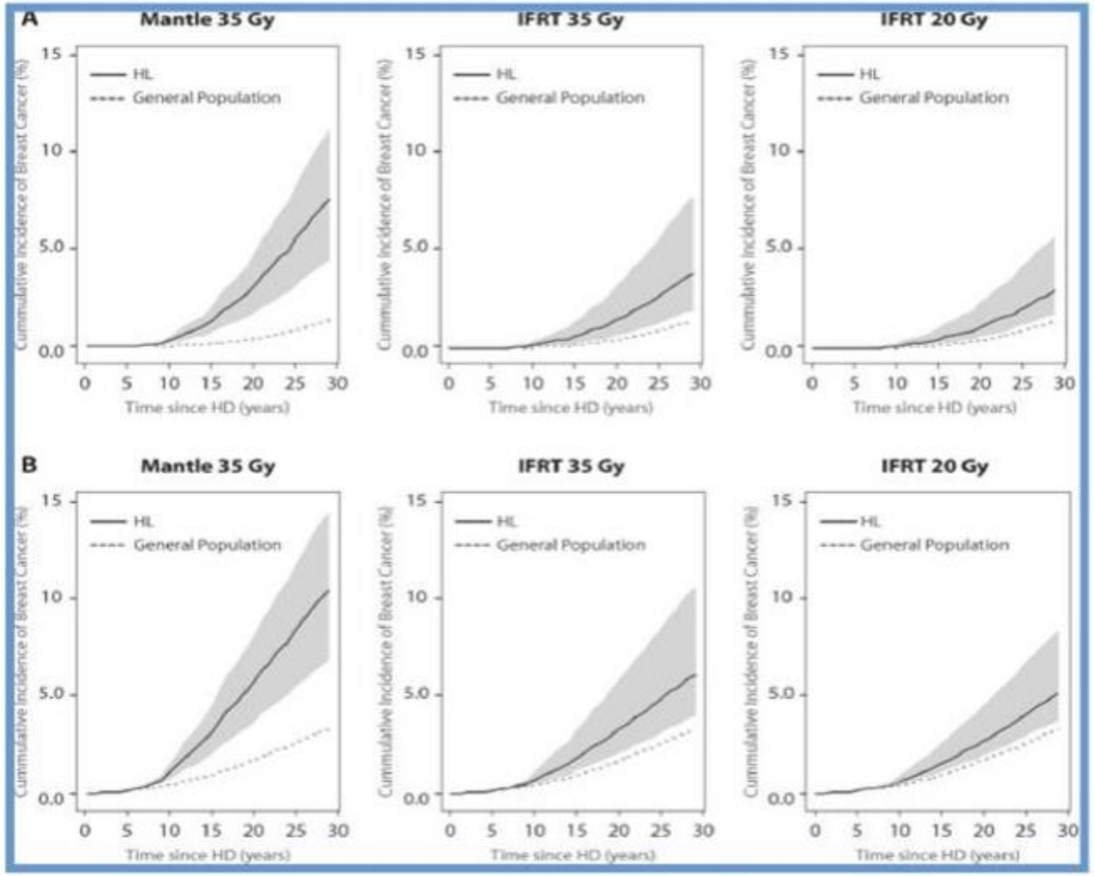
# HL: Individualized Estimates of 2NPL Risks after Contemporary RT

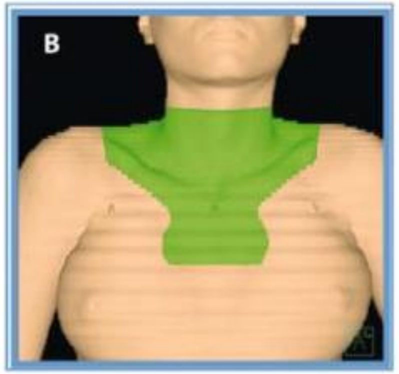
GHSG
www.ghsg.org

Breast Cancer Reduced 77%
Lung Cancer Reduced 57%w




Age 20




Age 30

Hodgson et al, Cancer 110: 2576, 2007

# Background - Toxicity

## Long-term side effects after mediastinal RT/RChT:

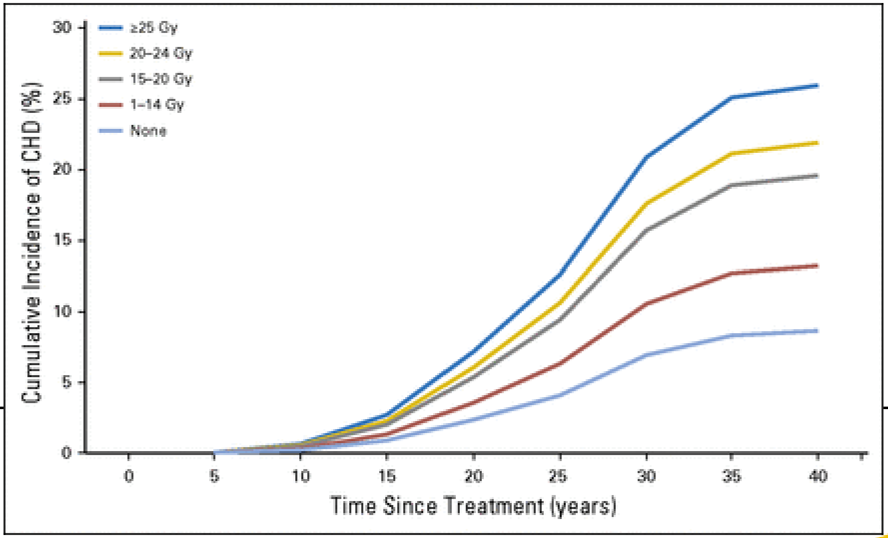
- Cardiovascular toxicity:

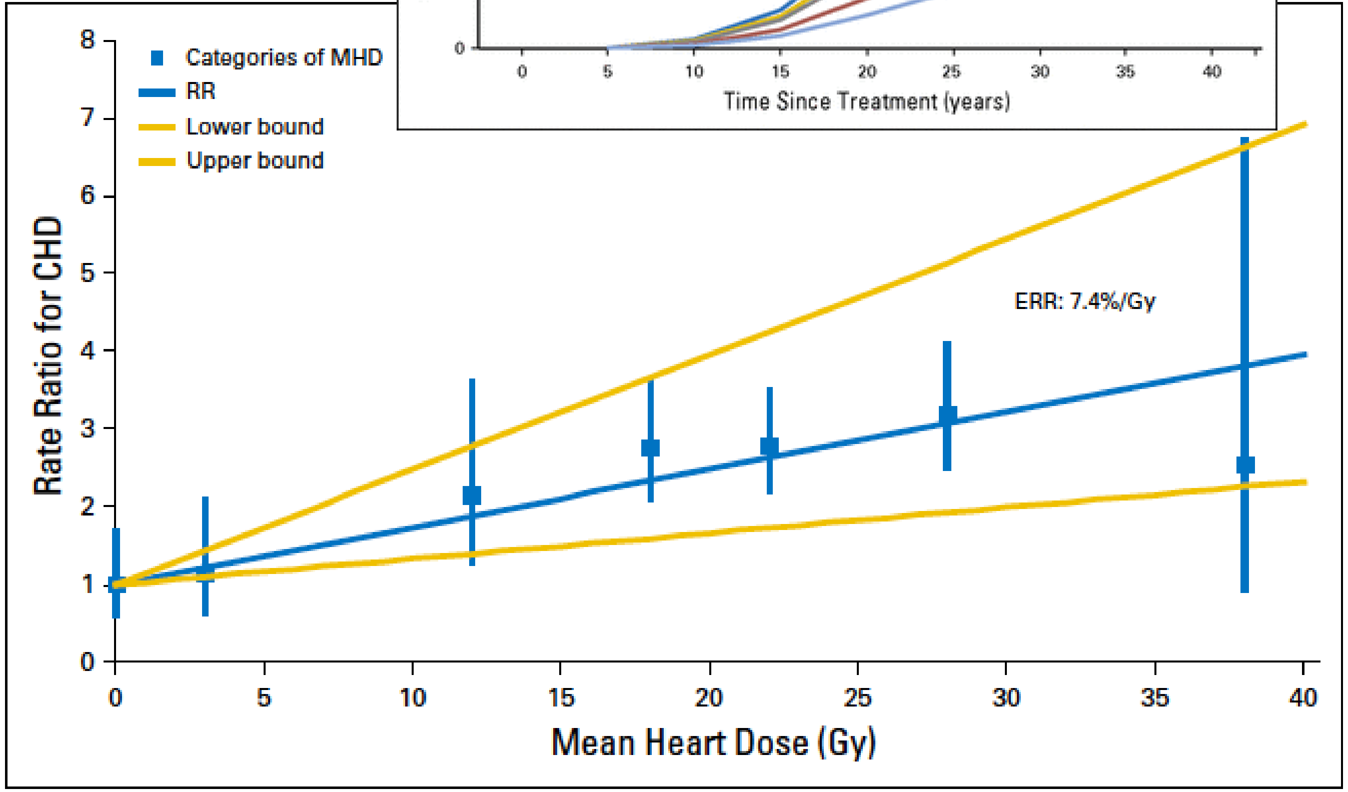
2617 patients: 2.5-fold increased risk of CHD for patients receiving a mean heart dose of 20 Gy, risk increased by 7.4% per Gy

Higher risk for younger patients: (<27.5 y.: 20% per Gy) [5]

Increase of cardiac mortality: 60% per Gy [6]

Additional effect of chemotherapy (anthracyclines) [6]



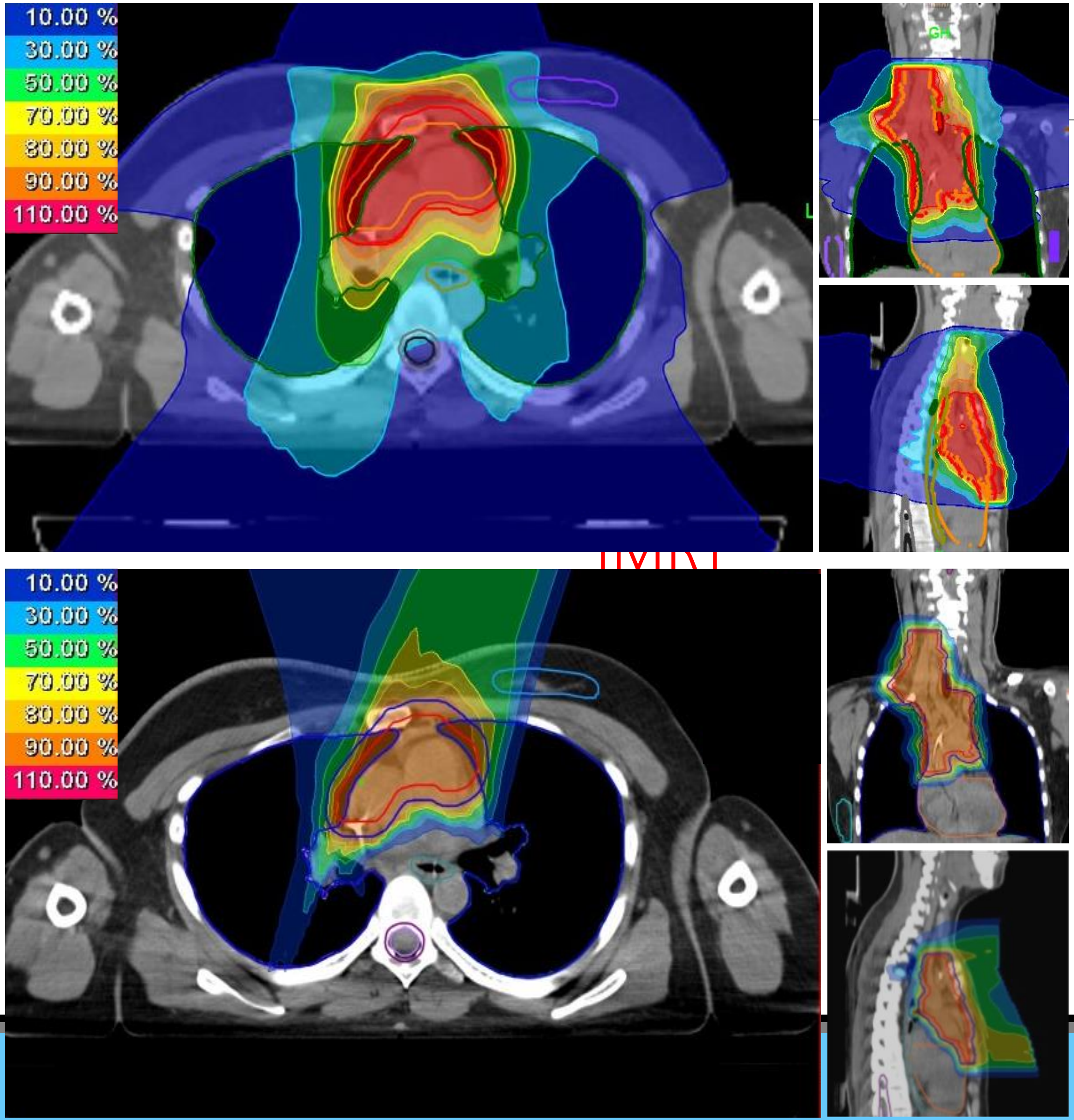





[5] van Nimwegen et al., Radiation Dose-Response Relationship for Risk of Coronary Heart Disease in Survivors of Hodgkin Lymphoma. J Clin Oncol. 2016 Jan 20;34(3):235-43.

[6] Lipshultz et al., Long-term cardiovascular toxicity in children, adolescents, and young adults who receive cancer therapy: pathophysiology, course, monitoring, management, prevention, and research directions: a scientific statement from the American Heart Association. Circulation. 2013 Oct 22;128(17):1927-95.

# dose reduction




**26 y, f, DLBCL**

St. IIA with bulky disease

RT: 36 Gy RBE in 18 Fx

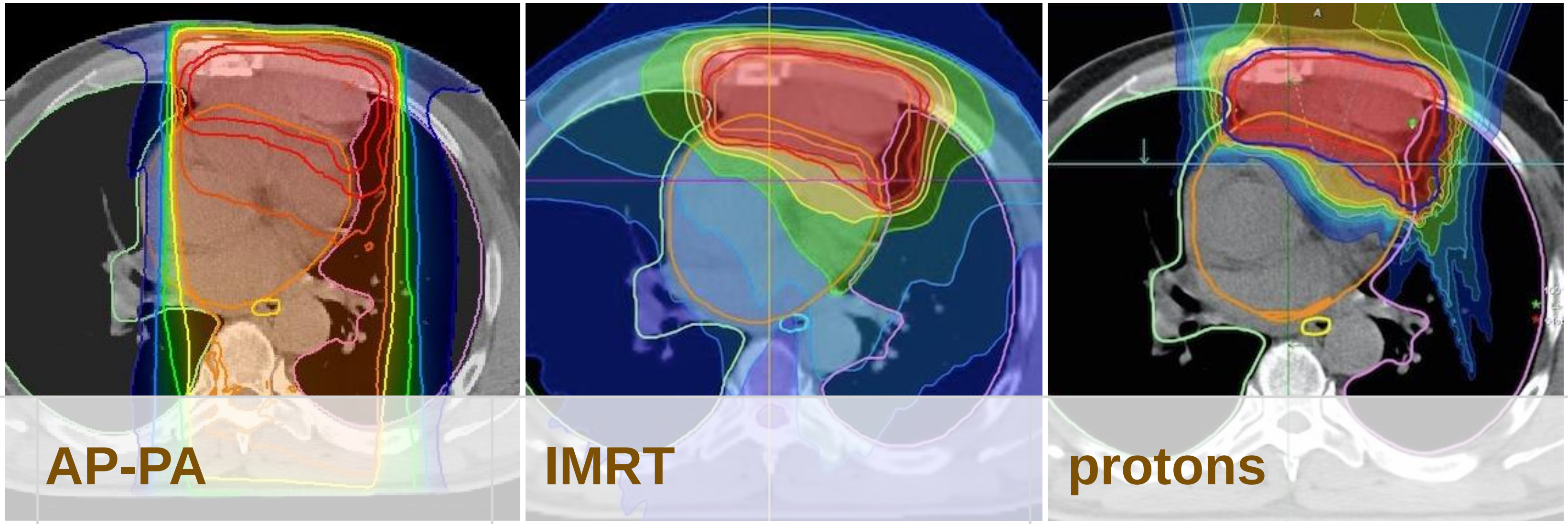
$D_{mean}$ heart:
7.2 Gy vs. 3.5 Gy RBE

$D_{mean}$ breast right:
1.4 Gy vs. 0.1 Gy RBE

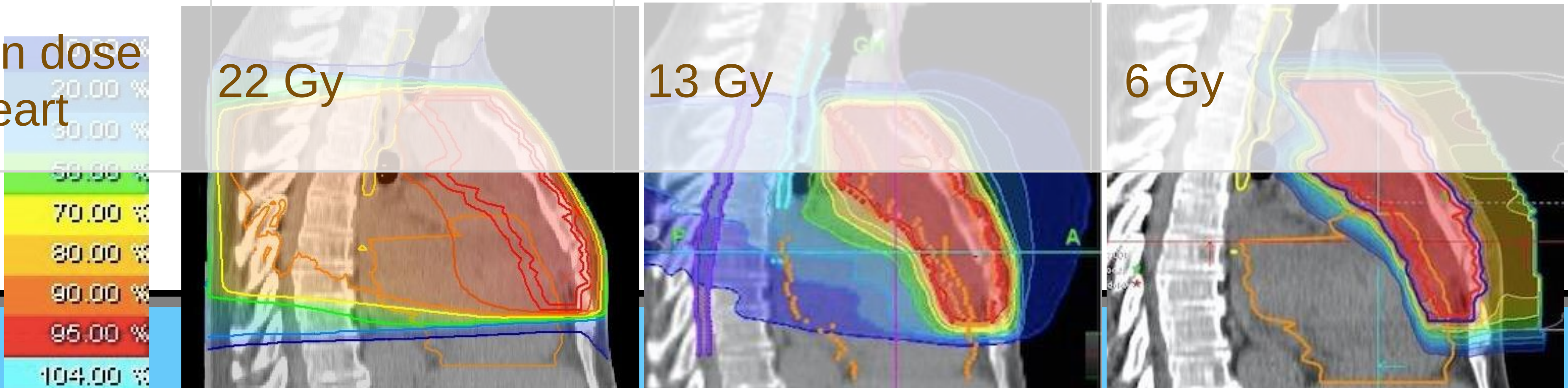
$D_{mean}$ breast left:
2.4 Gy vs. 1.7 Gy RBE

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

# DLBCL – consolidation RT 36 Gy



| Technik | AP-PA | IMRT | protons |
|---|---|---|---|
| Median dose to heart | 30 Gy | 9 Gy | 0 Gy |
| Mean dose to heart | 22 Gy | 13 Gy | 6 Gy |



# biological rationale for ion beam therapy

**biological properties of (heavy) ion beam therapy**

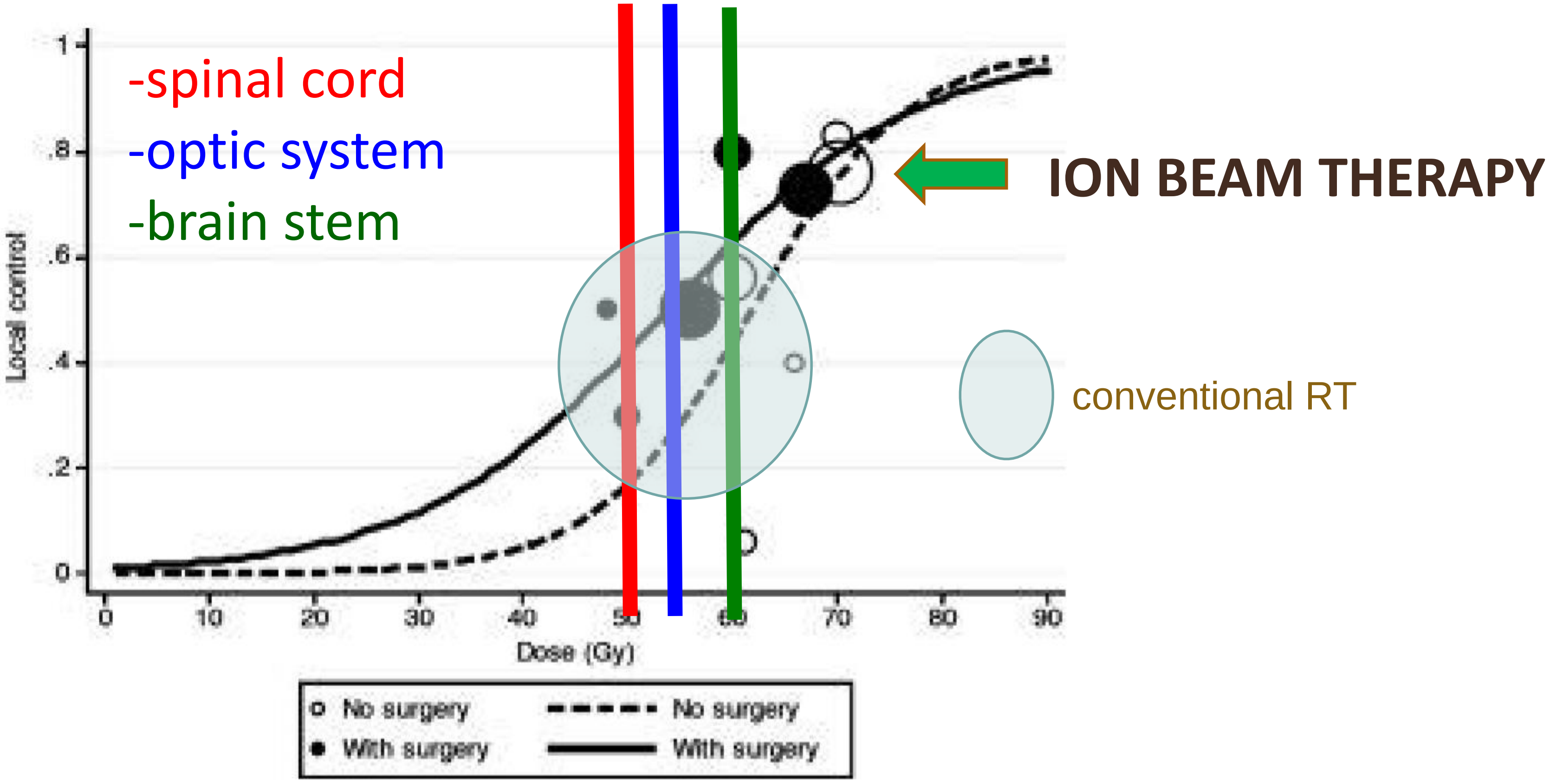
- Increased relative biological effectiveness (RBE)
- More efficient in killing hypoxic tumor cells
- Independent of cell cycle

**particularly relevant for**

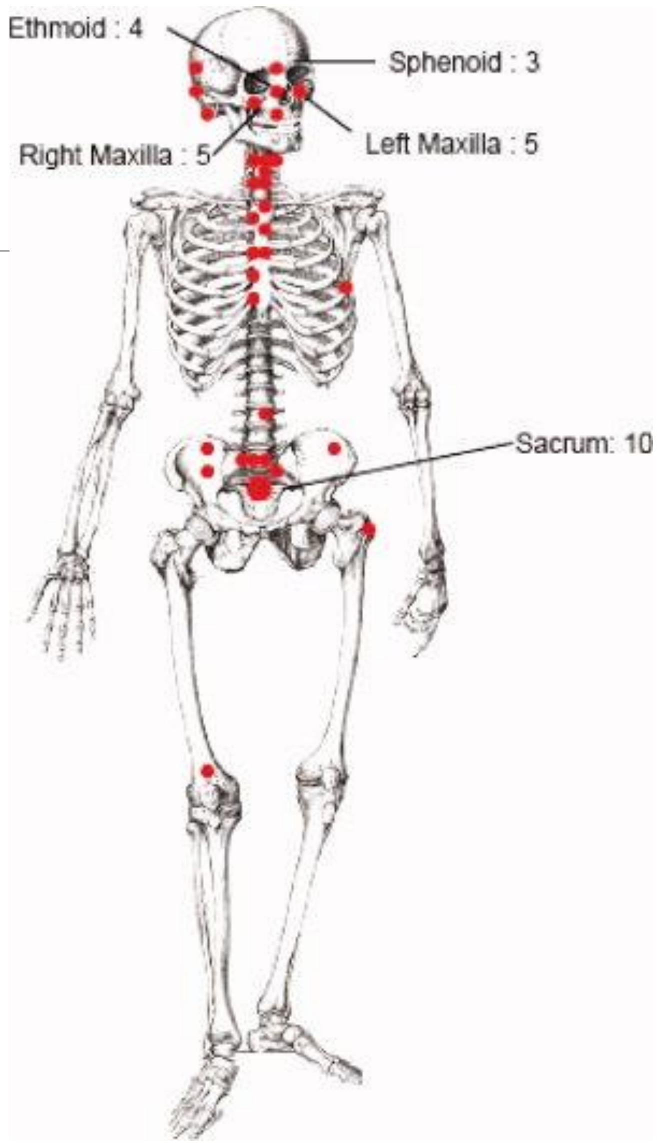
- Large inoperable diseases
- Radio-resistant tumors
- Previously with conventional radiation treated diseases

# osteosarcoma

## Dose dependency of local control rate



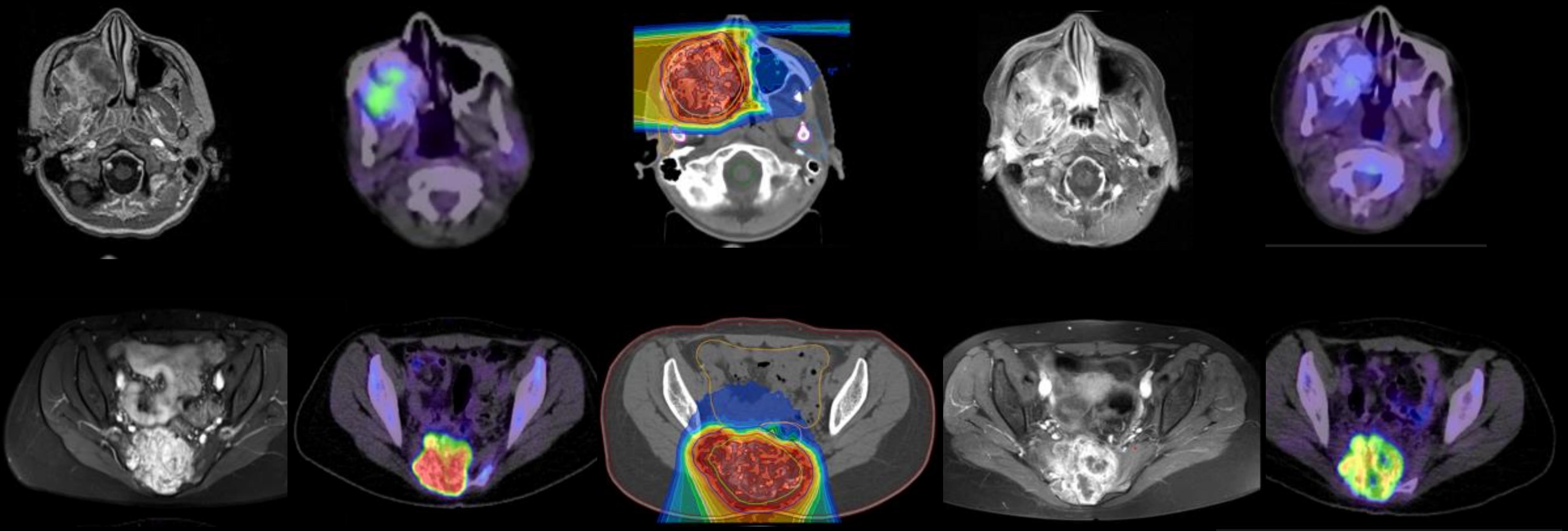

Ciernik IF et al., Cancer 2011




Ciernik IF et al., Cancer 2011

# typical examples

| MRT pre RT | PET pre RT | dose distribution | MRT post RT | PET post RT |
| --- | --- | --- | --- | --- |



Radiotherapy and Oncology 159 (2021) 8–16
Contents lists available at ScienceDirect
Radiotherapy and Oncology
journal homepage: www.thegreenjournal.com
ELSEVIER

Original Article

The role of combined ion-beam radiotherapy (CIBRT) with protons and carbon ions in a multimodal treatment strategy of inoperable osteosarcoma

Katharina Seidensaal[a,b,c], Matthias Mattke[a,b,c], Sabine Haufe[g], Hendrik Rathke[g], Uwe Haberkorn[g,k,l], Nina Bougatf[a,b,c,d,e], Andreas Kudak[a,b,d], Claudia Blattmann[h,i], Susanne Oertel[m], Marietta Kirchner[j], Christopher Buesch[j], Meinhard Kieser[j], Klaus Herfarth[a,b,c,d,e], Andreas Kulozik[i], Jürgen Debus[a,b,c,d,e,f], Matthias Uhl[a,b,c,d,e], Semi B. Harrabi[a,b,c,d,e,*]

# In the context…

| research group | modality | overall Survival | PFS | comment |
|---|---|---|---|---|
| OSCAR | P + C | 68 % (2 years) | 45 % (2 years) | |
| COSS-Kollektiv | Heterogen | 41 % (5 years) | 26 % (5 years) | |
| DeLaney 2002 | Ph / P | 66 % (5 years) | 40 % (5 years) | surgery, rarely pelvic |
| Ciernik 2011 | P | 67 % (5 years) | 65 % (5 years) | surgery, high tox. (>30 %grade III-IV) |
| Matsunobu, 2012 | C | 58 % (2 years) | n/a, 2y-LC 73 % | surgery, short FU, 10 % grade III-IV |
| Kamada, 2002 | C | 46 % (3 years) | n/a, 3y-LC 73 % | surgery |
| Mohamad, 2018 | C | 50 % (3 years) | 35 % (3 years) | Incl. pelcvic, 15 % grade III-IV |

# summary

- **Proton beam therapy is significantly superior in sparing OARs**
- **And therefore also in the reduction of long-term sequelae**

- **Suitable candidates for protons are**
  - young patients with long life expectancy
  - Female patients, particularly if elevated risk for breast cancer
  - Limited volumes in close proximity to the heart
  - Large treatment volumes such as CSI

UNIVERSITÄTS KLINIKUM HEIDELBERG

HIRO Heidelberger Institut für Radioonkologie

HIT Heidelberger Ionenstrahl-Therapiezentrum

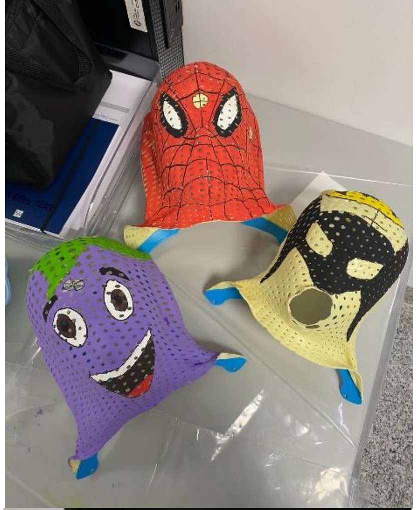
dkfz.

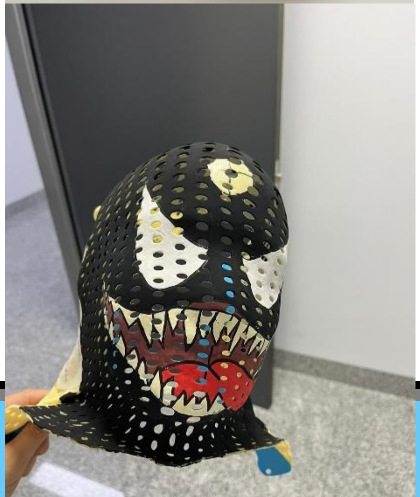
NCT NATIONALES CENTRUM FÜR TUMORERKRANKUNGEN HEIDELBERG

DIETMAR HOPP STIFTUNG

Deutsche Kinderkrebsstiftung

SIOPE RADIATION ONCOLOGY Working Group





# Thank you!

## parent‘s and children‘s radiotherapy video guide

**referenzzentrum-strahlentherapie @med.uni-heidelberg.de**





**Fon: +49 6221 56 35689**
**Fax: +49 6221 56 8968**

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