Challenges of low dose exposure in medical uses of ionising radiation

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Structure of the presentation

- Radiation protection in diagnostic radiology
  - Patient risks
  - Occupational risks
  - Challenges for research
- Radiation protection in radiotherapy
  - Role of radiation protection in planning treatments
  - Challenges for research
- Relevance to low-dose research
- Questions for MELODI

Medical use of radiation:

- The main source of man-made radiation exposures to humans is from the use of ionising radiation in medicine to diagnose and treat diseases.

- There are no legally binding dose limits in planned diagnostic or therapeutic radiation exposures of patients.

- *All medical use of radiation is moderated by our knowledge of the risks.*

Diagnostic radiology

- CT examinations contribute about 50% of the man-made radiation exposure of the general population
- In Germany, more than 30,000 CT examinations are performed per year in children under the age of 10.
- Do we really know the risks from this?
- We must use this population of radiation-exposed children for investigation into the long-term health consequences of low dose radiation exposure.
- First attempts in this direction are already being made by the ChildMedRad Euratom project

Pediatric CT: reference (organ) doses

body region	age	European Study 2000 (Shrimpton) mGy	German Study 2006 (Galanski) mGy	Swiss study 2008 (Verdun) measured values
brain	<1 y	40	33	19 – 41 mGy
	2 – 5 y	60	40	13 – 41 mGy
	6 – 10 y	70	50	13 – 50 mGy
	adult		60	
thorax	< 1 y	13	3.5	1 – 11 mGy
	2 – 5 y	20	5.5	1 – 20 mGy
	6 – 10 y	20	8.5	2 – 20 mGy
	adult		15	
abdomen	< 1 y	13	5	1 – 16 mGy
	2 – 5 y	17	8	1 – 16 mGy
	6 – 10 y	20	13	1 – 17 mGy

Occupational exposure in diagnostic radiology

- Interventional radiologists and cardiologists and who perform procedures such as catheterised angioplasty receive on average much higher occupational radiation doses than any other group of radiation workers.

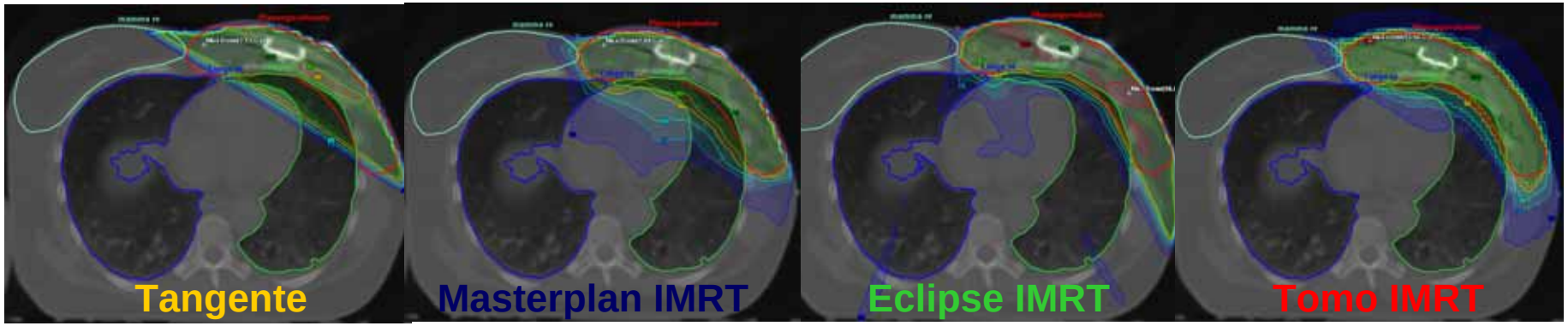
- Well designed cohort studies in these doctors would certainly be indicated.

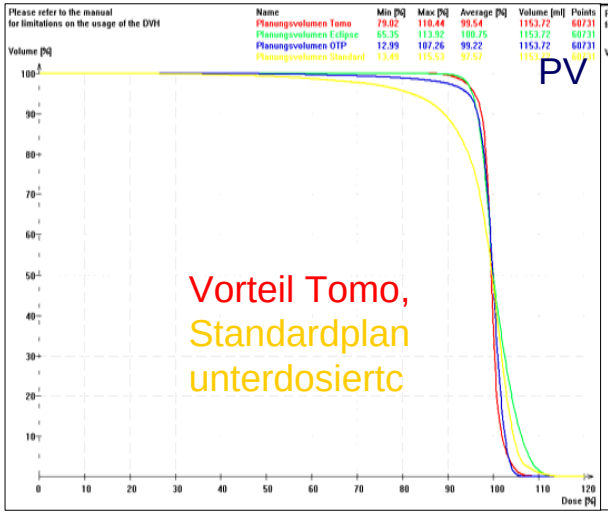
- It would be prudent to establish, with the help of national societies of cardiology and interventional radiology a registry of doctors working in this field which should contain information on the number of procedures and the radiation exposure of each member.

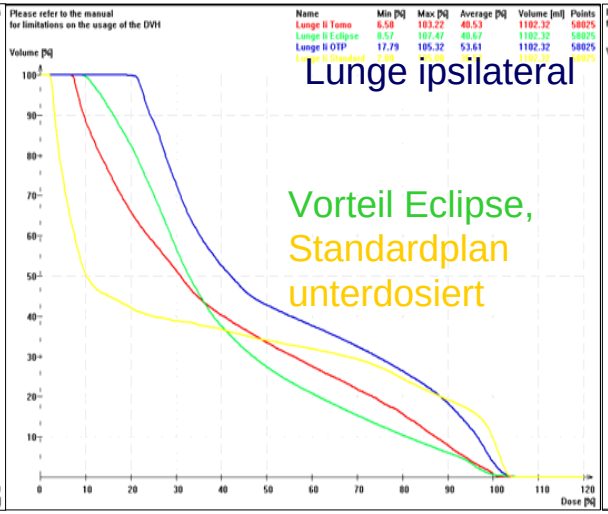
Radiotherapy

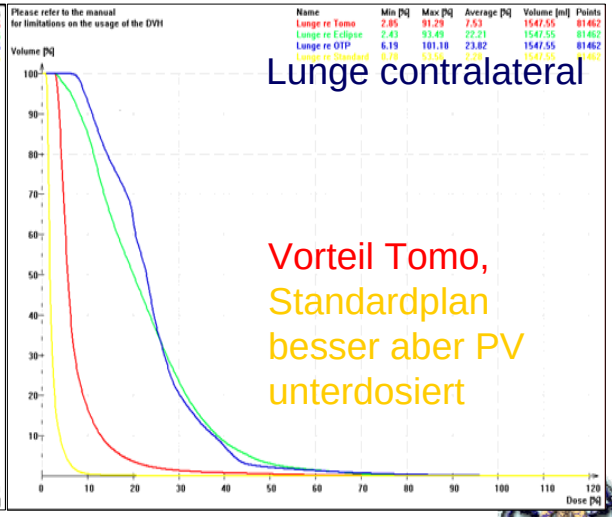
- For each new patient, the radiation oncologist is faced with the problem of balancing the different risks associated with the particular treatment prescriptions:
  - The risk of treatment failure, i.e. tumour recurrence.
  - The risk of signs and symptoms of late normal tissue damage.
  - The risk of very late but very serious late normal tissue effects such as cardiovascular radiation damage, radiation-induced cerebro-vascular incidents, and radiation-induced second cancers.
  - In children, local growth retardation (particularly of the vertebral column).
- *If this is not radiation protection, what is?*

Planungsvergleich



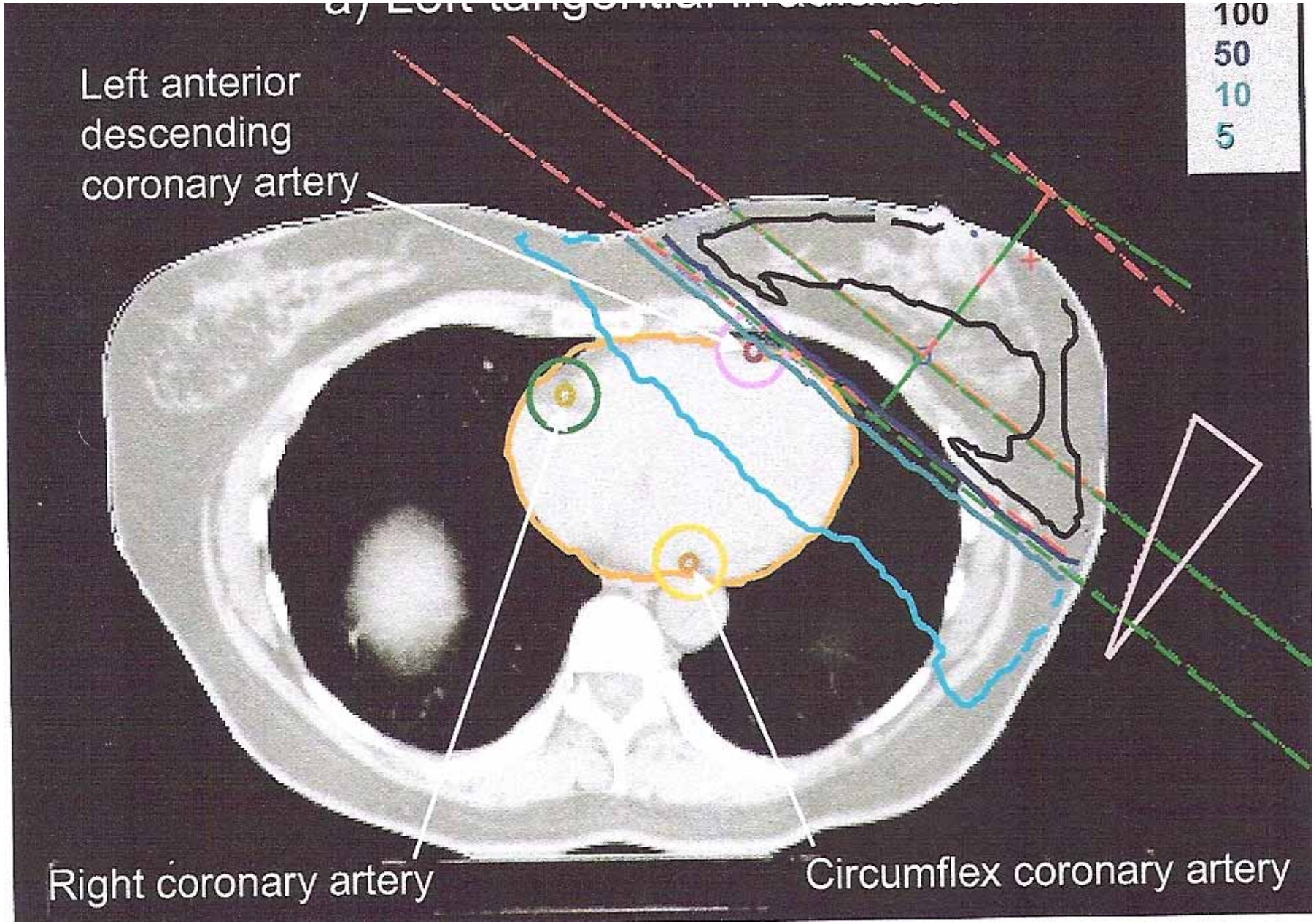






Dose volume histogram analysis
of three different treatment techniques
Johansen et al, 2009

	conventional	IMRT	Rapid Arc
heart			
mean dose (Gy)	2.6 +/- 1.6	5.5 +/- 1.3	4.6 +/- 2.4
V –4Gy (%)	9	64	41
D 2% (Gy)	18	12	11
ipsi-lateral lung			
mean dose (Gy)	18 +/- 1	13.6 +/- 1.8	14.3 +/- 0.9
V-10Gy (%)	52	53	47
V-20Gy (%)	42	18	24
contra-lateral lung			
mean dose (Gy)	1.4 +/- 0.3	2.9 +/- 0.4	2.9 +/- 0.4
V-10Gy (%)	1.2	1.3	0.2
V-20Gy (%)	0.1	0	0
contra-lateral breast			
mean dose (Gy)	2.2 +/- 1	2.9 +/- 0.8	2.0 +/- 0.4
V-10Gy (%)	7.1	0.7	0


100
50
10
5
Left anterior
descending
coronary artery
Right coronary artery
Circumflex coronary artery

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Relevance to low-dose research

- Some of the main sources of information about the biological basis of radiation protection and in particular on cancer induction by low radiation doses are derived from the analysis of the outcome of radiotherapy for benign and for malignant diseases.
- There are more than one million people living in Europe more than 10 years after cancer treatment including radiotherapy.
- This is producing a growing resource of clinical data on a cohort that is receiving a wide range of radiation doses, including dose from neutrons.

The ALLEGRO project - EURATOM FP7

- “Early and late risks to normal/healthy tissues from the use of existing and emerging techniques in radiation therapy”
- Investigating future research needs for radiotherapy normal tissue risks
- Likely recommendations:
  - *in-vitro-, animal-, clinical studies*
  - *Use of mechanistic as well as clinical data to improve risk prediction models*
  - *International cooperation on clinical data collection, long-term follow-up, and accessibility.*

Relevance cont.

The advantages of medical patients over other exposed populations:

- The data are accumulating in a predictable way allowing prospective studies to be planned
- Tissue exposures cover a wide range of doses, giving greater power to the analysis of dose-response mechanisms
- Dose reconstruction can (in principle) be done accurately
- Tissue samples can be taken for use in molecular epidemiology and mechanistic radiobiological research
- The results will have direct application on the most at-risk exposed population.

Relevance cont.

Do radiotherapy patients represent the “normal” population exposed to low-dose radiation?

- Who is normal?
  - Japanese A-bomb survivors? Mayak workers?
- Patients already have had cancer
  - One third of the population will get cancer
- They have received up to 70Gy
  - Only a small volume received high dose: most of the body receives a low dose
  - There is no clinical evidence for long term immune suppression
- They may also have chemotherapy etc.
  - Confounding factors are all documented

Challenges for research

- Studies must be based on the determination of doses in the particular organ which develops cancer

- The development of new, and relevant methods of specification of organ doses in medical radiation exposure should be given top priority.

- Without this, epidemiological studies, molecular epidemiology studies, predictive assays for individual radiosensitivity and the recommendations for dose constraints in diagnostic and therapeutic radiology are very uncertain.

Challenges for second cancer research

- ALLEGRO has identified shortcomings in radiotherapy databases that must be addressed:
  - Lack of morphometric data for dose reconstruction at site of second disease
  - Difficulty in determining precise pathological and location information about second disease (possibly from a different database)
  - Patient privacy laws restricting access to essential data
  - Lack of patient follow-up past 5 years

Questions for MELODI

- What are the critical areas needed to strengthen research into risks from diagnostic radiology?
  - Patient databases that link exposure history to later disease?
  - Better dosimetry?
  - Radiobiological mechanisms?

Questions cont.

- We propose that normal tissue response to radiation in radiotherapy patients can contribute to the understanding of the mechanisms of response to low-dose radiation exposure
  - What are the critical research areas?
  - Database development?
  - In vitro, in vivo, animal studies?
- Since MELODI supports research into radiation protection of the patient in diagnostic radiology, we propose that radiotherapy should be included as well
  - Should the research focus on benefit to the patients?
  - Should MELODI extend its range to include normal tissue complications?