German Quality Assurance for Congenital Heart Diseases

Cumulative Radiation Exposure in Congenital Heart Disease: Are We Accounting for Lifetime Risk?

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Padua 2026

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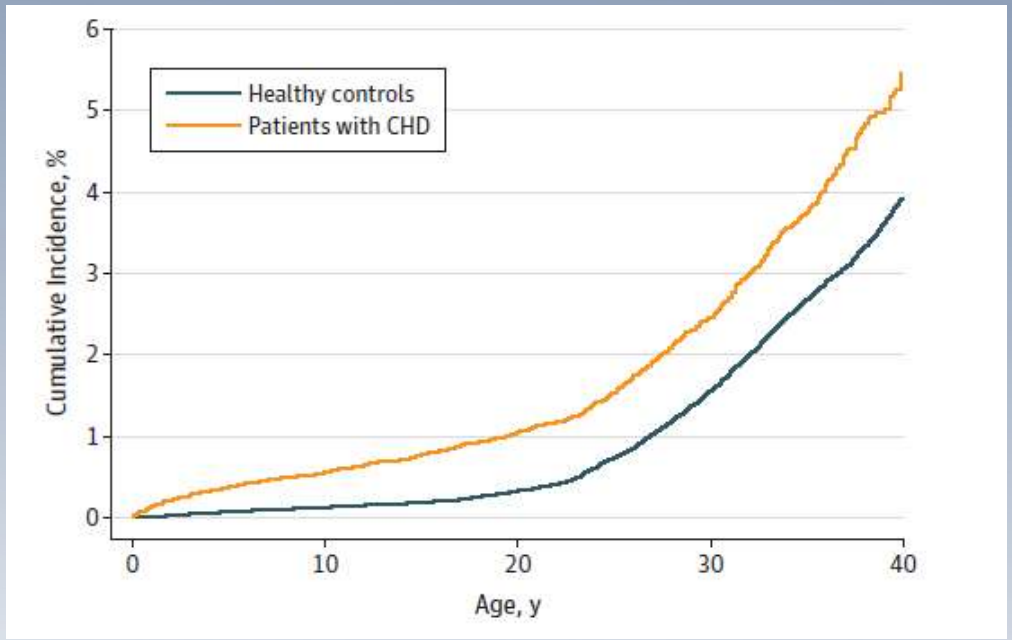
Possible conflicts of interest

Nothing to declare

Except for the fact
that I have been working most of my lifetime as an interventional cardiologist

Increased Risk of cancer in patients with CHD



Patients with CHD are known to be at an increased risk of cancer

Possible contributing factors:

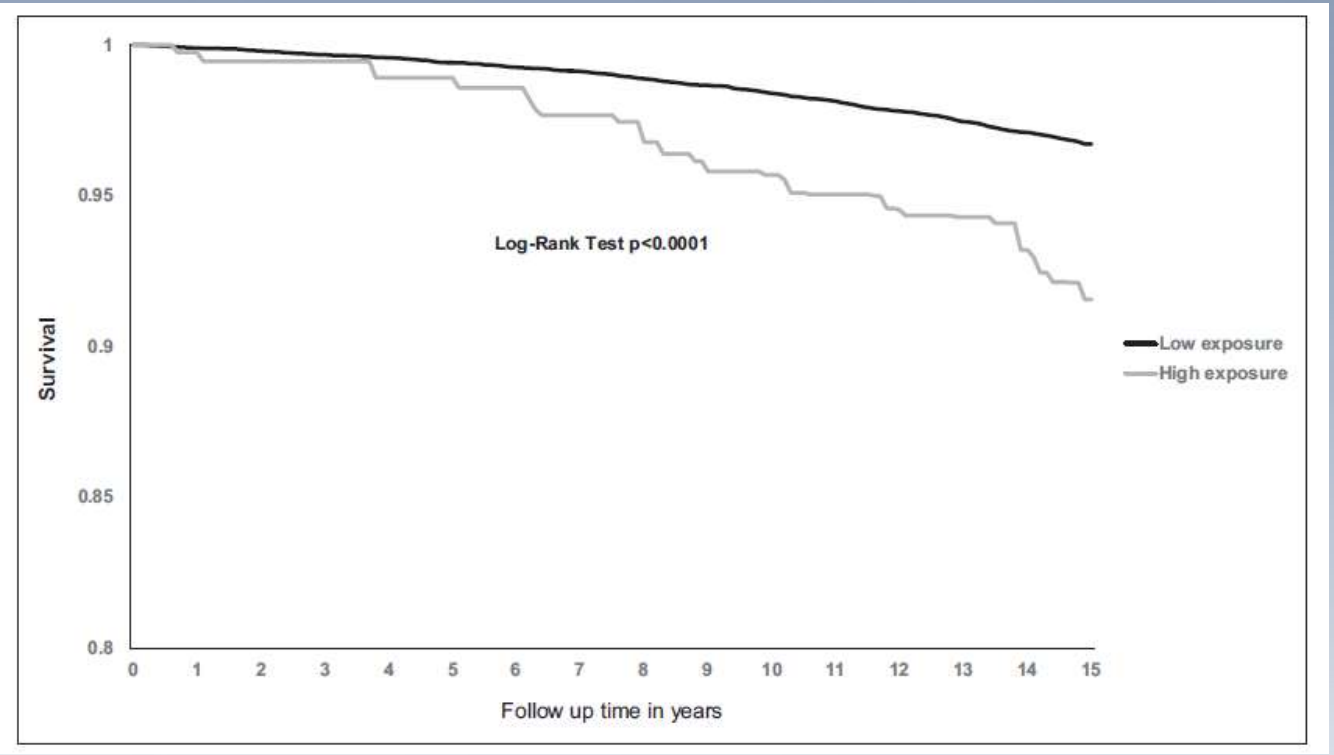
Common genetic and environmental risks
Altered blood flow
Hypoxia
Radiation exposure

Nationwide registry-based cohort study - 21982 children in Sweden from 1970 – 1993, follow-up until 2011

Hazard ratio for cancer in CHD: 2.24

Mandelanakis Z et al. JAMA Network Open 2019

Radiation burden and cancer



A number of studies showed an increased risk of cancer in patients following low-dose ionizing radiation from cardiac procedures

Quebec CHD database: Significantly lower cancer free survival in high exposure patients vs low exposure patients among 24833 adult CHD patients

Cohen et al., Circulation 2018

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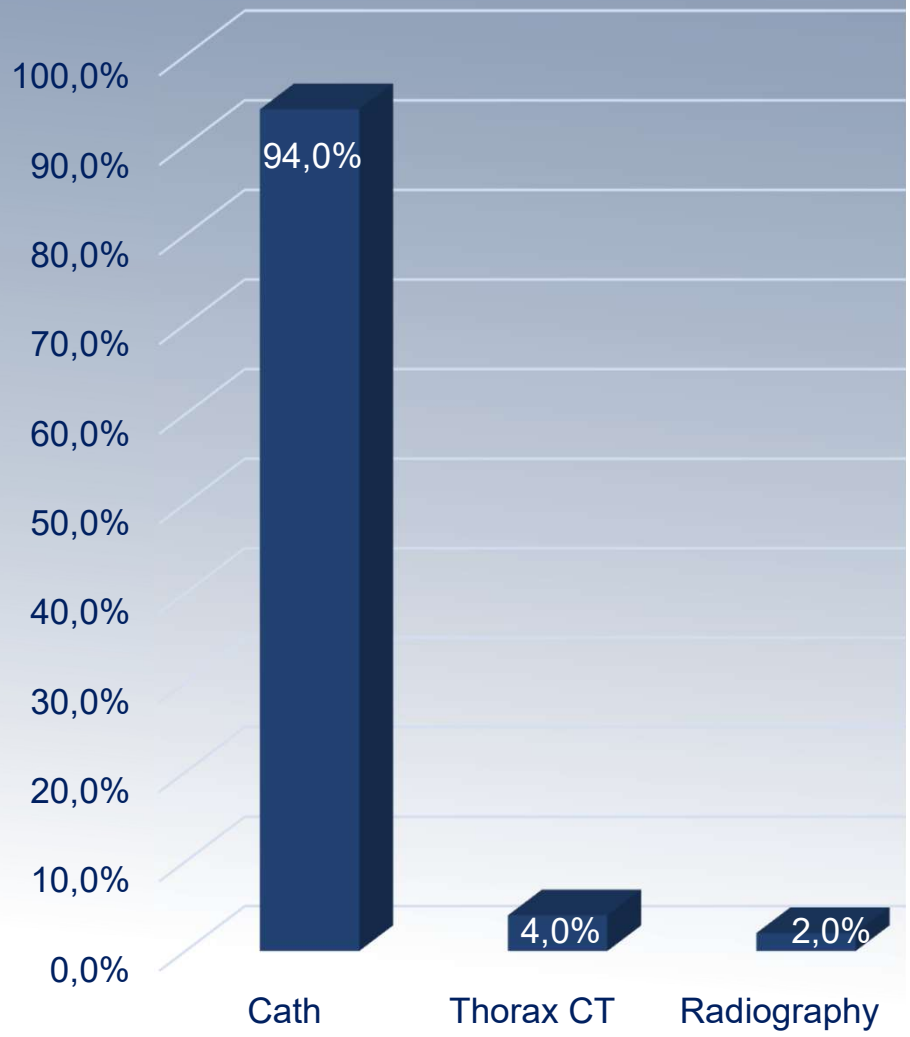
Cardiac cath and contribuation to radiation burden

Cardiac Cath is the procedure which contributes most to the radiation exposure in patients with CHD

1574 pts. with CHD from Norway
Born 2000 – 2020 < 18 years
with at least one cardiac cath
Comparison of ED from Cath, CT, Radiographies

Cumulative radiation dose in children with congenital heart disease: national data 2000–2021, stratified by diagnosis, age, and imaging modality

Afroz et al. Acta Radiologica 2025



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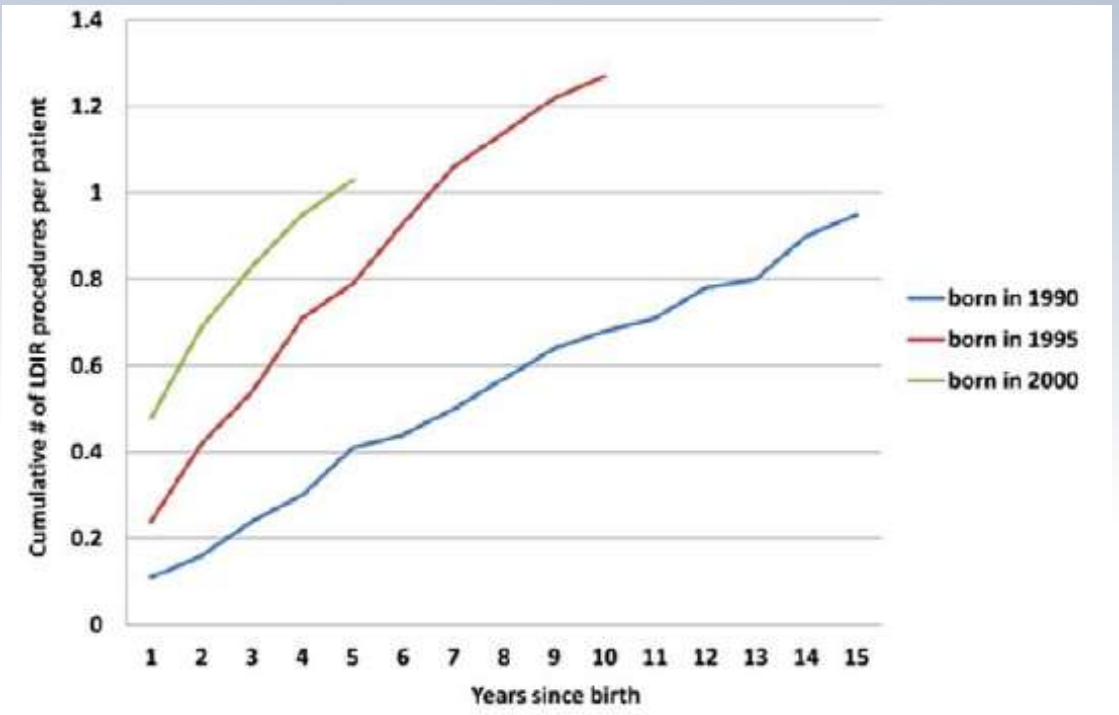
Cardiac Cath and severe CHD

The majority of patients with CHD does not require significant exposure to radiation from medical diagnostic or interventional procedures
74,5% of 71.467 patients Quebec CHD database1983 – 2005
(no cardiac cath, thoracic CT-scan, nuclear studies, pacemaker/defibrillator insertion or removal)



Virginie Beauséjour Ladouceur et al.:
Exposure to Low-Dose Ionizing Radiation From Cardiac Procedures in Patients With Congenital Heart Disease.
Circulation 2016
Quebec CHD database

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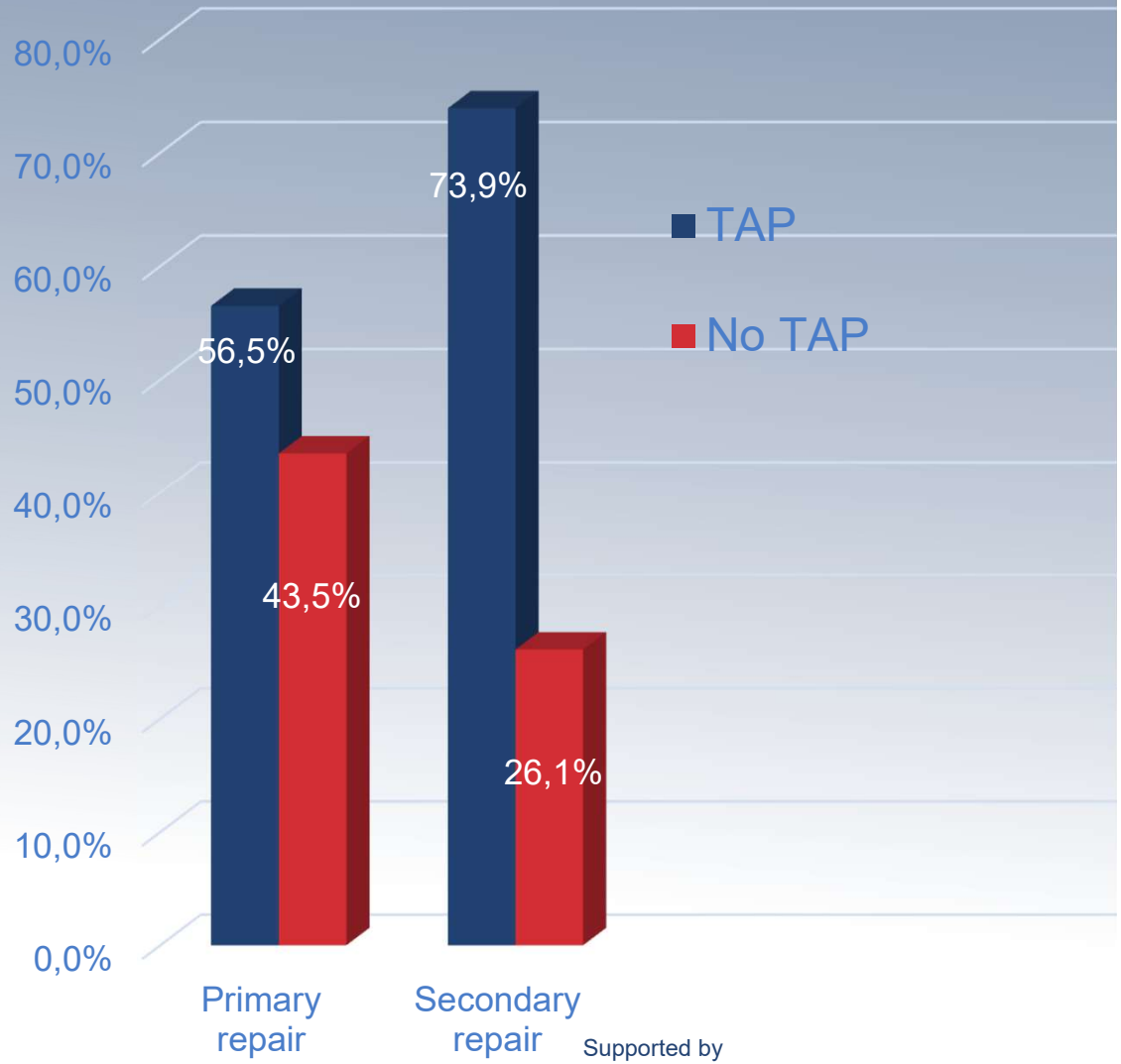
Radiation burden in selected groups of patients

Conotruncal malformations involving absence/stenosis of the pulmonary valve
Tetralogy of Fallot, TAC, DORV
PA-VSD and MAPCAs

Functionally univentricular hearts
Norwood HLHS

Data German Registry 2012 – 2023
2043 pts with repair of ToF



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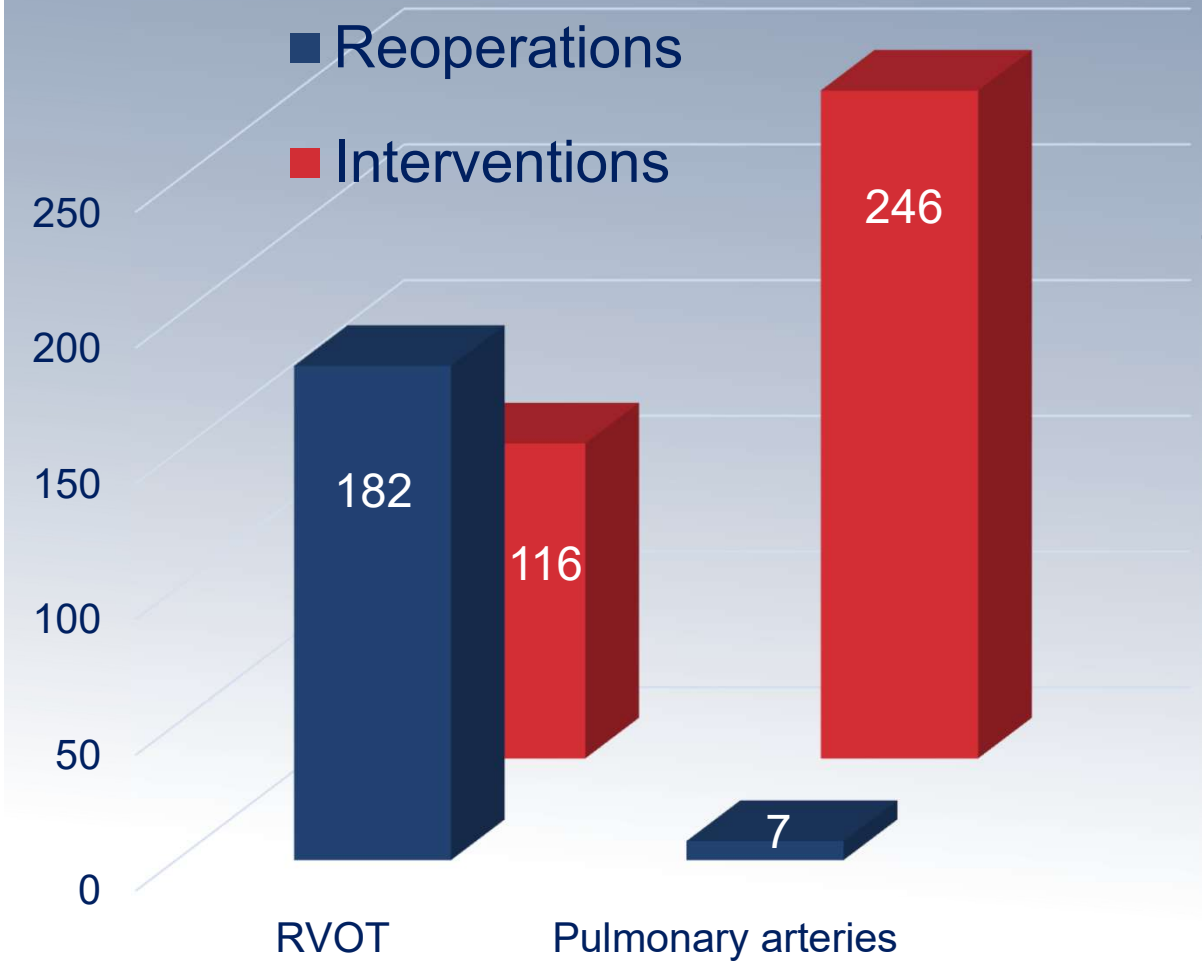
Requirement of repeat interventions



Interventional cardiac catheterisations have contributed to a large extent to the survival and life quality

PPVI will replace many surgical procedures

Since patients are dependent on these procedures the focus should be placed on reduction of the associated radiation burden

Data GR 2012 – 2023
2023 pts with repair of ToF

Measurements of Radiation burden

Effective dose (mSiev)
ED represents the sum of organ equivalent doses reflecting the sum of radiation burden for these organs. Calculation of the ED is based on complex calculations including so-called Monte-Carlo simulations

Total fluoroscopy time (TFT): Not very useful for radiation burden

Total Air Kerma (mGy): Reflects the radiation dose at the skin entrance. Predictor of threshold dependent risk of skin damage

Dose-Area product (DAP) - Air Kerma product
Represents total radiation exposure of the patient, routinely recorded by modern equipments summarizing fluoroscopy and all angiographies. DAP can be given in **different units** most frequently as cGy*cm^2 or µGy*m^2 or Gy*cm^2

Dose-Area product (DAP)/body weight (cGy*cm^2/kg)
Allows adjustment for patient age and size allows comparison of different cohorts and different age groups

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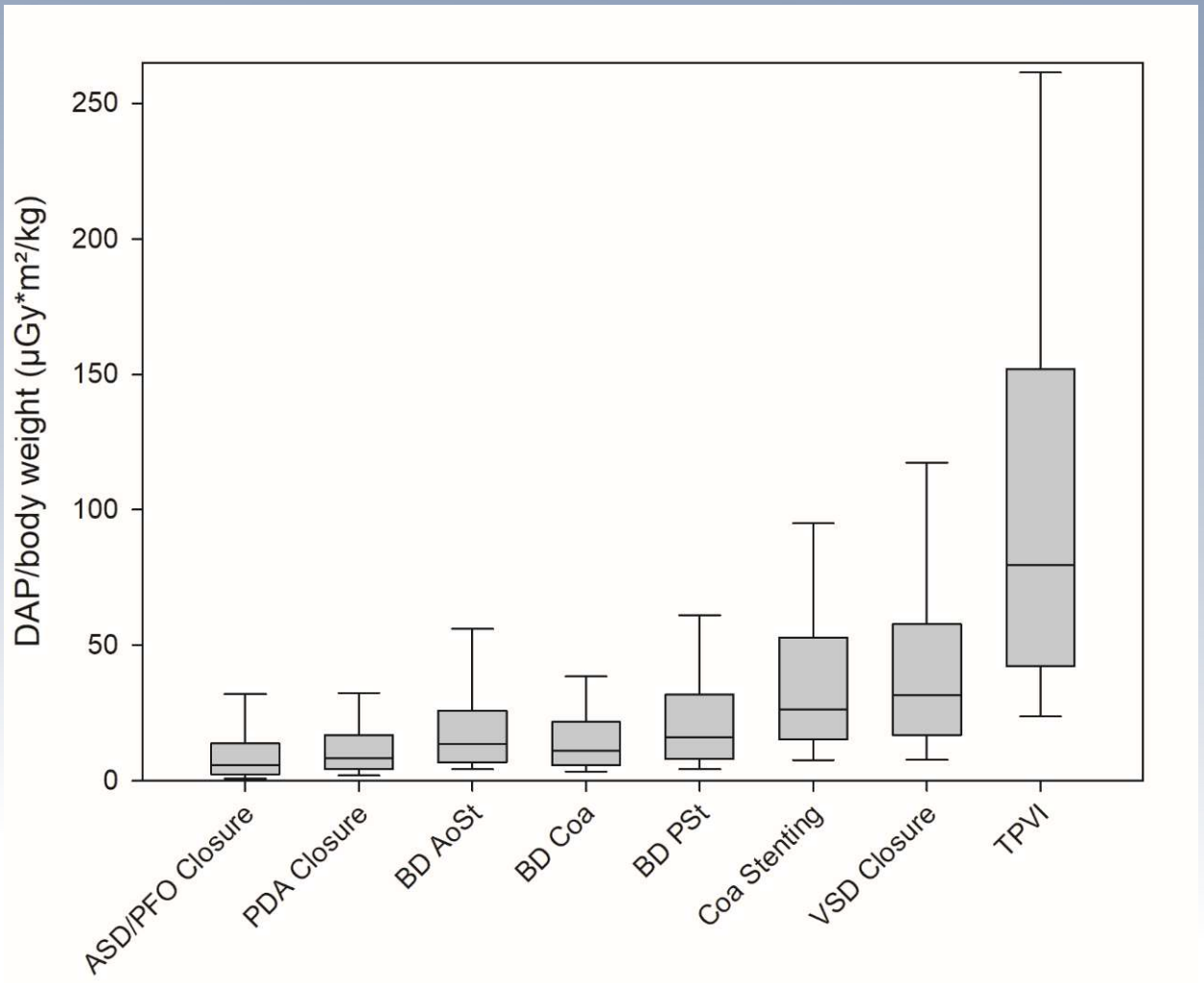
Radiation burden – Interventional cardiac cath



German Registry
Data of 8 frequent specific catheter interventions
9.350 procedures
2012 - 2020

Tengler et al. Thorac Cardiovasc Surgeon 2025

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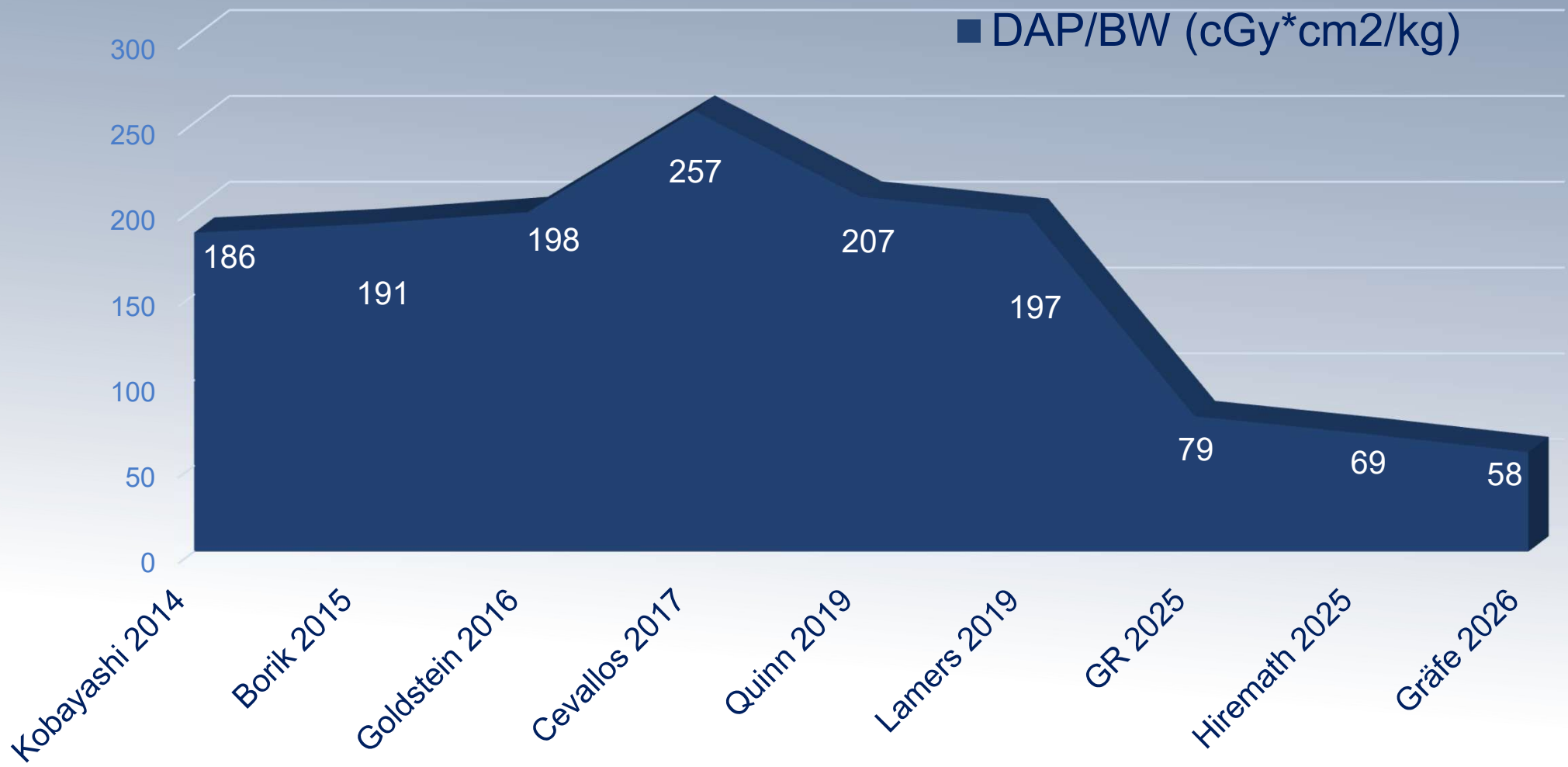
Radiation burden benchmarks: PPVI



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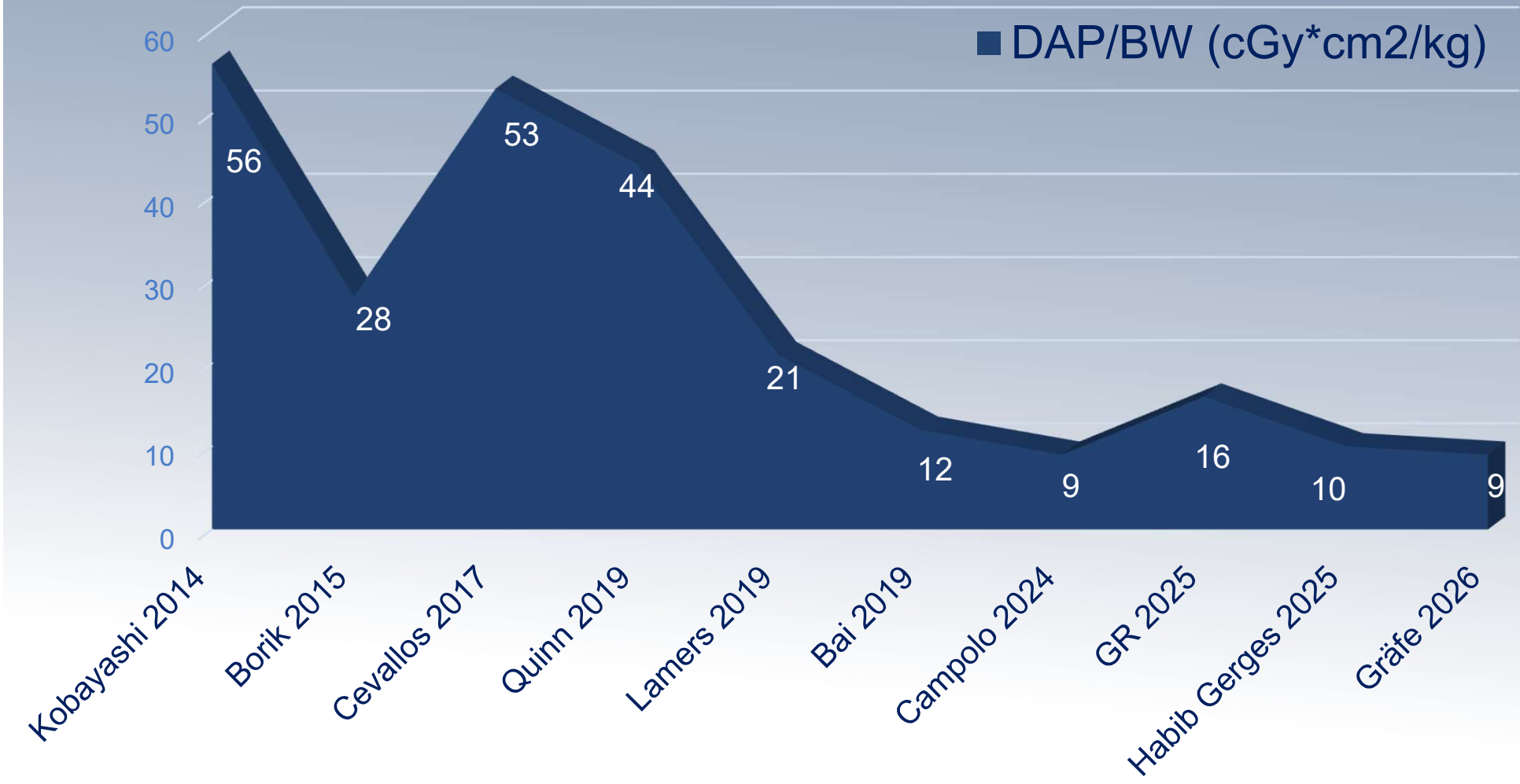
Radiation burden benchmarks – Pulmonary valvuloplasty



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Structured programs for improvement of radiation protection

Authors	Country	Patients	Reduction in DAP or DAP/kg	Year of publication
Schubert et al.	Germany	ASD closure	n.a.	2012
Borik et al.	Canada	Diagnostic and interventional	n.a.	2015
Haas et al.	Germany	Diagnostic and interventional	n.a.	2015
Sitefane et al.	France	ASD closure	51%	2017
Cevallos et al.	USA	Interventional	n.a.	2017
Amdani et al.	USA	Diagnostic and interventional	48%	2018
Boudjemline	France	PPVI	67%	2018
Bai et al	China	Interventional	n.a.	2019
Quinn et al.	USA	Diagnostic and interventional	30%	2020
Harrison et al.	USA	ASD closure	54%	2021
Zablah et al.	USA	PPVI	25%	2021
Campolo et al.	Italy	Diagnostic and interventional	78%	2024
Gräfe et al.	Germany	Diagnostic and interventional	n.a.	2026

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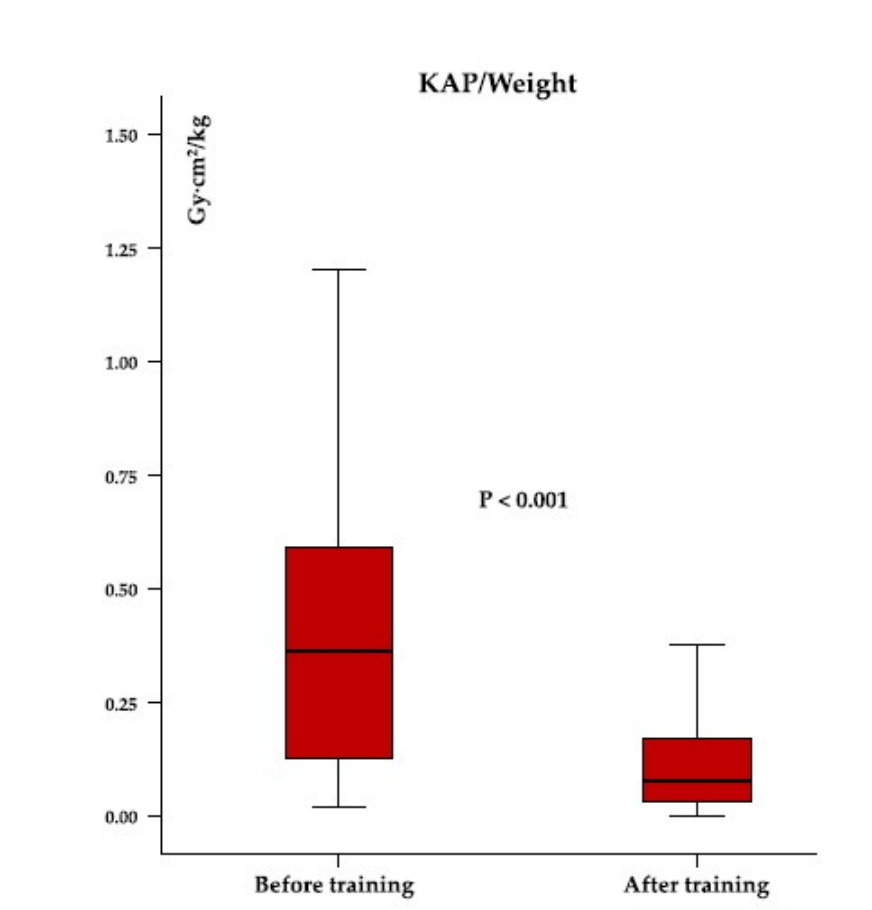
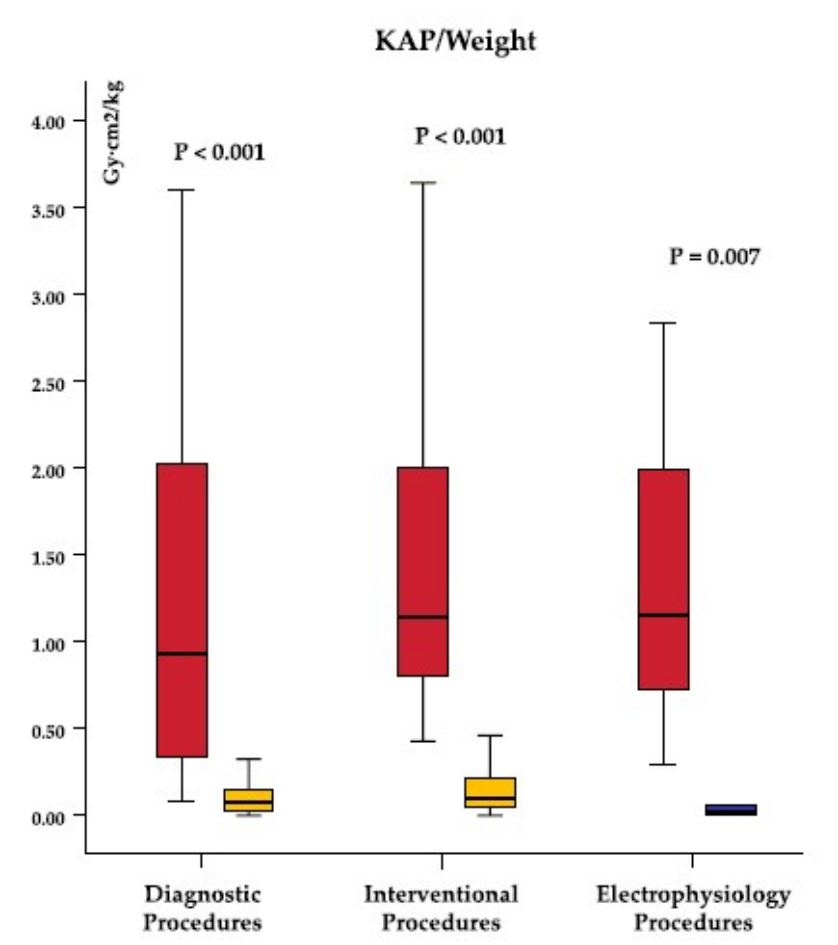
Improvements by structured programs and equimpment





Campolo J. et al.; Italian J Pediatrics 2024: The burden of radiation exposure in CHD: Effects of equipment and dose reduction program on radiation exposure

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Requirements for the Future

- Patients with complex CHD will require Cardiac Catheterizations in the future
- The key for futher improvement of radiation protection will be the continued structured collection of data from large registries
- Creation of scientific data on large cohorts (European Harmonics project)
- Improvements of hardware and software of cath lab equiment
- Improvement of interventional techniques and devices
- Establishment of a culture of radiation protection in all Cath Labs involved in the treatment of patients with CHD

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Reduction of radiation burden

- Extended use of diagnostic imaging modalities without radiation
- Avoidance of routine use of magnification, biplane imaging and steep angulation unless clinically indicated
- Reduction of fluoroscopic rate to 6 – 7.5 frames/sec
- Reduction of cineangiographic frame rate to 7.5 – 15 frames/sec
- Avoidance of anti-scatter grid in children < 15 kgs
- Weight adjusted acquisition presets according to patients weight
- Use of low dose protocol for 3D angiography
- Regular review of procedures with elevated doses

Borik et al CCI 2015
Sitefane et al. Arch Cardiovasc Dis 2018
Gräfe et al. Clinical Research Cardiol 2026

Conclusions

- There is a growing number of patients with complex CHD requiring repeat Cardiac Cath procedures during their lifetime
- Registries collecting data on cardiac cath will be of vital importance for further improvement of radiation protection
- Data from large registries have created valuable benchmark data on the most frequent standardized interventional procedures
- During the last decade the radiation burden during cardiac cath procedures decreased significantly
- To reduce radiation burden in our patients it is mandatory that centers involved in the treatment of CHD actively participate in local radiation protection measures
- If we are succesful to do so, I am optimistic that we are able to control the lifetime risk associated with radiation in our patients

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