

# Pediatric High-Pitch Spiral CT:

Flash Spiral CT Imaging  
without breath hold and sedation

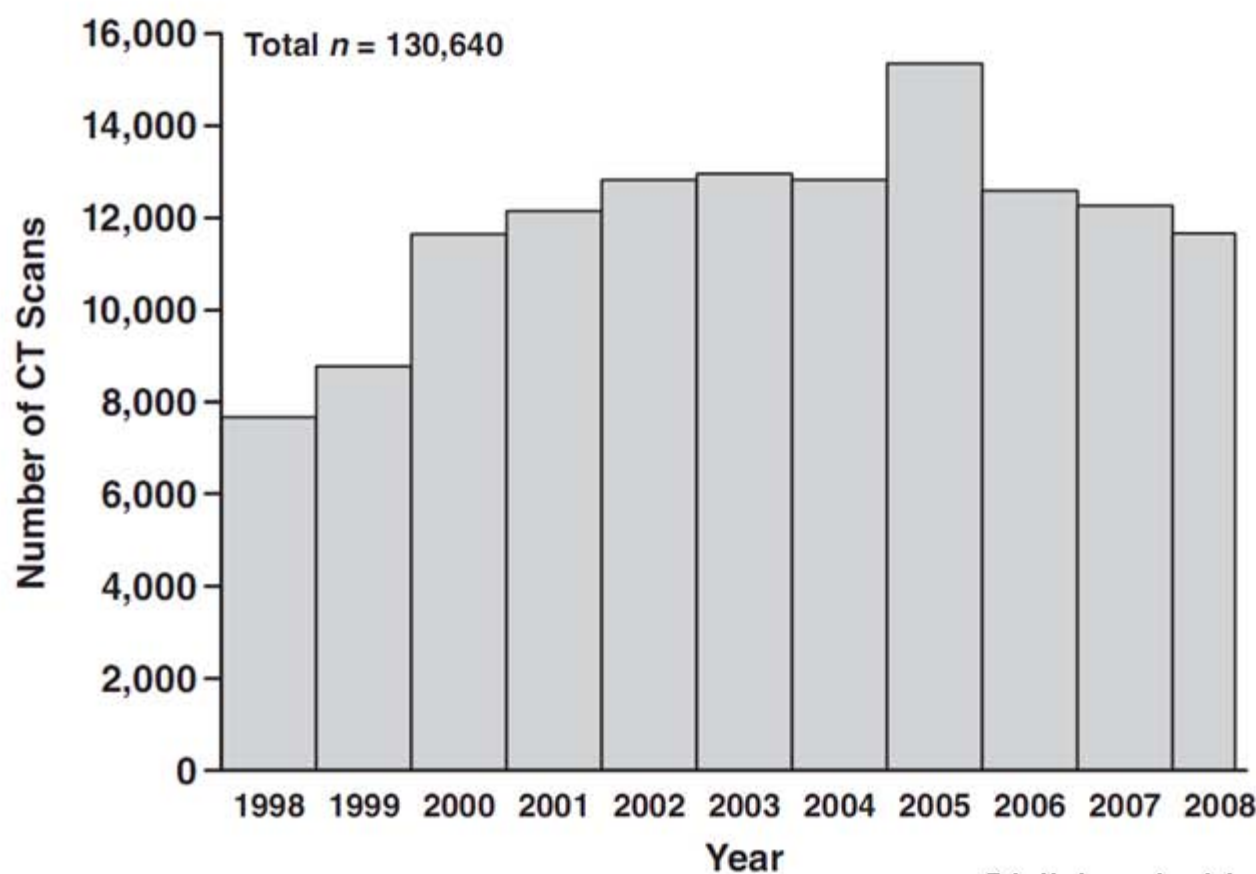
Michael Lell



University Erlangen  
Radiology



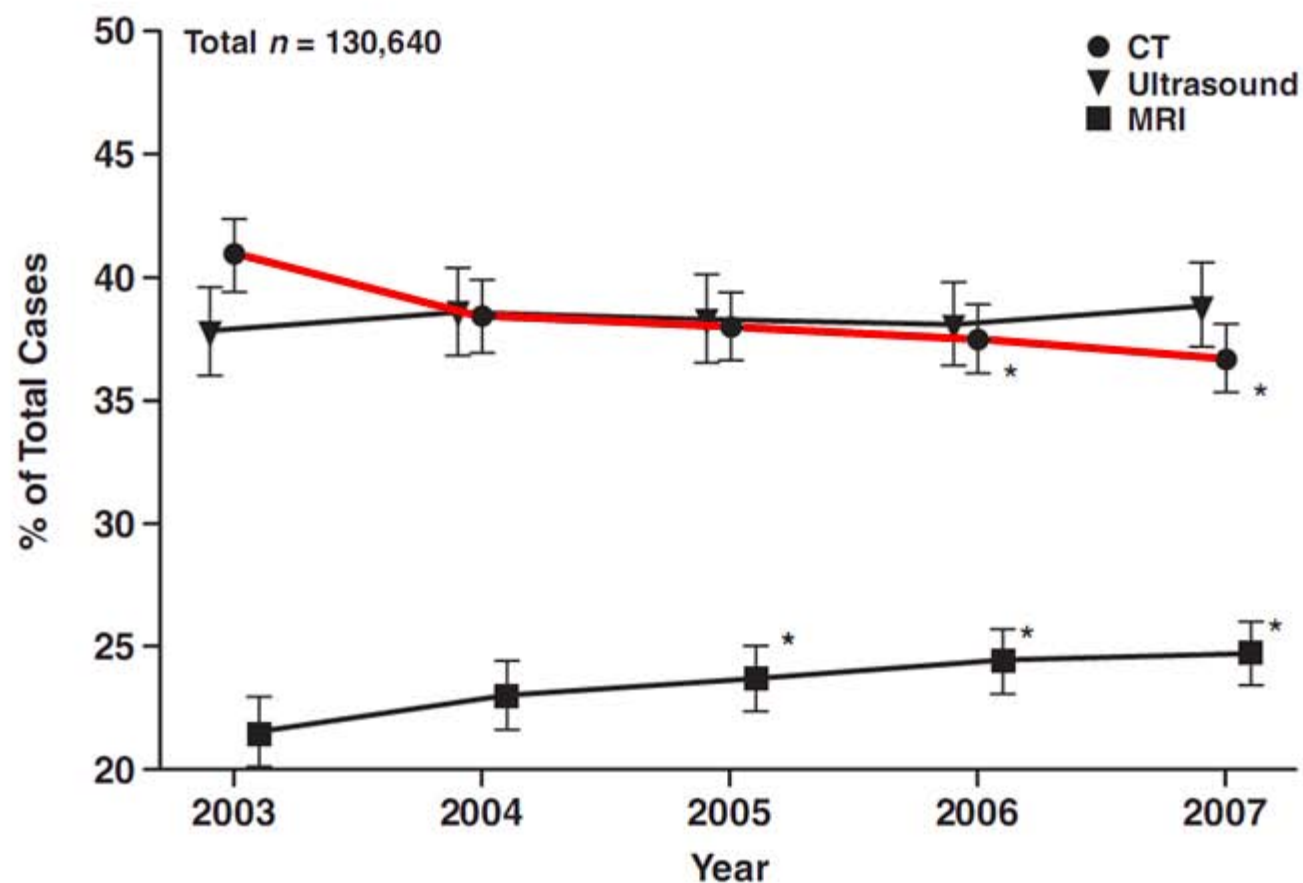
# Does CT still have a Role in Pediatric Imaging?



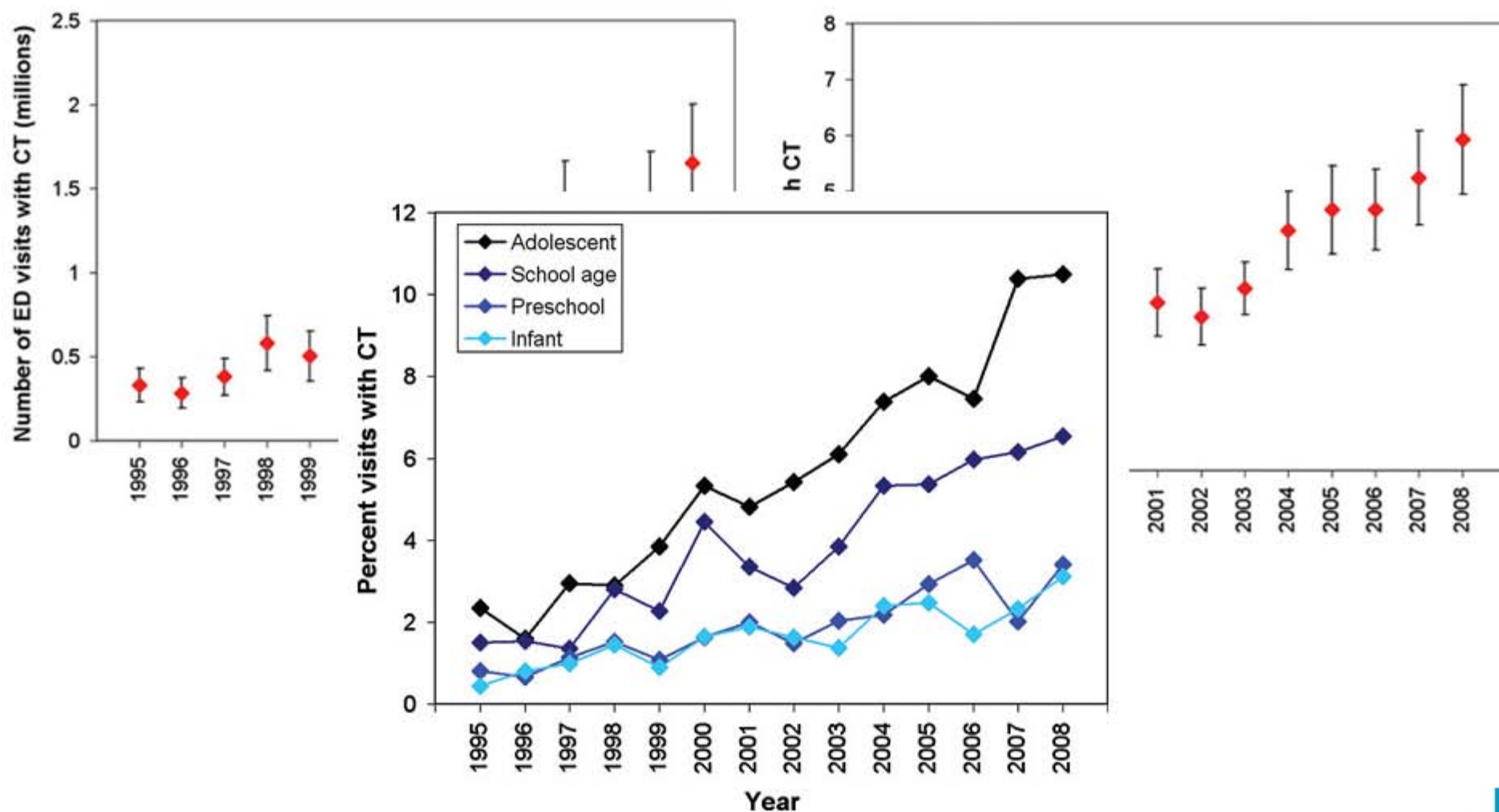
Children's Hospital Boston



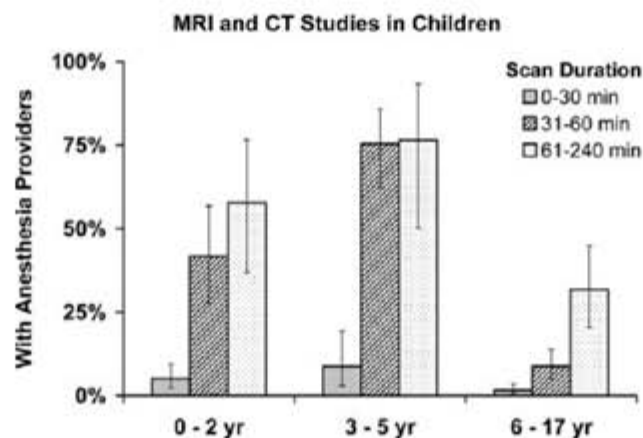
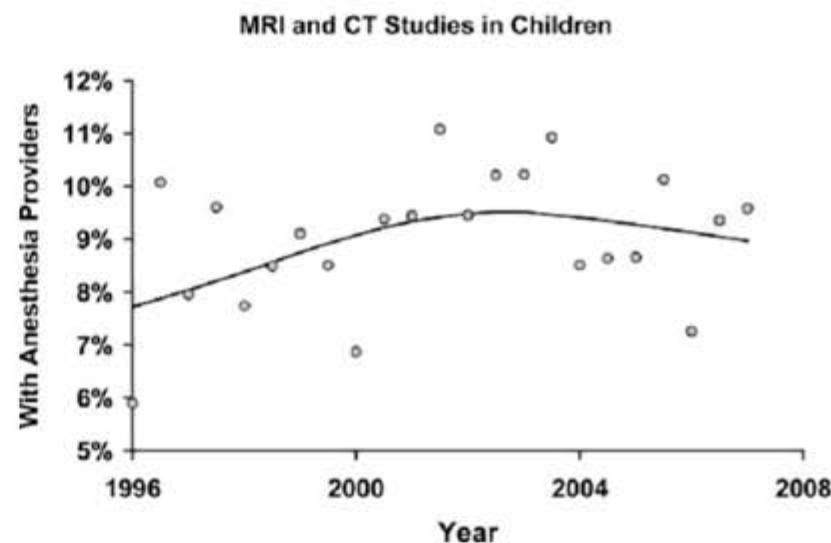
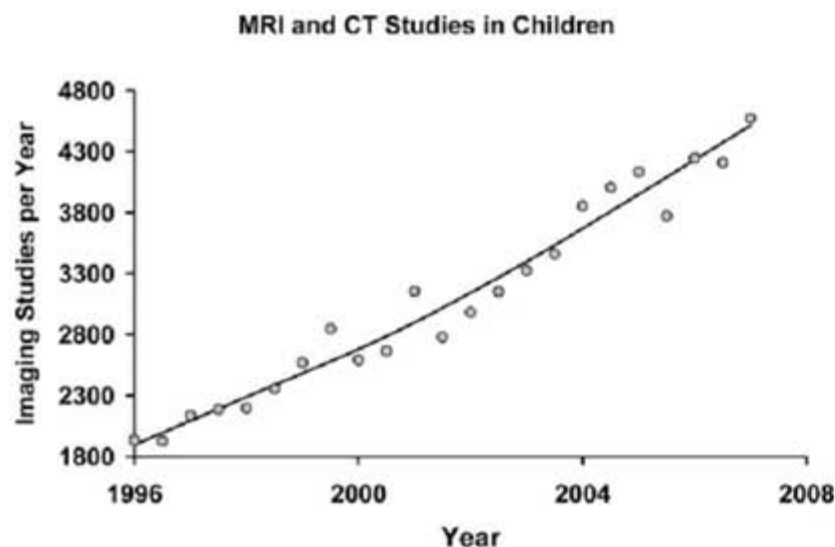
# US Internet Survey (SCORCH)



# Emergency Department CT Use in Children



# Growth Rates in Pediatric Imaging and Sedation



# Continuum of depth of sedation (ASA)

	<i>Minimal Sedation Anxiolysis</i>	<i>Moderate Sedation/ Analgesia</i> <i>("Conscious Sedation")</i>	<i>Deep Sedation/ Analgesia</i>	<i>General Anesthesia</i>
<i>Responsiveness</i>	Normal response to verbal stimulation	Purposeful** response to verbal or tactile stimulation	Purposeful** response following repeated or painful stimulation	Unarousable even with painful stimulus
<i>Airway</i>	Unaffected	No intervention required	Intervention may be required	Intervention often required
<i>Spontaneous Ventilation</i>	Unaffected	Adequate	May be inadequate	Frequently inadequate
<i>Cardiovascular Function</i>	Unaffected	Usually maintained	Usually maintained	May be impaired

# Physical Status Classification (ASA)

Class	Class Definition
I	A normally healthy patient
II	A patient with mild systemic disease with no functional limitation
III	A patient with severe systemic disease and clearly defined functional limitation
IV	A patient with severe systemic disease that is a constant threat to life



# Drugs for Sedation

**TABLE 11 Sedatives/Analgesics and Frequency of Use**

Sedative	% of All Sedations	No. of Times Used	
Ativan	0.2	46	
Chloral hydrate	11.7	3507	
Dexmedetomidine	1.3	393	
Etomidate	2.1	639	
Ketamine	13.6	4075	
Methohexital	0.4	113	
Midazolam	27.1	8142	0.1mg/kg iv bolus 1-2min 0.4-0.5 mg/kg oral 20-30min 0.5-1 mg/kg rectal 15min 0.2-0.3mg/kg intranasal 8-10min
Pentobarbital	13.2	3953	
Propofol	50.1	15 059	3mg/kg iv bolus 20-30s duration 4-10min
Thiopental	0.5	151	
Valium	0	10	
Opiate			
Fentanyl	8	2417	
Meperidine	0.2	54	
Morphine	1.8	552	
Nalbuphine	0	9	
Remifentanyl	0.3	77	

# Complications of sedation

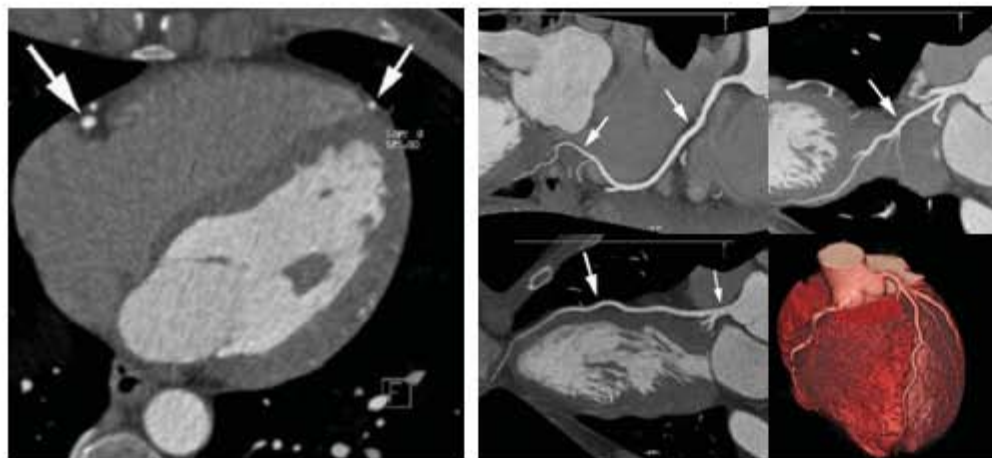
**TABLE 12** Complications

	Incidence per 10 000	n	95% CI
Adverse events			
Death	0.0	0	0.0–0.0
Cardiac Arrest	0.3	1	0.0–1.9
Aspiration	0.3	1	0.0–1.9
Hypothermia	1.3	4	0.4–3.4
Seizure (unanticipated) during sedation	2.7	8	1.1–5.2
Stridor	4.3	11	1.8–6.6
Laryngospasm	4.3	12	2.2–7.4

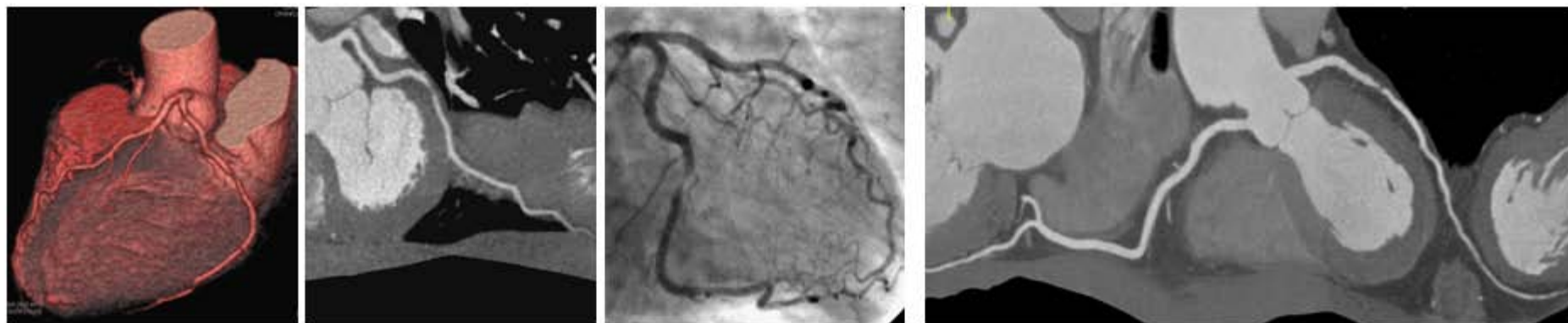
**Total adverse events 1 : 29**  
**Unplanned treatments 1 : 89**  
**Abortion of Exam 1 : 338**

Reversal agent required (unanticipated)	1.7	5	0.6–3.9
Emergency anesthesia consult for airway	2.0	6	0.7–4.3
Admission to hospital (unanticipated; sedation related)	7.0	21	4.3–10.7
Intubation required (unanticipated)	9.7	29	6.5–13.9
Airway (oral; unexpected requirement)	27.6	83	22.0–34.2
Bag-mask ventilation (unanticipated)	63.9	192	55.2–73.6
Total unplanned treatments	111.9 (1 per 89)	336	85.3–130.2
Conditions present during procedure			
Inadequate sedation, could not complete	88.9 (1 per 338)	267	78.6–100.2

# High-Pitch Coronary-CTA



Mean scan duration	<b><math>266 \pm 22</math> ms</b>
Mean DLP:	$62 \pm 5$ mGy*cm
Mean effective dose:	<b><math>0.87 \pm 0.08</math> mSv</b> (range: 0.78 – 0.99 mSv)



# High-Pitch Chest-CT

CT is still considered the method of choice in thoracic imaging and emergency imaging.

Sedation is usually necessary to enable CT and to avoid deterioration of image quality because of patient movement in small children.

Aim:

Evaluation of a new, sub-second high-pitch scan mode (HPM), that obviates the need of sedation and to hold the breath.



## High-Pitch Chest-CT

60 patients included:

30 patients (15 m, 15 f), mean age  $14 \pm 17$  mo (0-55 mo)  
examined with HPM

30 patients (16 m, 14 f), mean age  $15 \pm 17$  mo (0-55 mo)  
examined with CPM in sedation

HPM:

Def. Flash (Siemens), Pitch 3.0, 128 x 0.6 mm, 0.28 s RT, 80 kV,  
50 eff.mAs <5kg, 80 eff.mAs 5-10 kg, 100 eff.mAs >10 kg BW

CPM:

Sens.10/64 (Siemens); Pitch 1.3, 10 x 0.75 / 64 x 0.6 mm, 0.5 s  
RT, 80 kV; 50 eff.mAs <5kg, 80 eff.mAs 5-10 kg, 100 eff.mAs  
>10 kg BW



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RT, 80 kV; 50 eff.mAs <5kg, 80 eff.mAs 5–10 kg, 100 eff.mAs  
>10 kg BW



# High-Pitch Chest-CT

Image reconstruction:

0.75/0.4 mm slice thickness/increment; standard (B30) and sharp (B60) kernel

Assessment of Image Quality:

2 independent readers; 4-point score system;

0 = no artifacts

1 = mild artifacts without diagnostic relevance

2 = marked artifacts

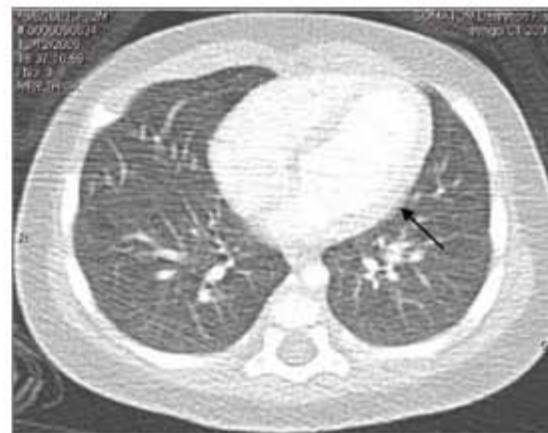
3 = severe artifacts

Assessment of radiation dose:

$CTDI_{VOL}$  and DLP



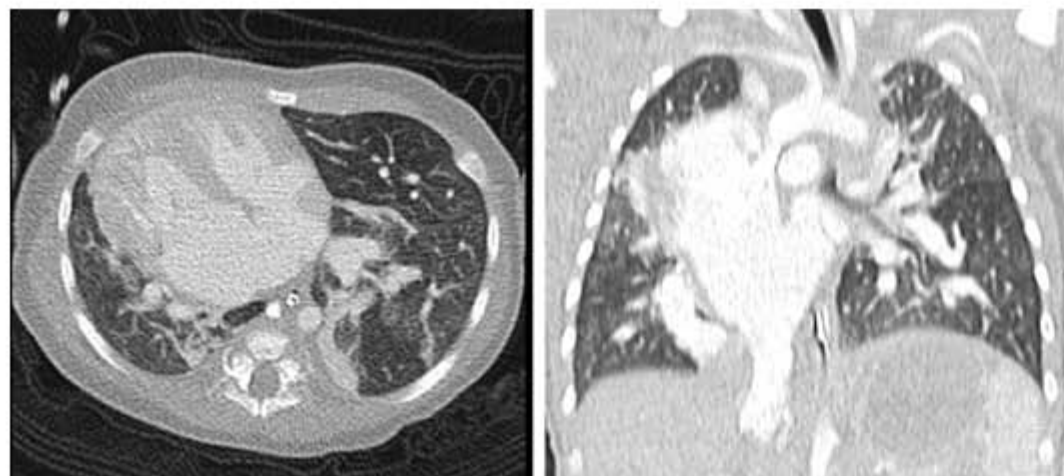
## 2 month old girl; s/p coarctation



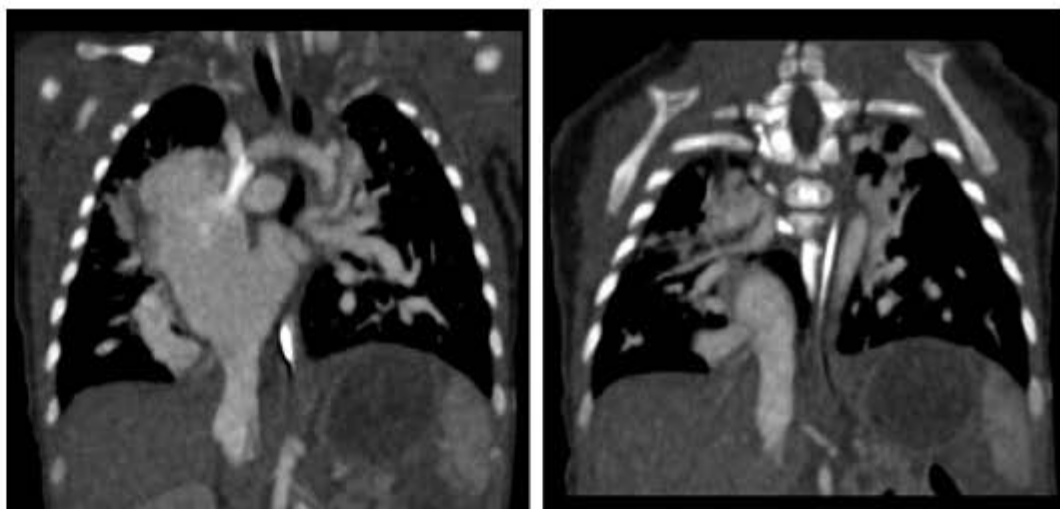
128 x 0.6 mm  
dual source  
0.3 s/rot; p=3.0  
no sedation



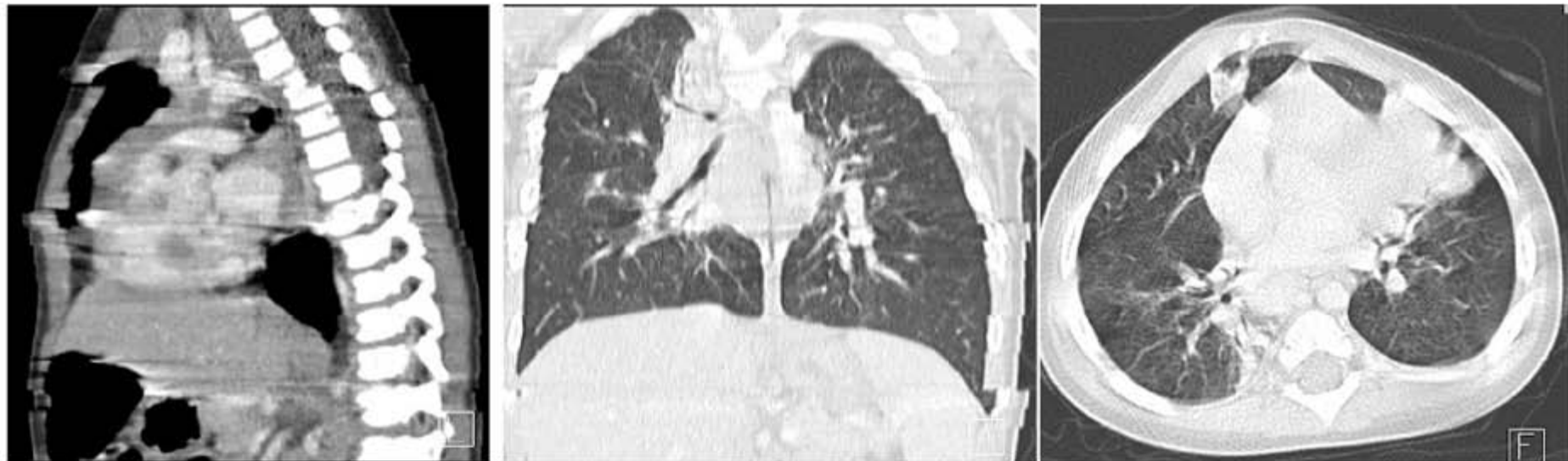
## 2 month old boy; dextrocardia, Scimitar syndrome



128 x 0.6 mm  
dual source  
0.3 s/rot; p=3.0  
no sedation



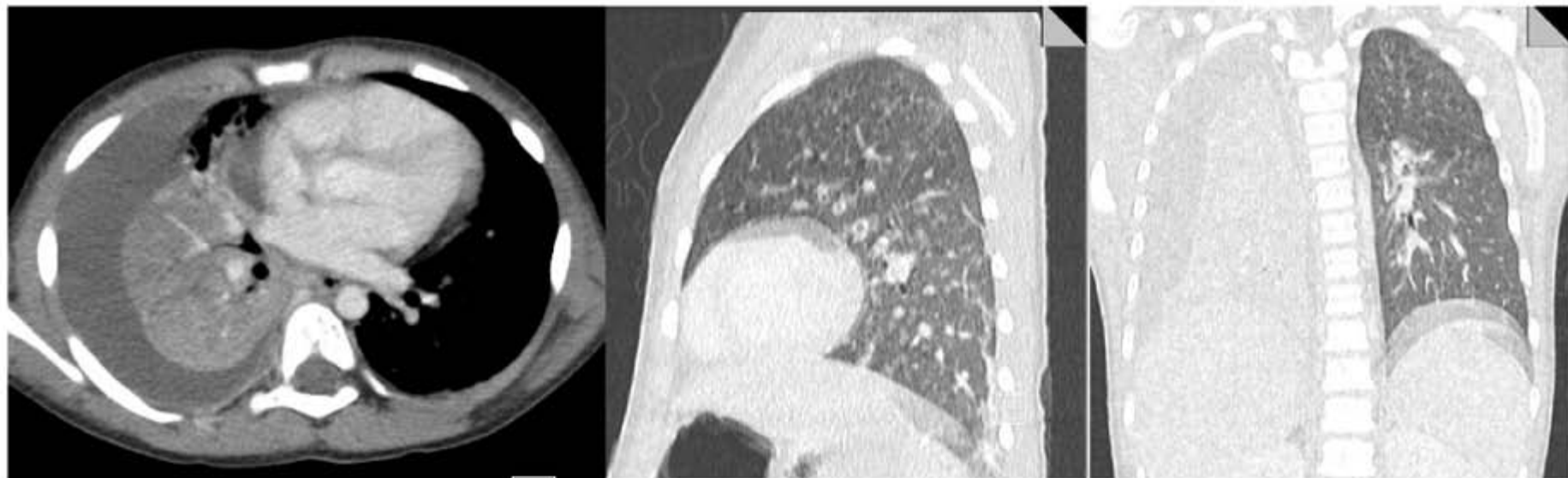
# 3y old boy; Down Syndrome, chronic recurr. pneumonia



10 x 0.75 mm, single source  
0.5 s/rot, pitch = 1.3  
sedation



## 4y old girl; pneumonia and empyema



64 x 0.6 mm, single source  
0.5 s/rot, pitch = 1.3  
sedation



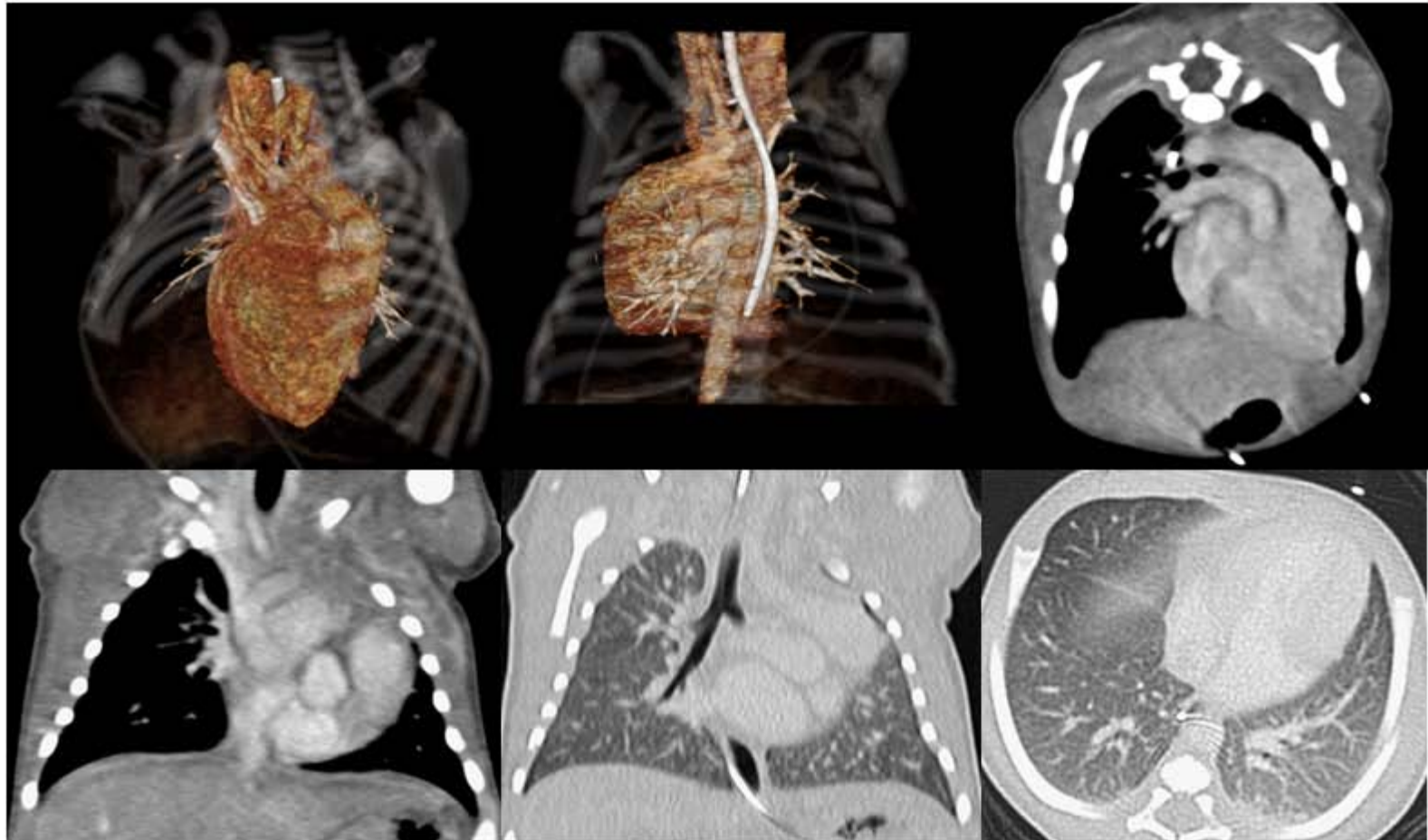
## 2y old girl; s/p oes. atresia, compl. pneumonia



128 x 0.6 mm  
single source  
0.3 s/rot  
sedation



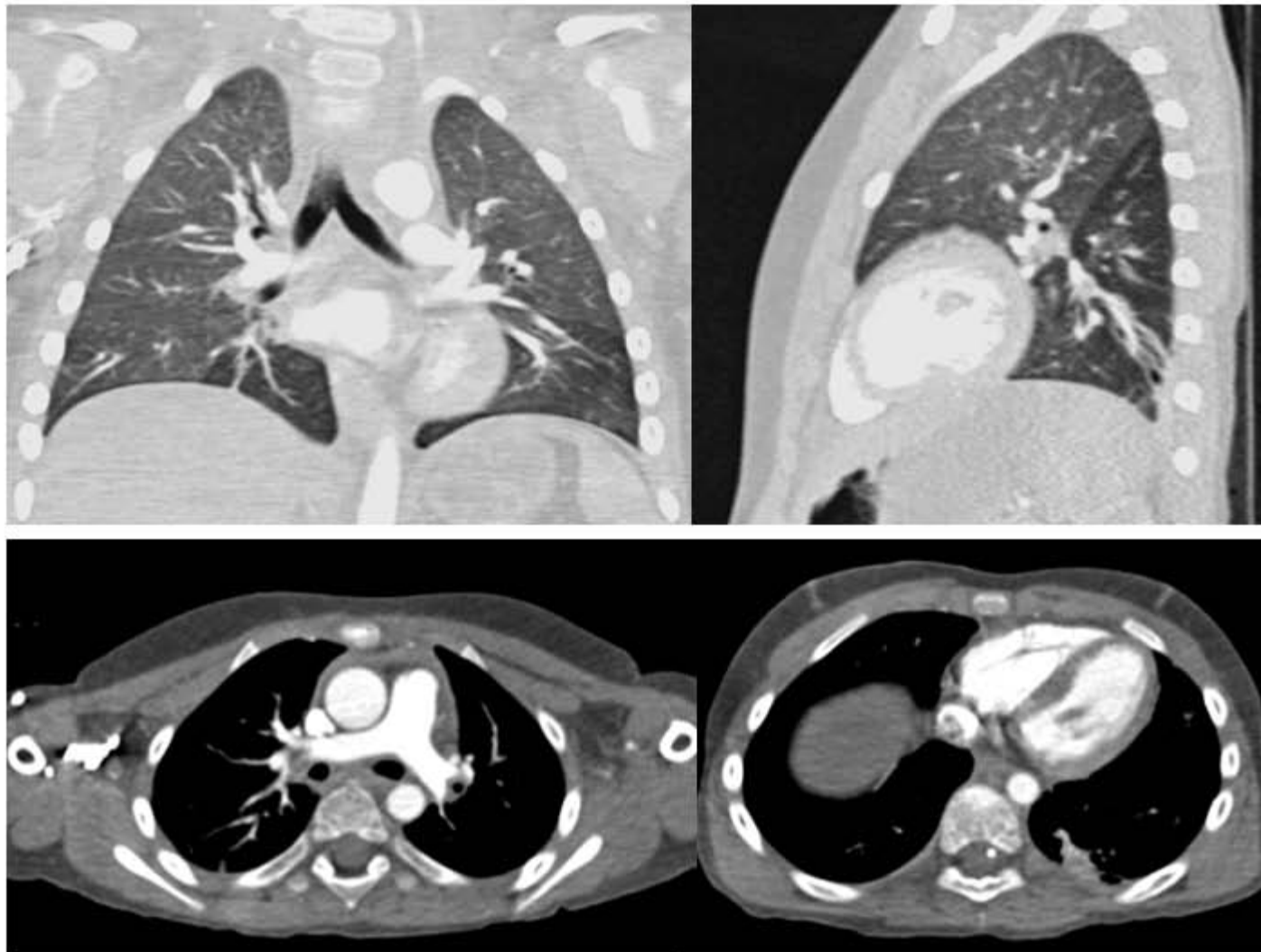
## 2 weeks old boy; TGA



Scan	KV	mAs / ref.	CTDIvol mGy	DLP mGycm	TI s	cBL mm
Patient Position H-SP						
Topogramm	1	120 35 mA			1.7	0.8
Fl_Thorax	2D	100 50	1.85	25	0.28	0.8



## 5y old boy; recurr. thromboembolism



# High-Pitch Chest-CT

## Mean scan time:

HMP	$0.49 \pm 0.1$ s	(range, 0.38 – 0.64 s)
CPM	$7.6 \pm 1.4$ s	(range, 5.6 – 10.3 s) [10]
	$3.5 \pm 0.7$ s	(range, 2.5– 4.6 s) [64]

## Artifacts:

	HPM	CPM	
no artifacts	n=24	n=0	exams
minor artifacts	n=4	n=9	exams
marked artifacts	n=2	n=11	exams
severe artifacts	--	n=10	exams



# A word about dose ...

AAPM REPORT NO. 96  
AAPM Report No. 204



Region of body	Conversion factor from DLP to Effective Dose in [mSv / (mGy · cm)]				
	0 year old	1 year old	5 year old	10 year old	Adult
Head and neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen and pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

16 cm phantom

32 cm phantom

$$\text{CTDIvol}_{(16\text{cm})} = d \times \text{CTDIvol}_{(32\text{cm})}$$

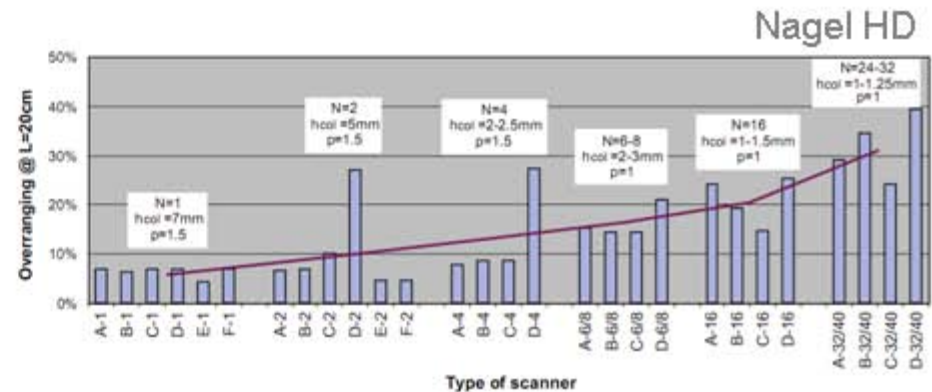
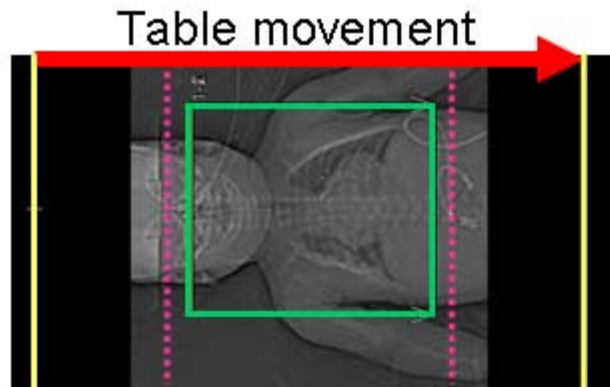
$$d = 2.0 \text{ (S10)}; 2.2 \text{ (S64)}; 2.4 \text{ (DS) at 120kV}$$

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGy·cm	TI s	cBL mm
Patientenposition H-SP							
Topogramm	1	70	80 mA	0.04 L	1	2.0	0.6
Thorax	2	70	119 / 358	1.07 L	18	0.3	0.6

L = 32 cm

S = 16 cm

# Overscanning/Overranging



Depends on collimation and table speed (pitch)

## CT Protocols

Protocol*	Tube Potential (kVp)	Scan Field of View	Bow Tie Filter	Pitch	Collimation (mm)	CTDI <sub>vol</sub> (mGy/100 mAs) <sup>†</sup>	Overranging Distance (cm) <sup>‡</sup>
A	120	Pediatric body	Small	1.375	40	12.19	6.40
B	120	Medium body	Medium	1.375	40	6.23	6.40
C	120	Large body	Large	1.375	40	6.01	6.40
D	120	Pediatric body	Small	1.375	20	13.41	3.34
E	120	Pediatric body	Small	0.984	40	17.04	4.72
F	80	Pediatric body	Small	1.375	40	4.39	6.40
G	100	Pediatric body	Small	1.375	40	7.19	6.40
H	140	Pediatric body	Small	1.375	40	17.07	6.40

Li et al. Radiology 2011

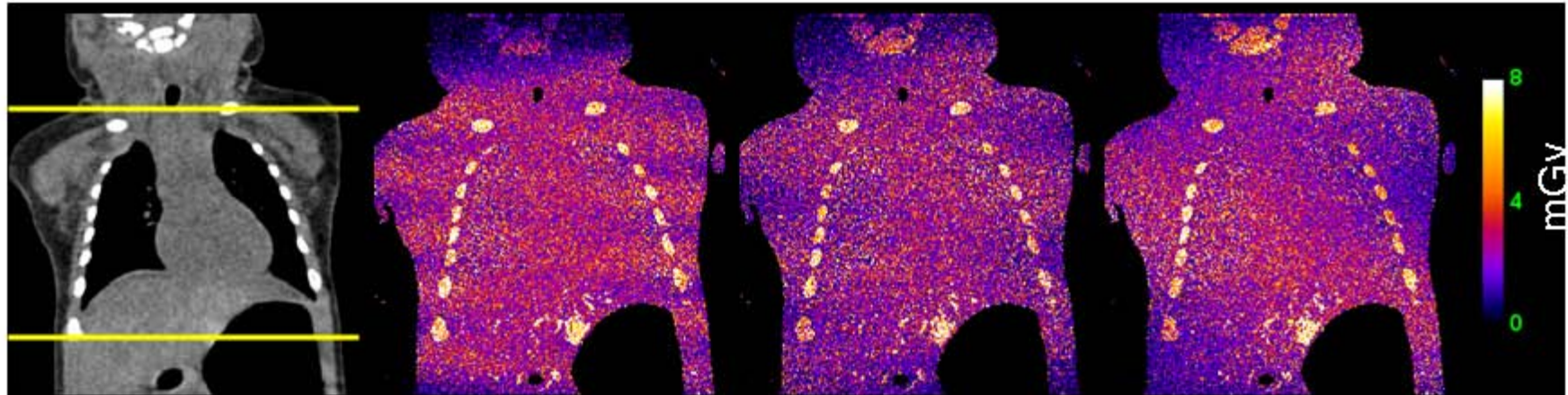
# MC-Simulations

Scan range

S64 (p=1.3)

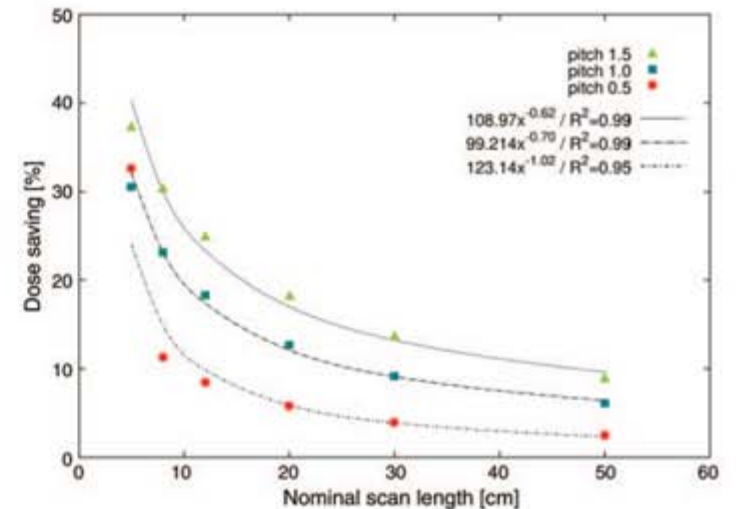
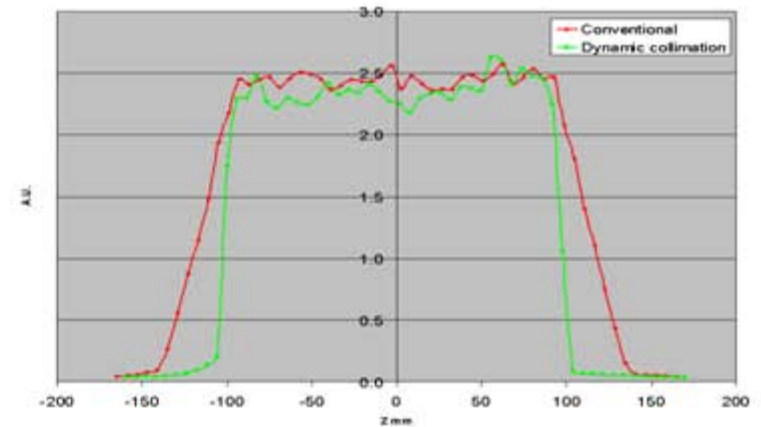
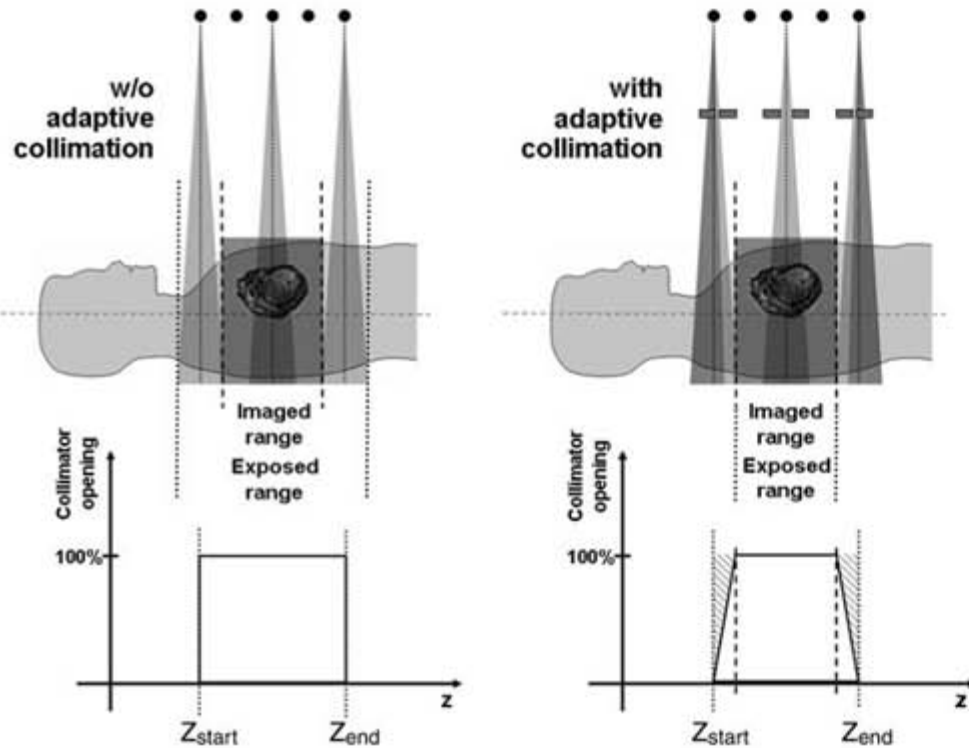
DF (p=1.3)

DF (p=3.0)



Organ	64-SSCT (p=1.3)	CPM-DSCT (p=1.3)	HPM-DSCT (p=3.0)
Bone	6.1	5.77	6.07
Heart	2.97	2.69	2.75
Lung	2.99	2.66	2.66
Soft tissue	2.33	2.11	2.21
Average	3.60	3.31	3.42

# Adaptive Collimation

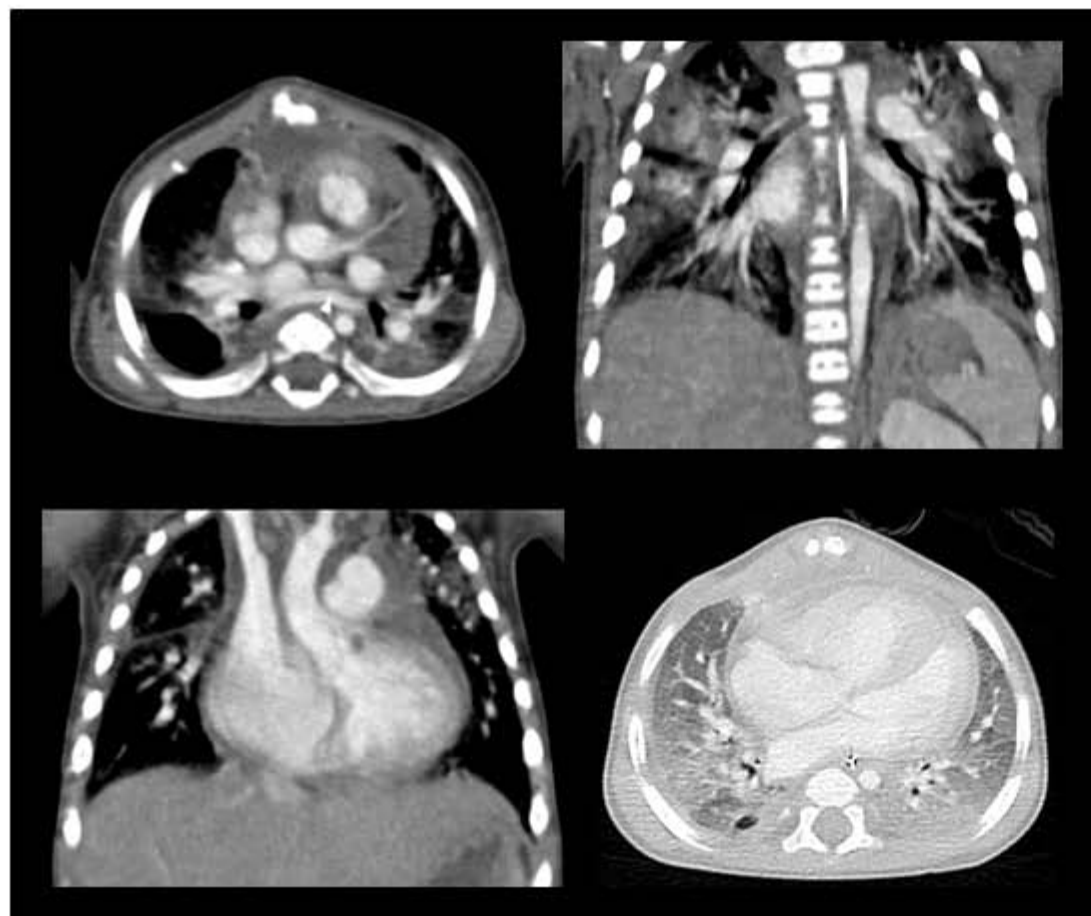


# Results

Typical Scan Parameters for CPM and HPM Protocols:

CT	Scan Length (mm)	Tube Current (mAs)	Tube Voltage (kV)	$t_{rot}$ (s)	Pitch	Nominal Total Collimation (mm)	DLP <sub>32</sub> (mGy cm)	DLP <sub>16</sub> (mGy cm)
10-SSCT	110	50	80	0.5	1.3	7.5	17	34
	150	80	80	0.5	1.3	7.5	34	68
	180	100	80	0.5	1.3	7.5	51	102
64-SSCT	110	50	80	0.5	1.3	19.2	15	33
	150	80	80	0.5	1.3	19.2	31	68
	180	100	80	0.5	1.3	19.2	45	99
CPM-DSCT	110	50	80	0.28	1.3	38.4	13	31
	150	80	80	0.28	1.3	38.4	25	60
	180	100	80	0.28	1.3	38.4	36	86
HPM-DSCT	110	50	80	0.28	3.0	38.4	14	34
	150	80	80	0.28	3.0	38.4	27	65
	180	100	80	0.28	3.0	38.4	38	91

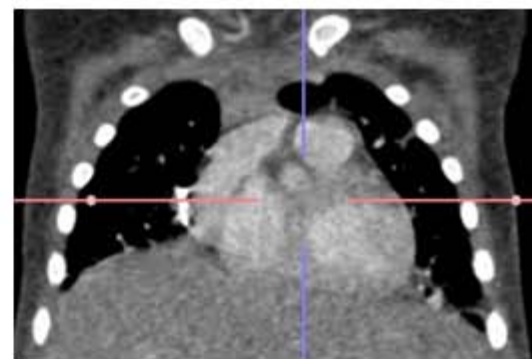
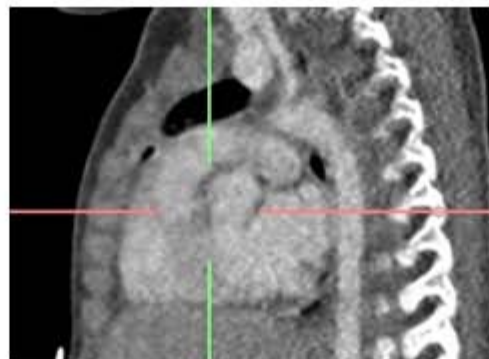
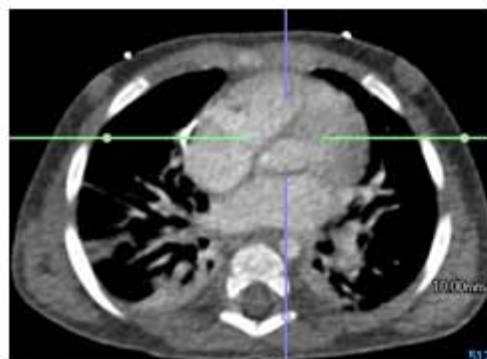
## Perspective: Low-kV Scanning



Multiple VSD  
R → L shunting  
Pulmonary hypertension  
s/p pulm. banding sept. corr.



# Low-kV Scanning: Pediatric Chest CT (70 kV)



**Gesamt mAs 192    Gesamt DLP 6 mGycm**

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	TI s	cSL mm
<b>Patientenposition H-SP</b>							
Topogramm	1	120	35 mA	0.13 L	2	1.7	0.6
Thorax	2	70	26 / 50	0.24 L	4	0.5	0.6

# How we do it

## ■ Dual-Source CT: high-pitch mode

- no sedation
- 80 or 100kV depending on body size and indication, AEC
- 128 x 0.6 mm collimation

## ■ Single-Source CT: conv.-pitch mode

- sedation
- 70 - 100kV depending on body size and indication, AEC
- 128 x 0.6 mm collimation

## ■ i.v. contrast by hand injection (1.5-2 ml/kg)



# Pediatric High-Pitch Spiral CT

Thank You



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