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Abdomen CT bei Kindern – Wann? Wie?

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Wie kann man Dosis ↑?

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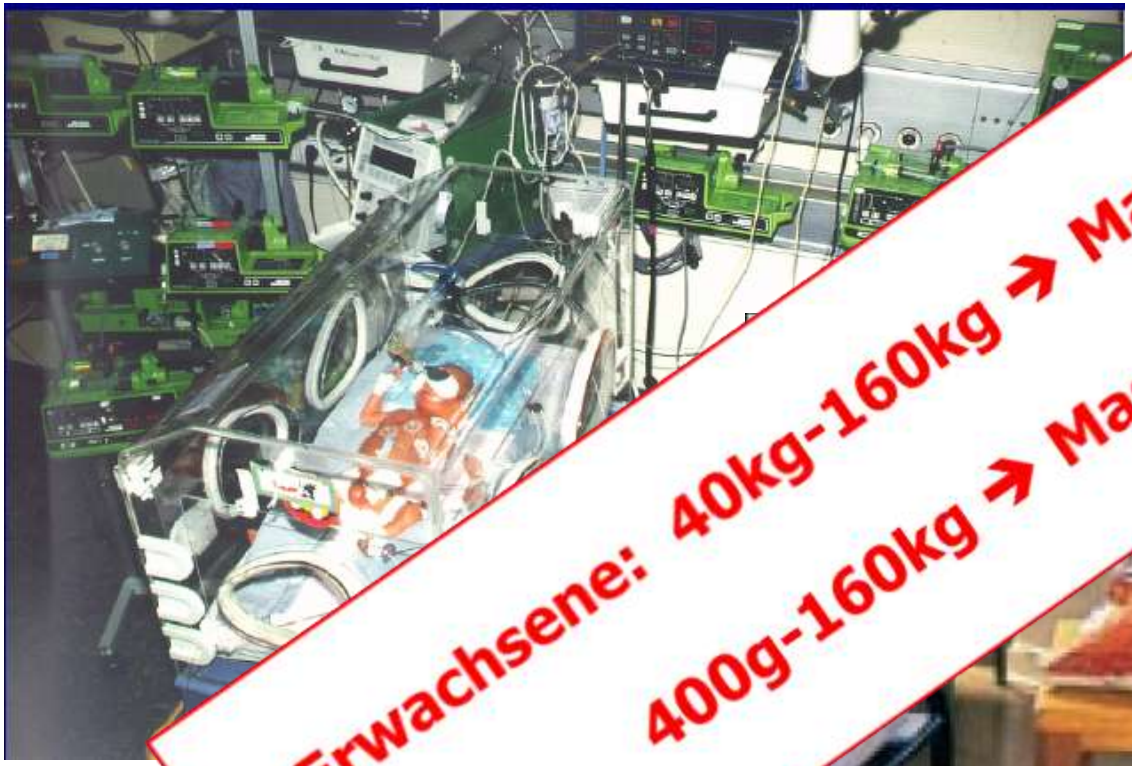
[redacted]

Kinder??!!??



Erwachsene: 40kg-160kg → Massenfaktor 1:4

Kinder: 400g-160kg → Massenfaktor 1:400

Wo stehen wir heute?

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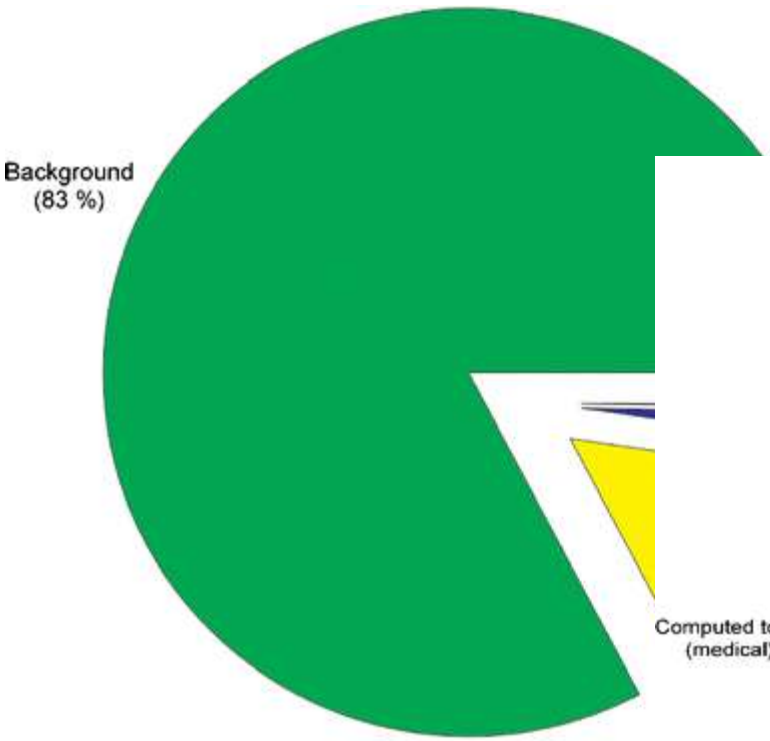

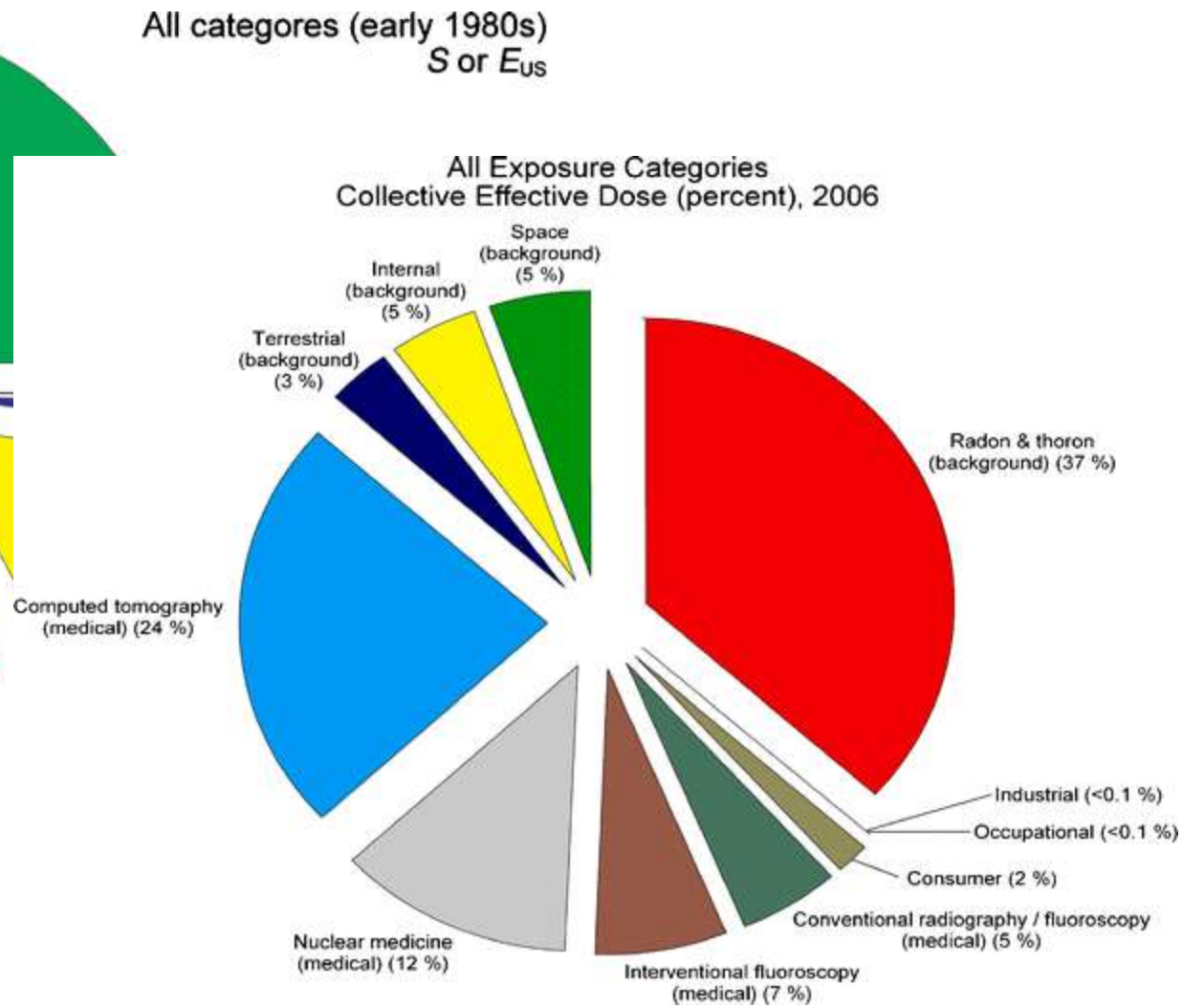

NCRP Rep.160
nach T.Slovis Pediatr Radiol 2011,

Kinder – anders?

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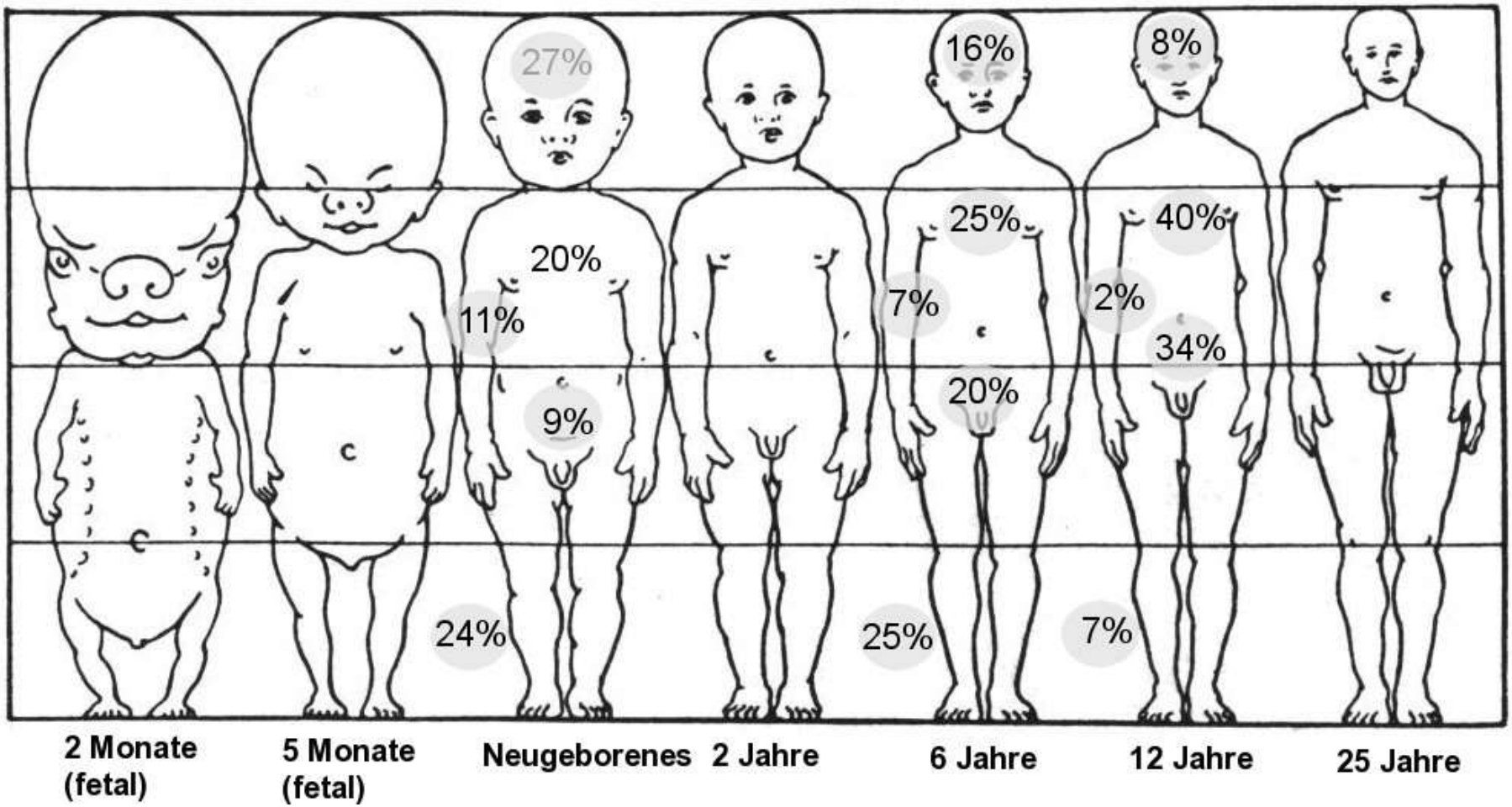

Wie ist die Praxis?

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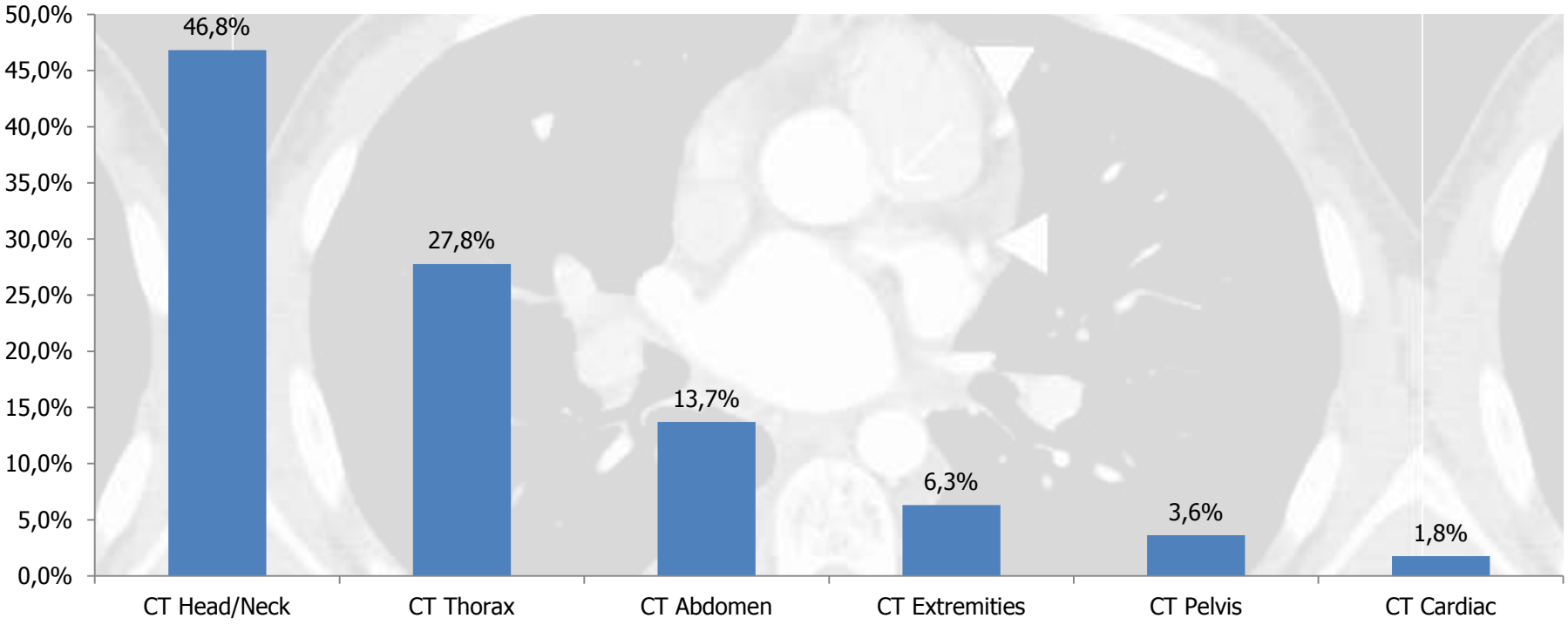
- **Häufigste CT Untersuchungen (PiDRL):**



Wie ist die Praxis?

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- **IAEA Umfrage in 40 Ländern:**
  - **In 50% keine Kinderprotokolle**
  - **Protokolle per Indikation nur in 57%**
  - **CTDI für cCT 2-5x soviel bei Erwachsenen ➔ Optimierung?**

Jenia Vassileva, Madan M. Rehani, AJR:198, May 2012
Jenia Vassileva & Madan M. Rehani,
Kimberly Applegate & Nada A. Ahmed,
Humoud Al-Dhuhli & Huda M. Al-Naemi, Eur Radiol (2013) 23:623–631

  - **NB: ALARA wurde 1912 publiziert**

A.Oestreich RadioGraphics 2014; 34:1457–1460

Wie ist die Praxis?

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- **CT Beitrag kollektiven Dosis:**

Region	Description (PiDRL)	Relative collective effective dose to population, normalized to thorax radiography.
Radiography		
Thorax	Thorax AP/PA	1,0
Spine	Cervical spine AP/PA and LAT	
	Thoracic spine AP/PA and LAT	
	Lumbar spine AP/PA and LAT	
	Whole spine/Scoliosis AP/PA, AP/PA+LAT	
Abdomen-pelvis	Abdomen-pelvis AP	0,1
	Pelvis and hip AP	
Skull	AP/PA + LAT	0,01
Computed Tomography (CT)		
Head	Routine	2,6
	Sinus	
	Inner ear/ Internal auditory means	
	Ventricular size (shunt)	
Chest	Routine chest	10,2
	Cardiovascular CTA	
Abdomen	Abdomen	4,5
	Abdomen+pelvis	
Trunk	Neck+chest+abdomen+pelvis (trauma, oncology)	
Spine	Cervical+thoracic+lumbar	

Wann CT?

- **Schwierige Frage:**
  - **MR und US zu bevorzugen ☺**
  - **Geräteaustattung der Abteilung**
    - **US, Radiographie, Durchleuchtung**
    - **CT**
    - **MR?**
    - **CT und MR?**
  - **Verfügbarkeit**
    - **Termine, Zeitschlitze etc.**

Wann CT?

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- **American College of Pediatrics** (www.aap.org)
  - **How can we minimize radiation risk?**
    - **There are ways to ensure that your patient is exposed to the smallest amount of radiation possible during an imaging study. The Image Gently Campaign is promoting optimal scanning strategies for children, and they are listed below:**
    - **Image when there is a clear medical benefit.**
    - **Use the lowest amount of radiation for adequate imaging based on size of the child (reducing tube output – kVp and mAs)**
    - **Image only the indicated area**
    - **Avoid multiple scans**
    - **Use alternative diagnostic studies (such as ultrasound or MRI) when possible)**

https://www.aap.org/en-us/about-the-aap/Committees-Councils-Sections/Section-on-Radiology/Pages/What-Every-Pediatrician-Should-Know.aspx

Wann Abdomen CT?

- **Polytrauma:**
  - **Der Begriff „Polytrauma" steht für eine gleichzeitig entstandene Verletzung mehrerer Körperregionen oder Organsysteme. Dabei ist bereits eine einzelne dieser Verletzungen oder die Kombination mehrerer für den Betroffenen lebensbedrohlich (Deutsche Gesellschaft für Unfallchirurgie).**
- **Urolithiasis:**
  - **nur bei spez. Fragestellungen**
- **Orthopädie in Ergänzung MR**
- **Ev. Planungs CT (Eingriffe, Strahlenth.)**
- **Wenn kein MR möglich/verfügbar**
  - **Abszesssuche**
  - **Postoperative Komplikationen**

Abd.CT-Wie: Dosisfaktoren

- Scoutview (Länge, Röhrenposition, Bismuth)
- „Field of View" – asym. Formfilter
- Scanlänge („Excess Range")
- Scantechnik (single slice, spiral, volume)
- Schichtdicke, mAs, kV, Pitch
- Automated exposure control (AEC)
- Bildrekonstruktion
  - (Kernel, Backproj, stat. Rekonstruktion)

Abdomen CT

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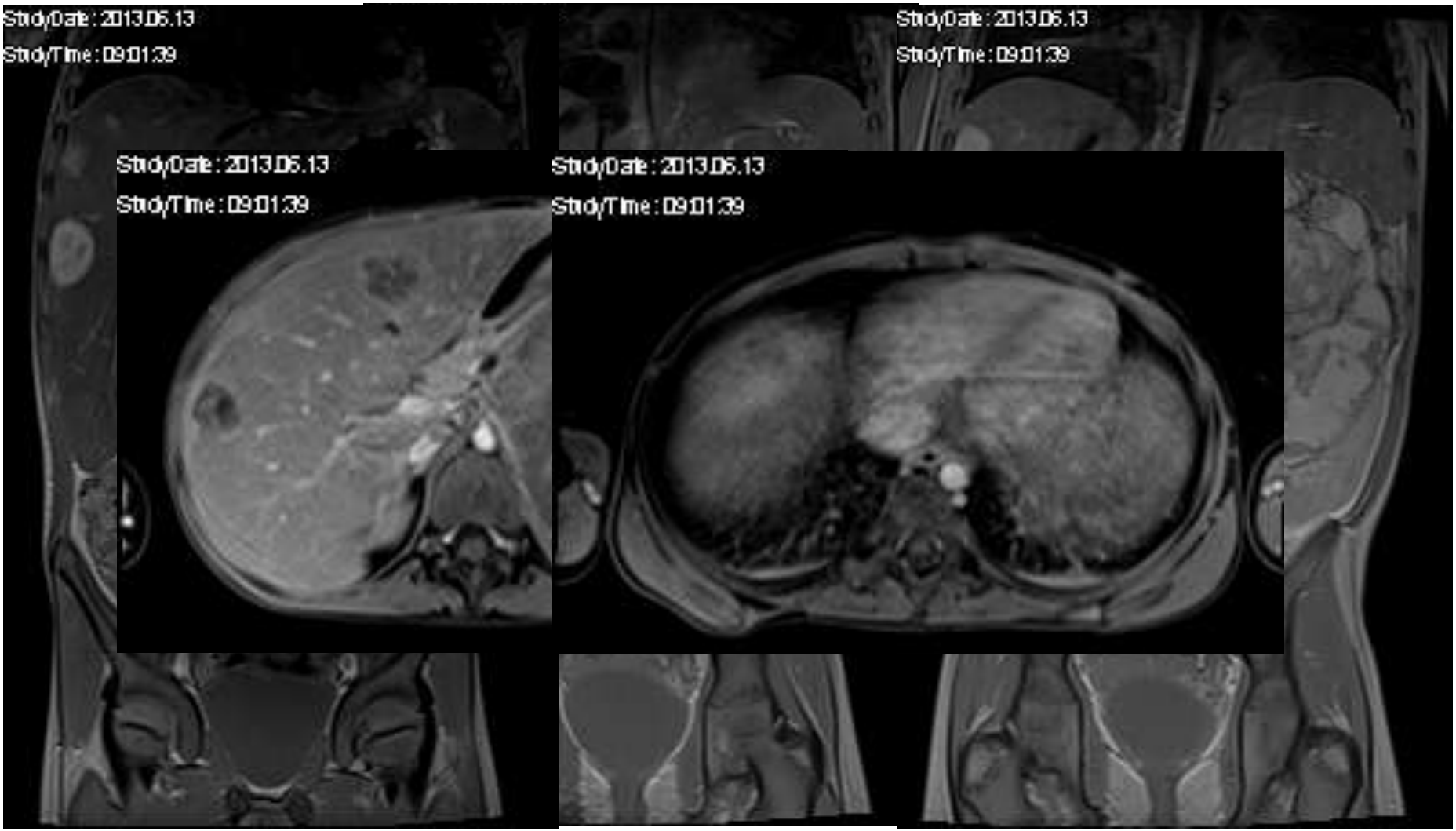

Abdomen CT

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Abdomen CT

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„Imaging Chain" - CT

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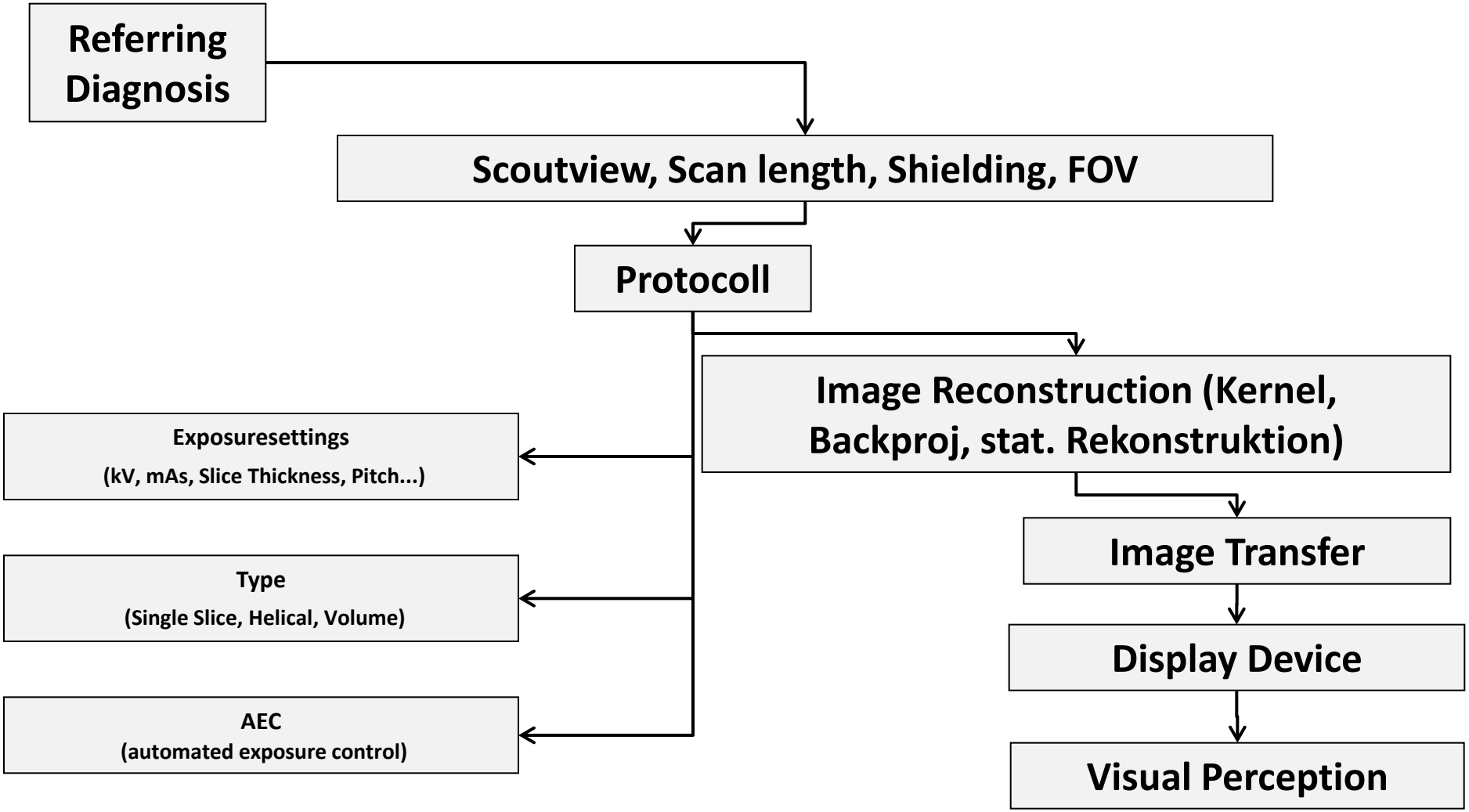

E.Sorantin, Pediatr Radiol. 2008, EJR 2011

Imag.Chain - Scoutview

- Üblicherweise nicht beachtet
- Wichtige Parameter
  - Länge
  - Belichtungswerte:
    - Üblicherweise konstant für alle Patienten ☹
  - Röhrenposition:
    - Top
    - Down

Imag.Chain-Scoutview

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- **Röhre top/down?**

Imag.Chain-Scoutview

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- **Röhre top/down?**

Imag.Chain-Scoutview

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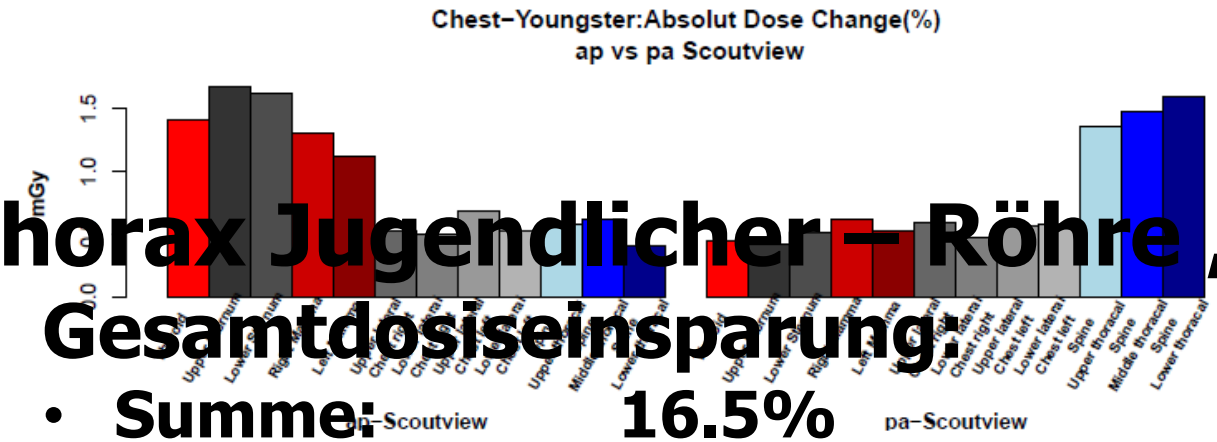
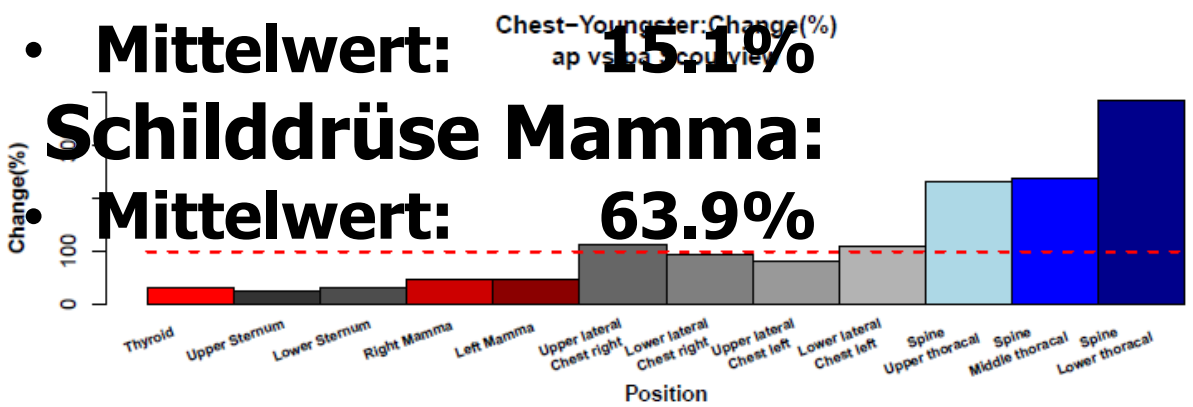
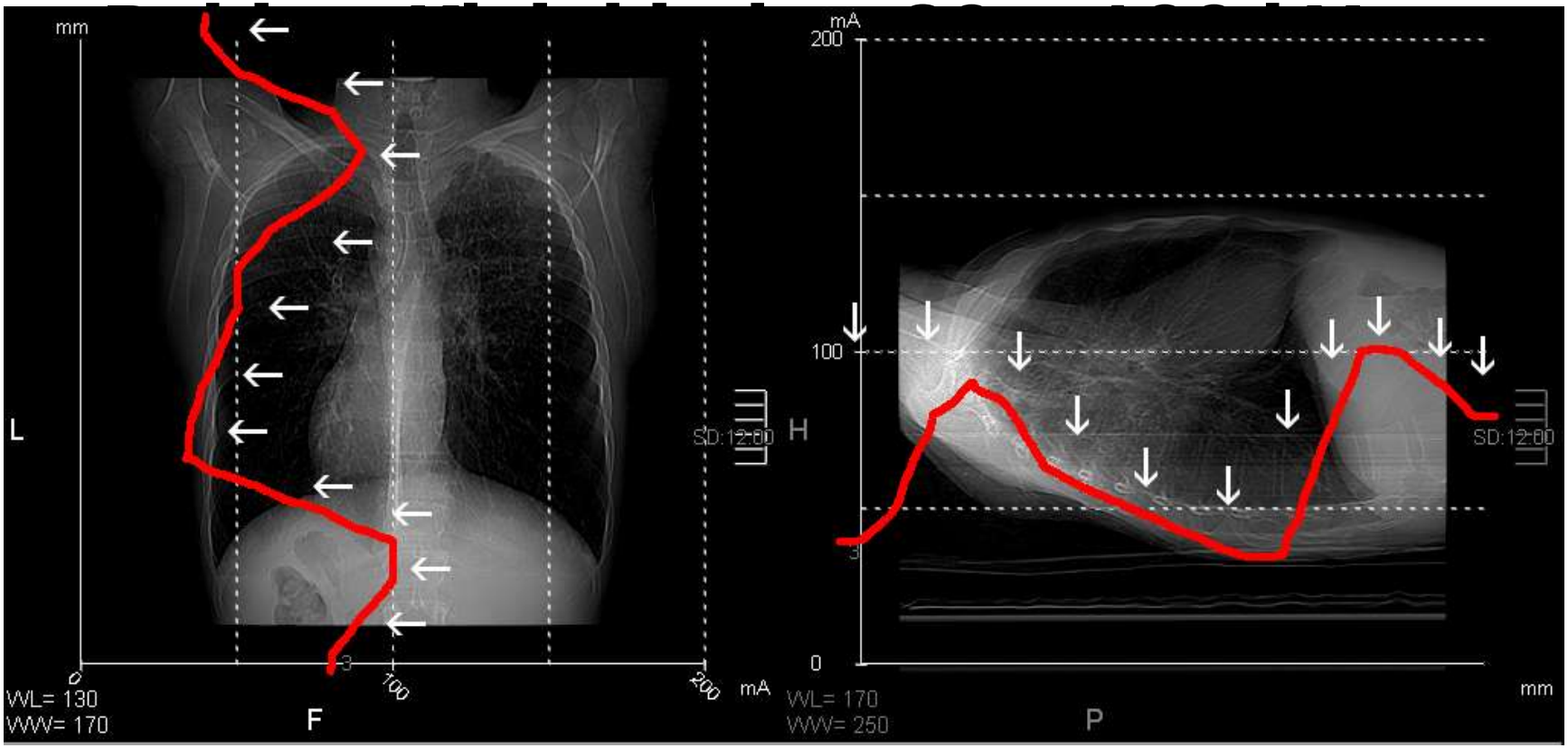


- **Thorax Jugendlicher – Röhre „down“:**
  - **Gesamtdosiseinsparung:**
    - **Summe: 16.5%**
    - **Mittelwert: 15.1%**
  - **Schilddrüse Mamma:**
    - **Mittelwert: 63.9%**



Scoutview AEC



Imag.Chain-Scanlänge

- **DLP: 36.8**

Imag.Chain-Scanlänge

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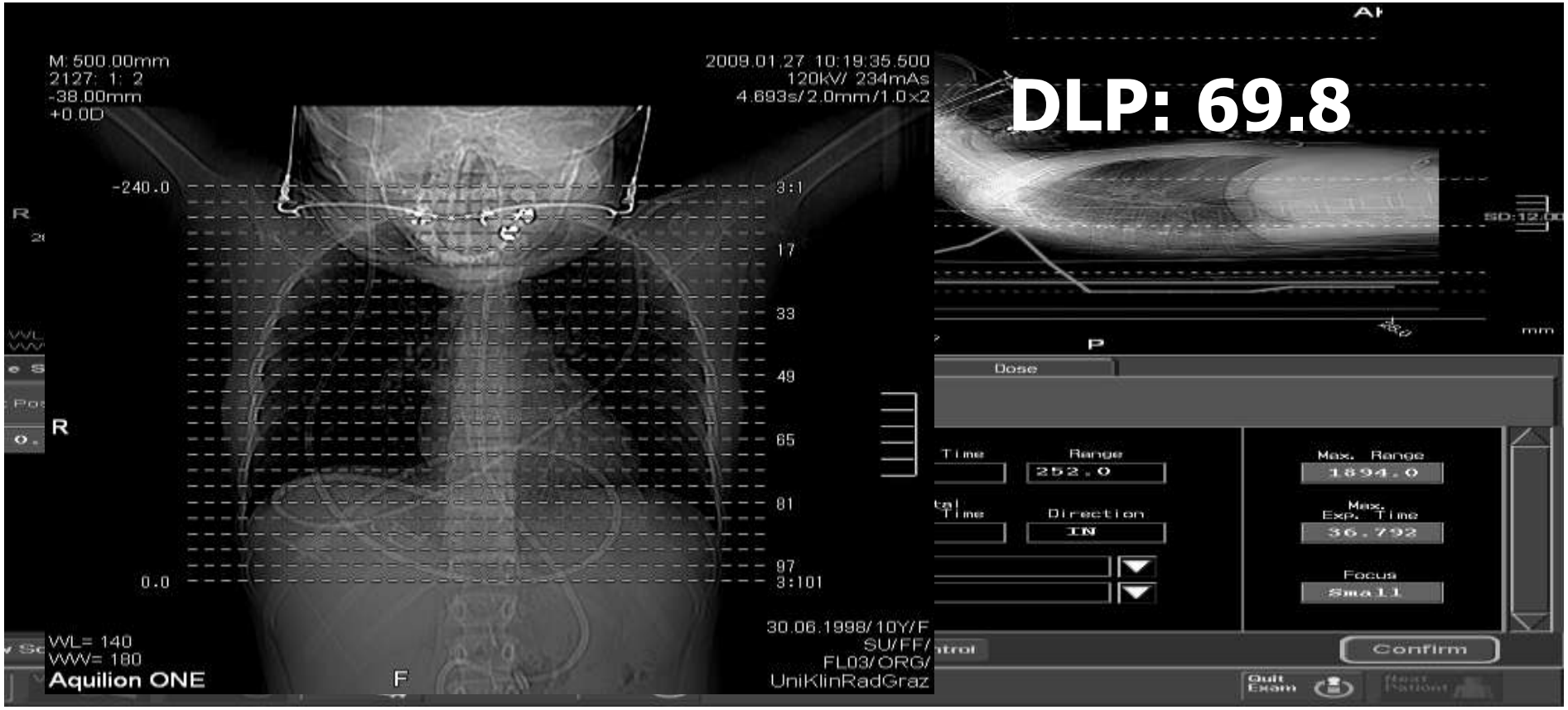
- **Scanlänge**



Imag.Chain-Scanlänge

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- **Patienten:**
  - **739 Thorax CT (Einzelregion):**
    - **Routine Follow-Up kinderonk.Patienten**
    - **Von 90 Patienten: Alter ➔ 14.9±5.0, 1.2-24.7a**
- **Methoden:**
  - **Totale Scanlänge:**
    - **Distanz table_start – table_end**
  - **Gewünschte Scanlänge:**
    - **Lungenapex ➔ Lungenbasis**
- **Overscanning: Normalsiert zu Gew.Scanlänge**

Imag.Chain-Scanlänge

- **Patientenalter vs RT Team Erfahrung:**
- **„Experienced Team“: 15.2 5.0a (n=184)** } **n.s.**
- **„Young Team:“ 14.9 5.0a (n=555)**
- **Total overscanning:**
  - **Mean: 14.5 6.9%**
  - **Min: 1.02, Max: 43.5%!!!!**
- **„Total overscanning“ vs Team:**
  - **Experienced Team: 12.96 6.9%** } **P<0.05**
  - **Young Team: 14.99 6.9%**

Imag.Chain-Scanlänge

- **ANOVA:**

	Df	*SumSq*	*MeanSq*	*F value*	*Pr(>F)*
scout12	2	112.9	56.5	0.7317	0.4842253
team	1	1079.3	1079.3	13.9892	0.0003418***
AGE	1	1365.6	1365.6	17.6999	6.637e-05***
scout12:team	1	151.5	151.5	1.9639	0.1649141
scout12:AGE	1	48.1	48.1	0.6240	0.4318889
team:AGE	1	68.8	68.8	0.8923	0.3476542
scout12:team:AGE	1	44.5	44.5	0.5764	0.4499225
Residuals	81	6249.6	77.2		

Imag.Chain-Shielding/AEC

Imag.Chain-Shielding/AEC

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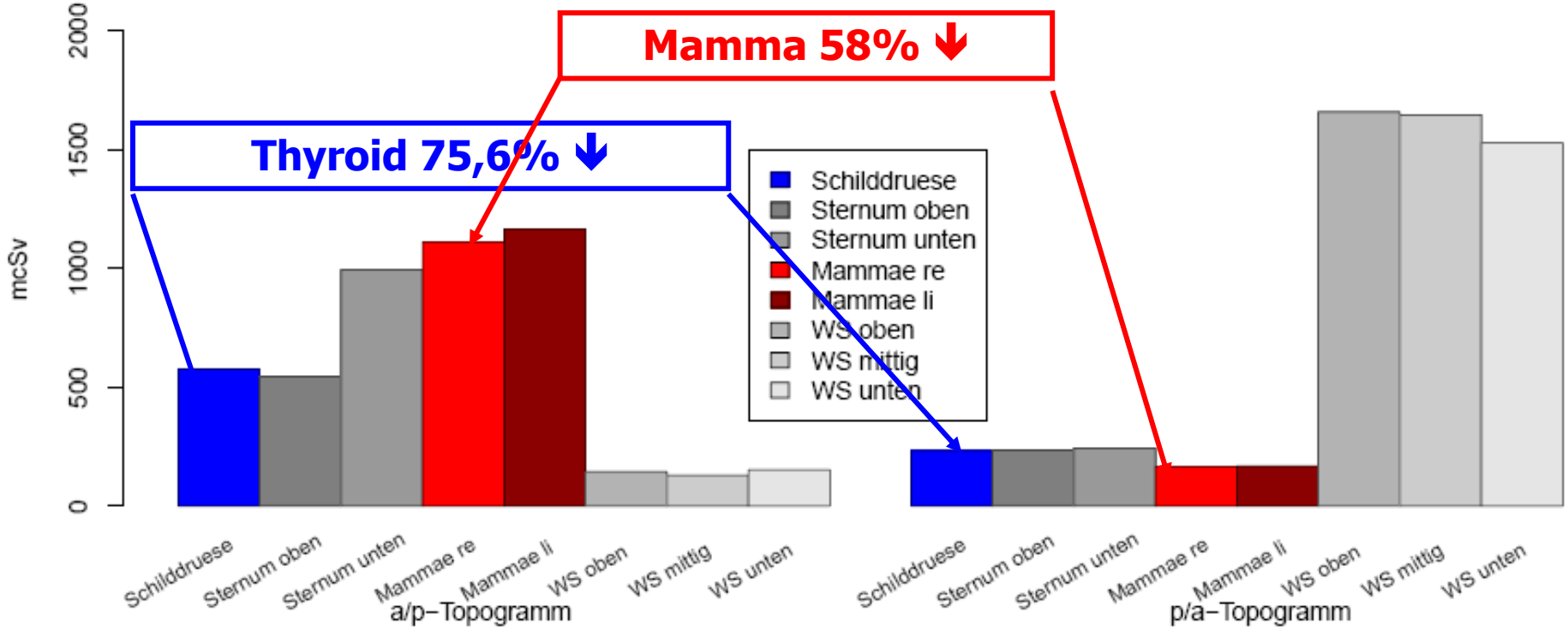

Imag.Chain-Shielding/AEC

- **Automated Exposure Control:**
  - Z, XYZ Modulation (4D Modulation)
- **Bismuth Shielding:**
  - **Augen**
  - **Schilddrüse**
  - **Thorax**
  - **Gonaden**
- **Kann man das kombinieren??**

Imag.Chain-Shielding/AEC

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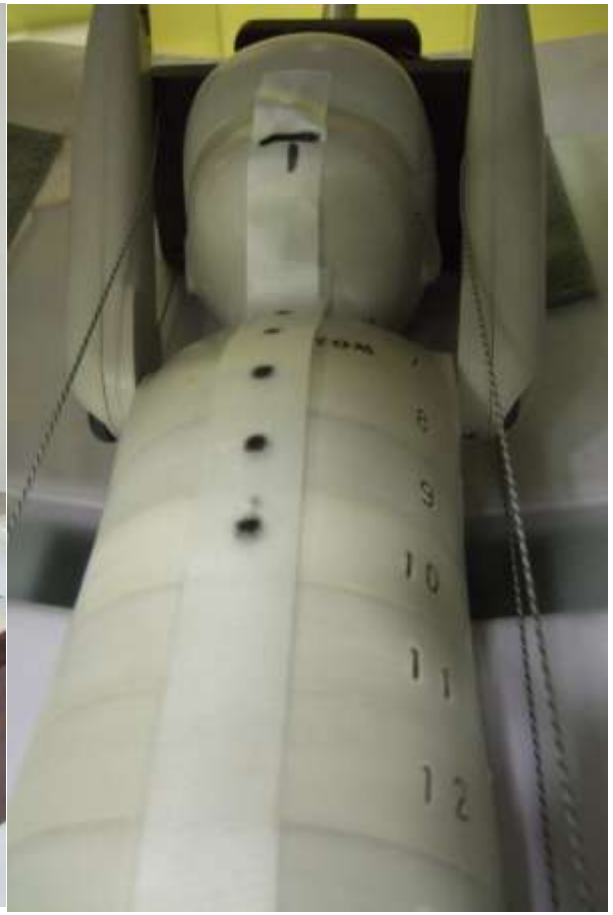
- **Baby & Kinderphantom**



Imag.Chain-Shielding/AEC

- **Scans (Baby & Kind):**
  - **Kein Bismuth**
  - **Bismuth nicht beim Scoutview aber Scan**
  - **Bismuth bei Scoutview und Scan**

  - **Fixe mAs Werte = 100% Dose**
  - **Z – Modulation**
  - **XYZ – Modulation**

Baby - Shielding/AEC

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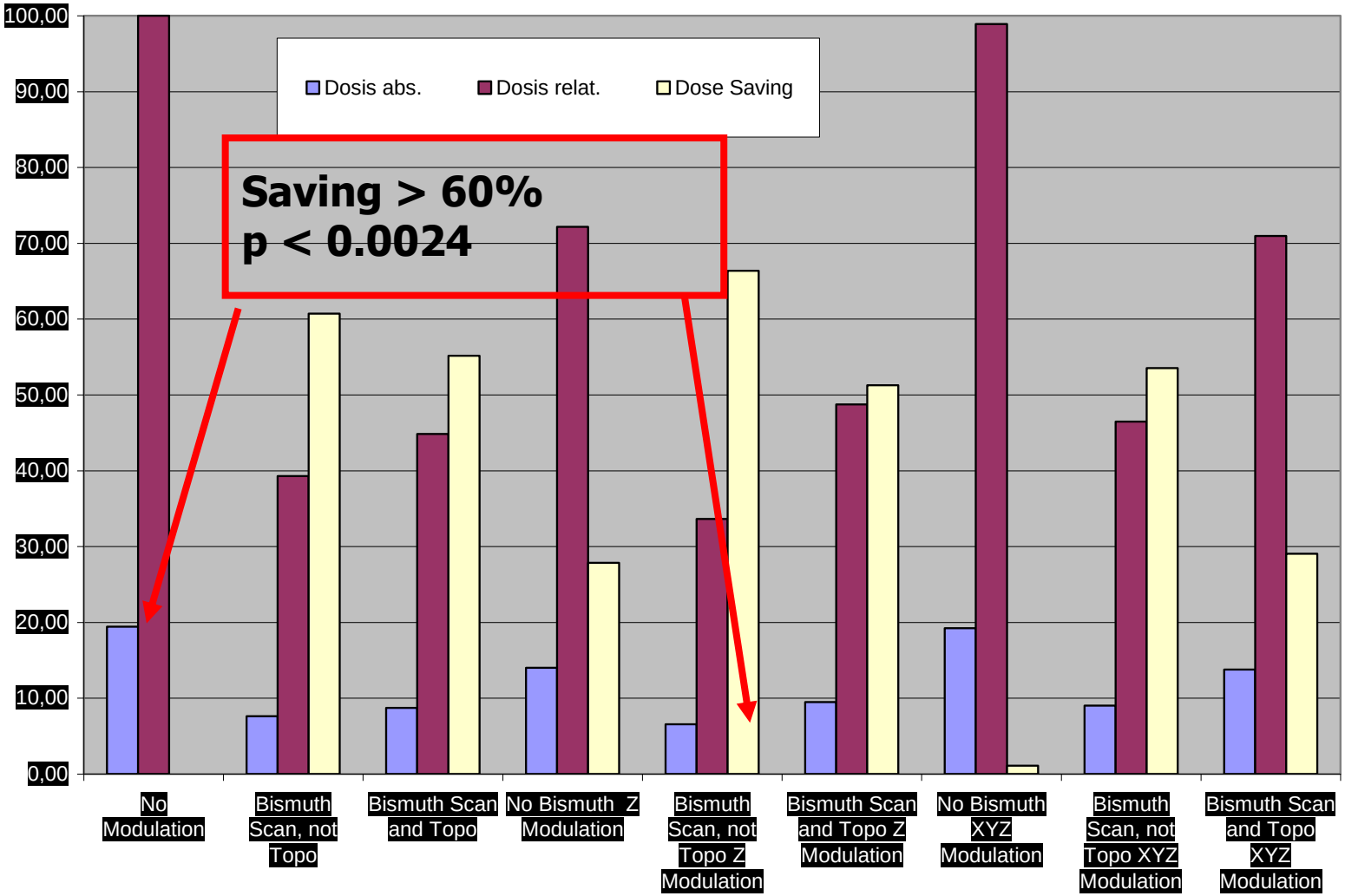

Child - Shielding/AEC

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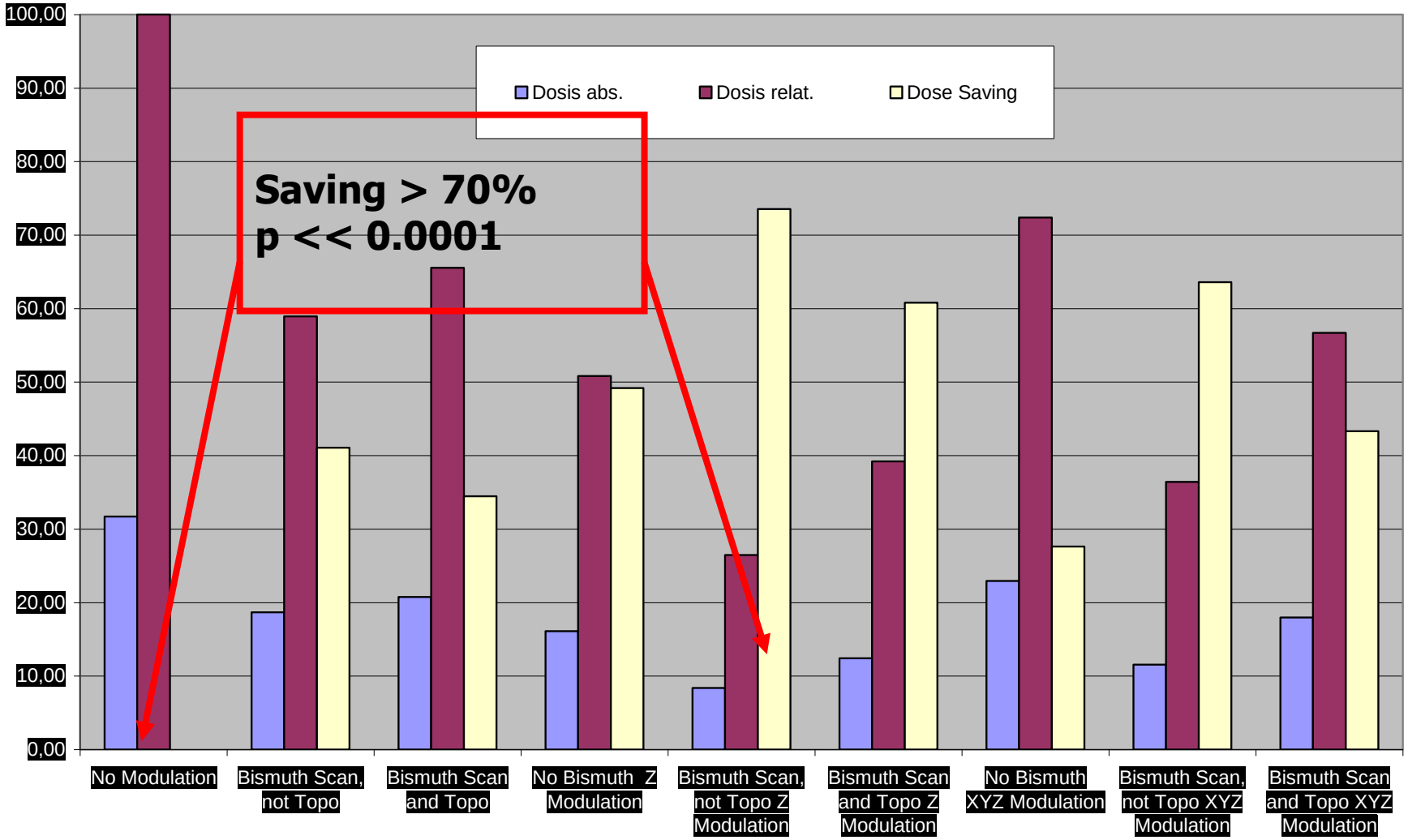

Imag. Chain: Technik

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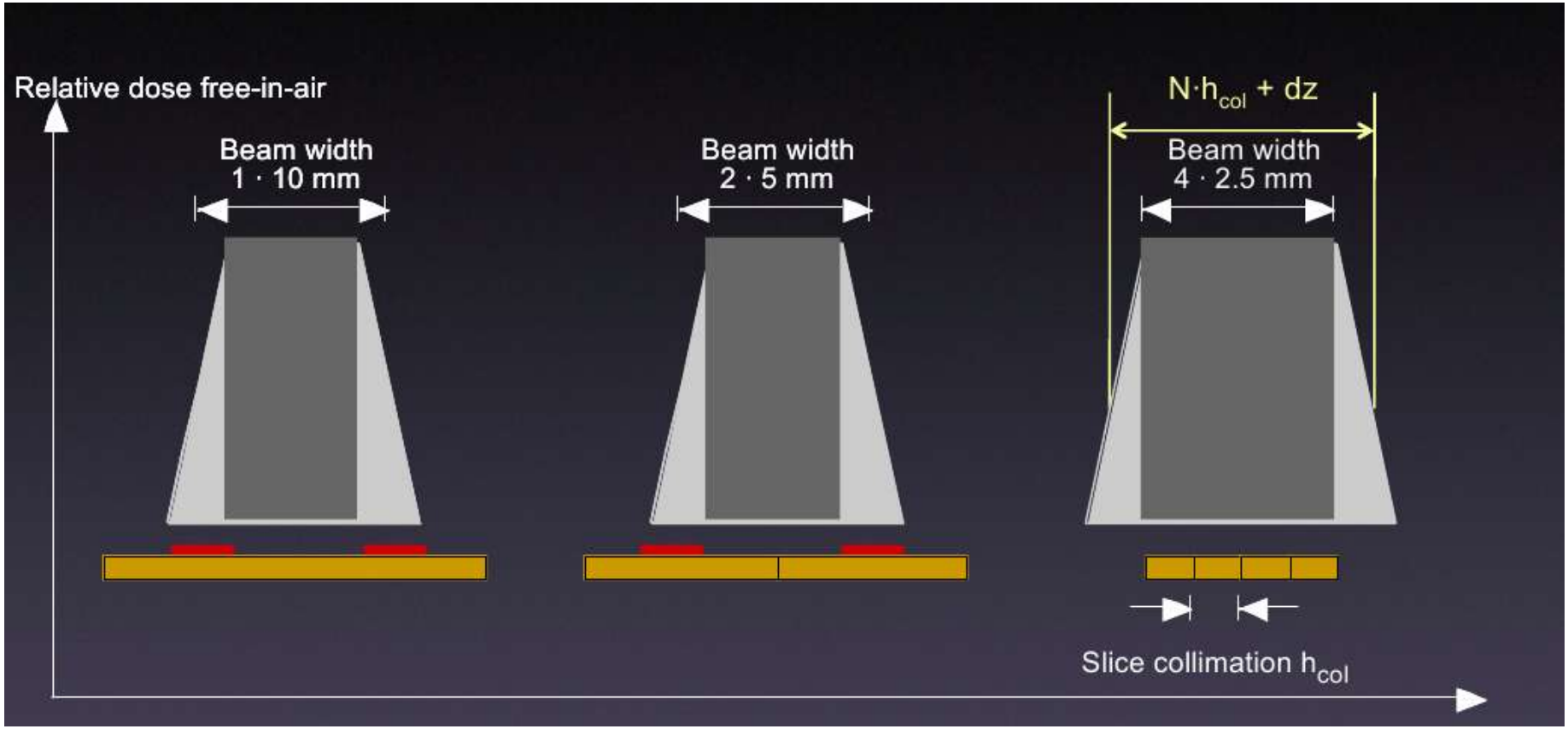
- **Overbeaming**



von H.D.Nagel, Philips Medizinsysteme, Clinical Science CT, Hamburg /D

Imag. Chain: Technik

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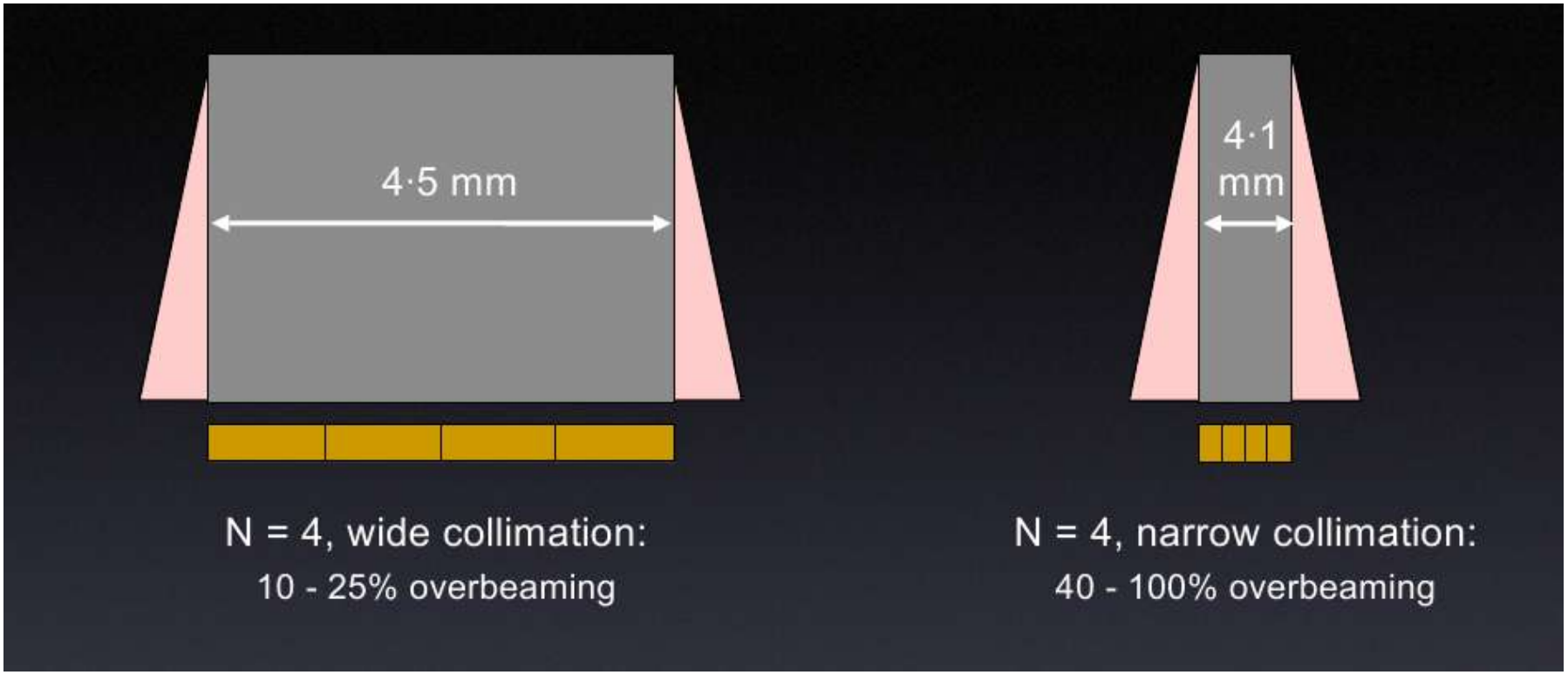
- **Overbeaming**



von H.D.Nagel, Philips Medizinsysteme, Clinical Science CT, Hamburg /D

Imag. Chain: Technik

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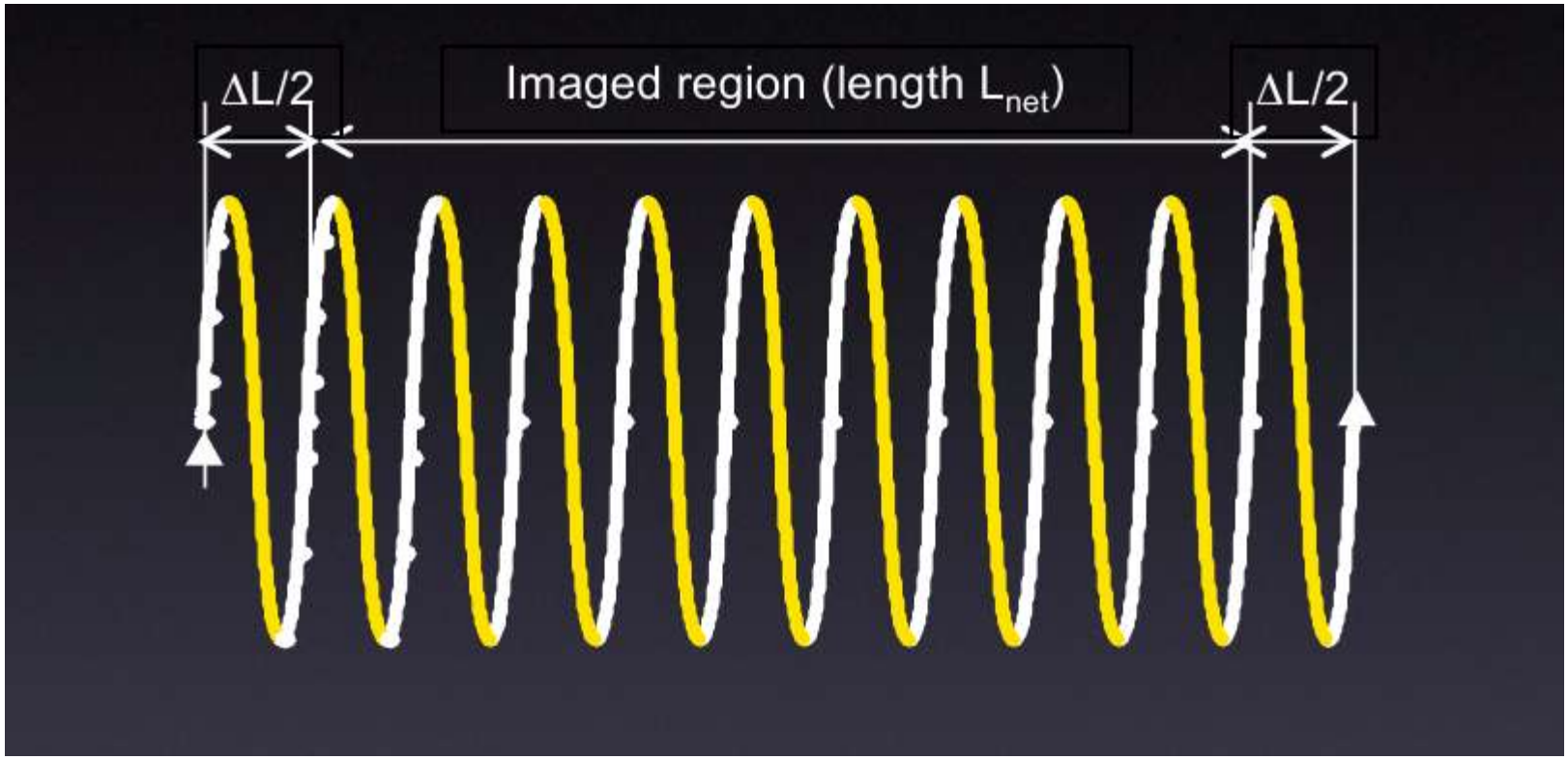
- **Overranging**



von H.D.Nagel, Philips Medizinsysteme, Clinical Science CT, Hamburg /D

Imag. Chain: Technik

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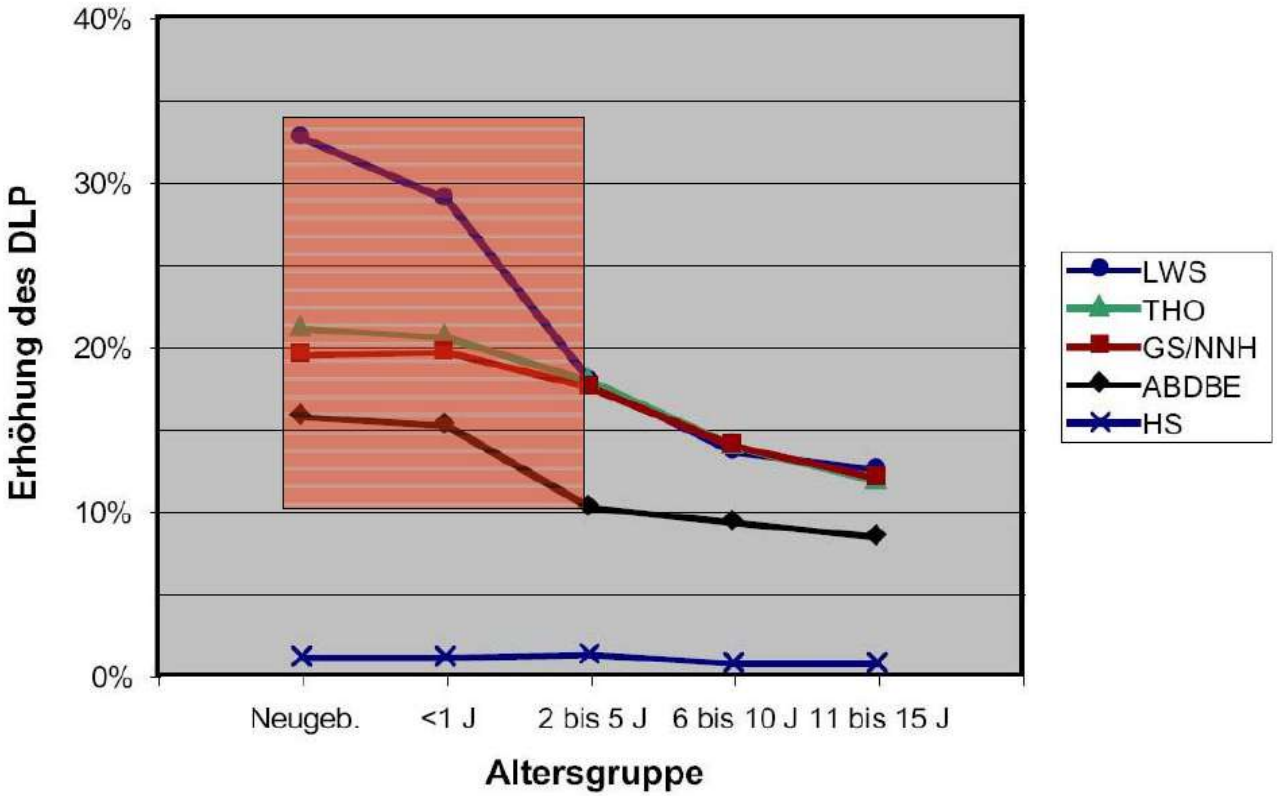
‚Overranging'



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Imag. Chain: Technik

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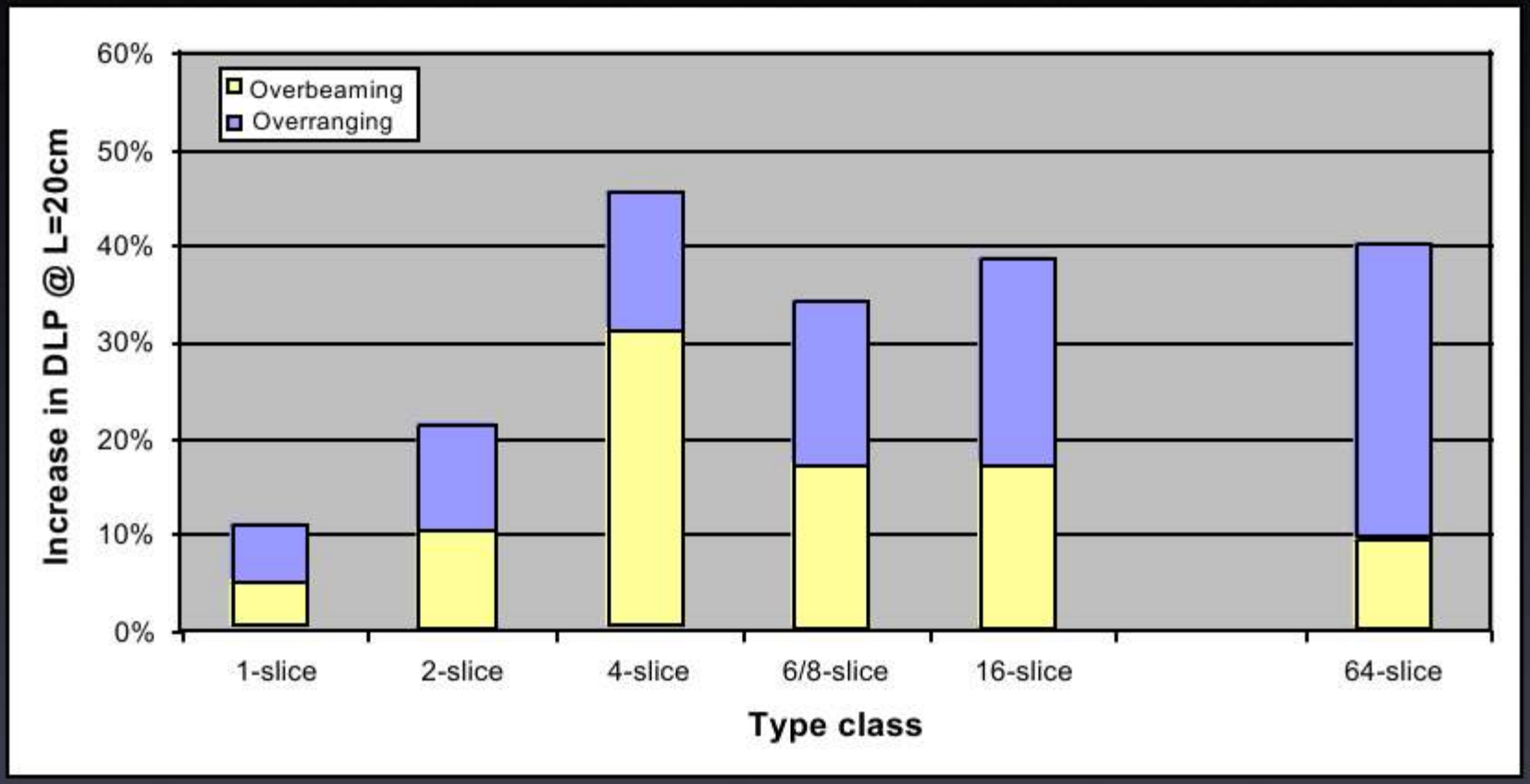

von H.D.Nagel, Philips Medizinsysteme, Clinical Science CT, Hamburg /D

Overranging/beaming

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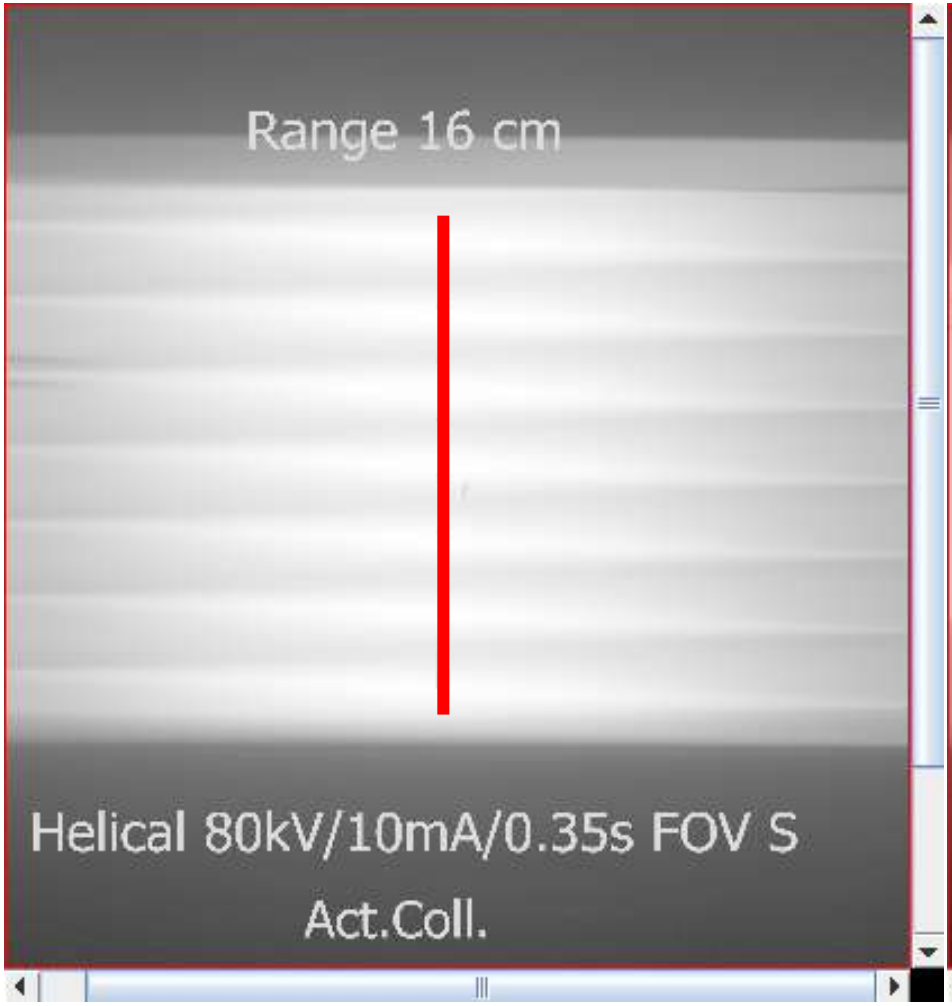

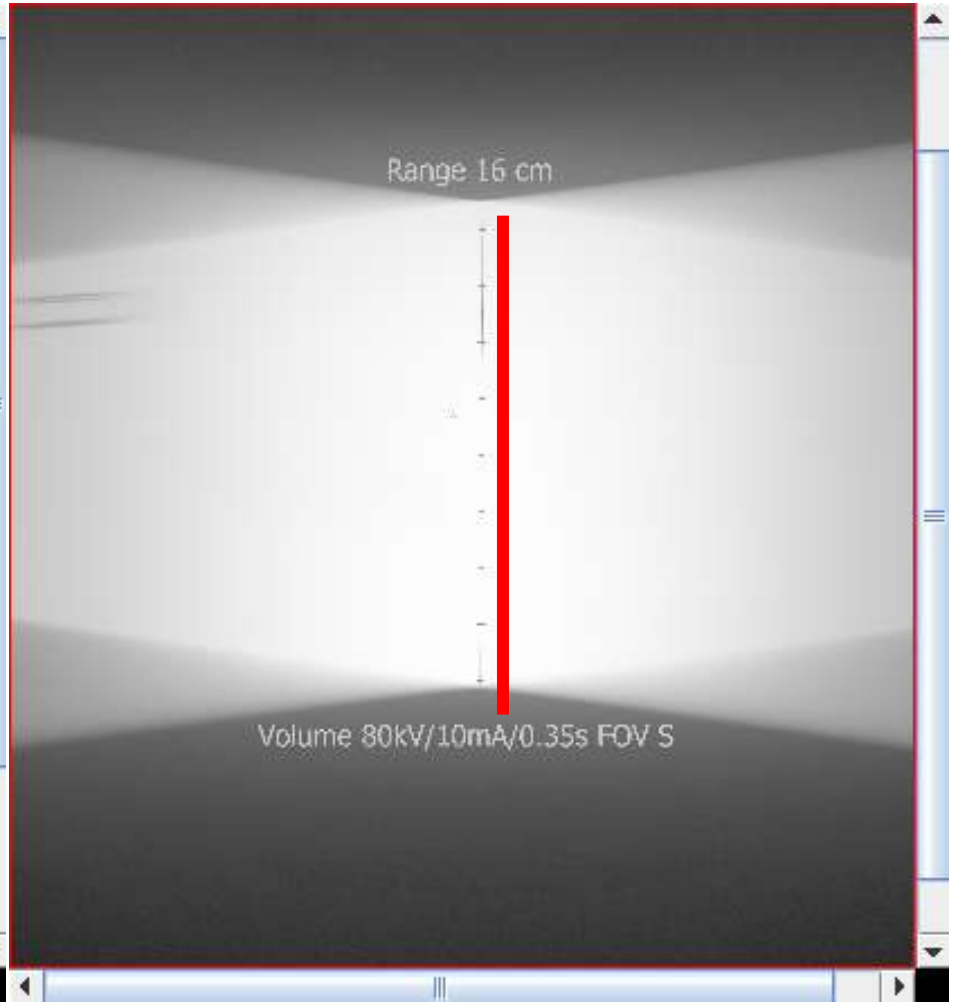

Imag. Chain: Technik

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Helical (0.5 x 32)	**Scanlength 4.0cm**	**161%**
Helical (0,5 x 64)	**Scanlength 4.0cm**	**182%**
Volume	**Scanlength 4.0cm**	**100%**
Sequence	**40 x 1.0mm**	**541%**

CT-Phantom 32cm, DLPc =Center dose, PTW-Chamber 9001 – 10cm, 120 kV, 160 mAs eff,
UDoz.Dr.Mag.Stücklschweiger / Mag. Guss, Strahlenschutzstelle Univ.-Klinikum Graz

Imag.Chain - Rauschen

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$$D \propto \frac{B}{\sigma^2 \cdot a^2 \cdot b \cdot h} \quad with \;\; B = \exp(\mu \cdot d)$$

$$D \propto \frac{B}{\sigma^2 \cdot a^2 \cdot b \cdot h} \quad with \;\; B = \exp(\mu \cdot d)$$

where

D = patient dose
B = attenuation factor of the object
μ = mean attenuation coefficient of the object
d = diameter of the object
σ = standard deviation of CT numbers (noise)
a = sample increment
b = beam width (sample width)
h = slice thickness

- **Rauschen (Brook Theorem)**

Rauschen ≈ 1/ √ mA
Rauschen ≈ 1/ √ Rotationszeit
Rauschen ≈ 1/ √ Schichtdicke

Imag. Chain - Rauschen

- **Kinder Rauschen ↑:**
  ↓ Dosis benutzt
  ↓ absolute Absorption
  ↓ relative Absorption:
    - **Weniger Fett & Muskulatur**
    - **Knochen geringer kalzifiziert**

Imag. Chain - Rauschen

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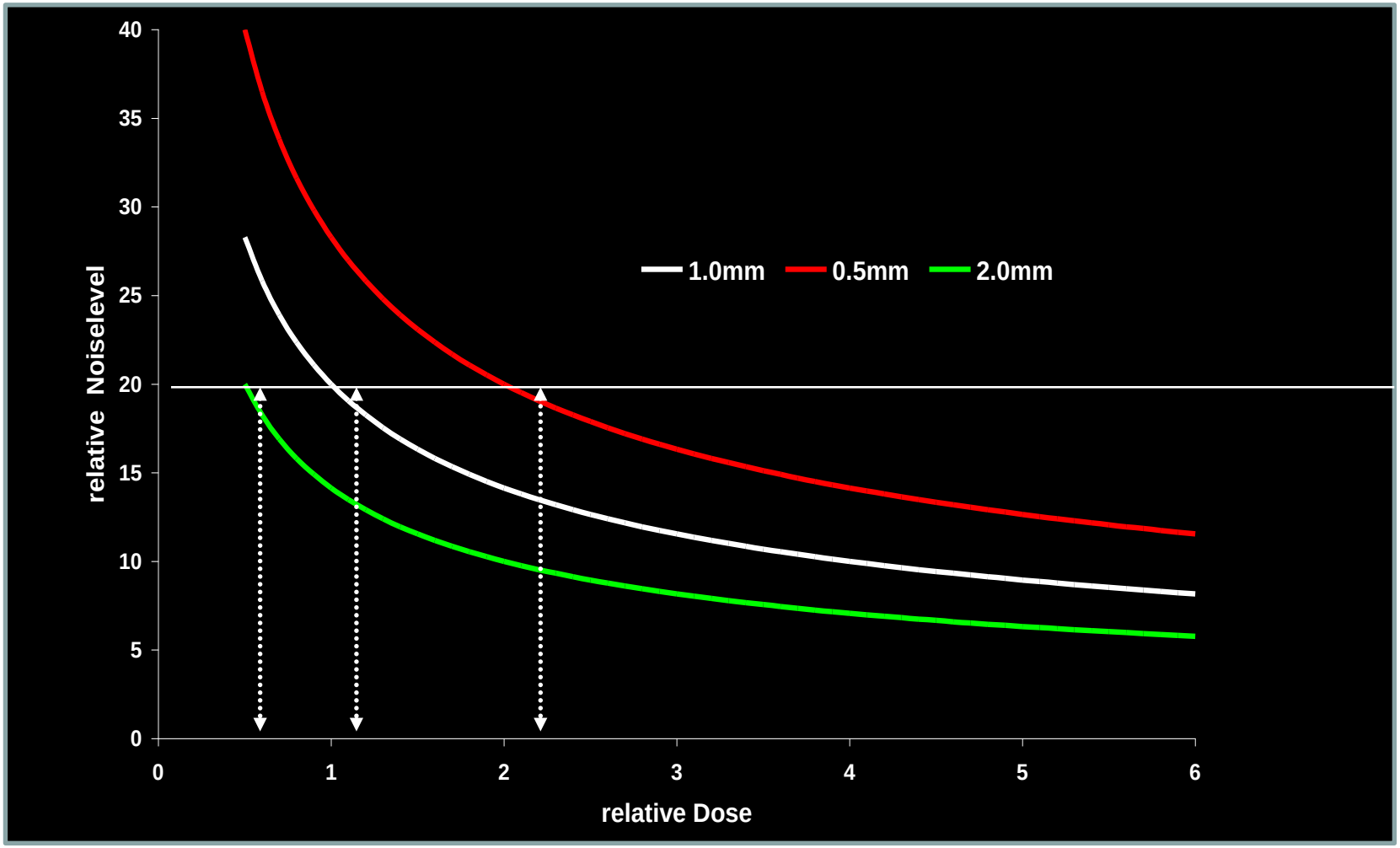
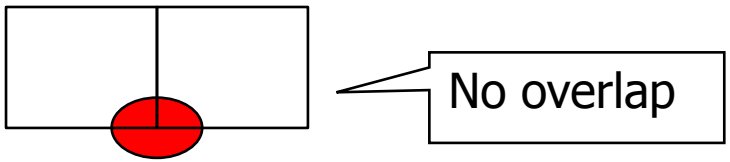
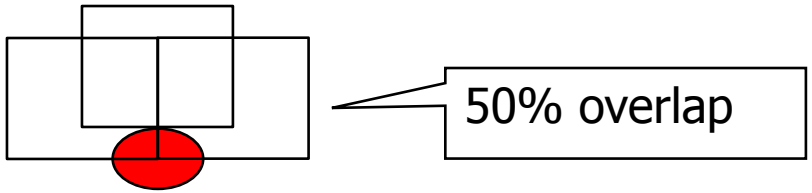


Imag.Chain-Schichtdicke

- **Sampling Theorem (Nyquist Frequenz):**
  Aufnahmesystem muß doppelte Auflösung haben
  Aber: MSCT → überlappende Schichten (Increment 50% Schichtdicke) → geometrische Auflösung ↑ OHNE DOSISERERHÖHUNG!!!!





Imag. Chain- mAs

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- **mAs – lineare Zusammenhang mit Dosis ➔doppelte mAs ➔ doppelte Dosis**
- **Erhöhung von 4.0cm Körper DM ➔ 2x mAs für gleiches Rauschniveau**
- **Halbe Schichtdicke ➔ doppelte mAs für gleiches Rauschniveau**

Imag. Chain - kV

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- **kV – quadratische Dosisabhängigkeit:**
  - **120 kV → 80kV:**
    - **80=2/3 * 120**
    - **(2/3)2 = 4/9 ≈ 50% Dosis**
    -
  - **120 kV → 100 kV:**
    - **100=5/6 * 120**
    - **(5/6)2 = 25/36 ≈ 66% Dosis**

Contrast ↑

Imag.Chain - Kernel

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- **Convolution**

1 1	15 1	38 1	40 1	7 1	15 1
255 1	3 1	240 1	9 1	10 1	11 1
19 1	8 1	5 1	0 1	3 1	200 1
36 1	100 1	200 1	226 1	225 1	255 1
10 1	20 1	0 1	255 1	100 1	0 1
228 1	193 1	111 1	0 1	0 1	255 1

Imag.Chain - Kernel

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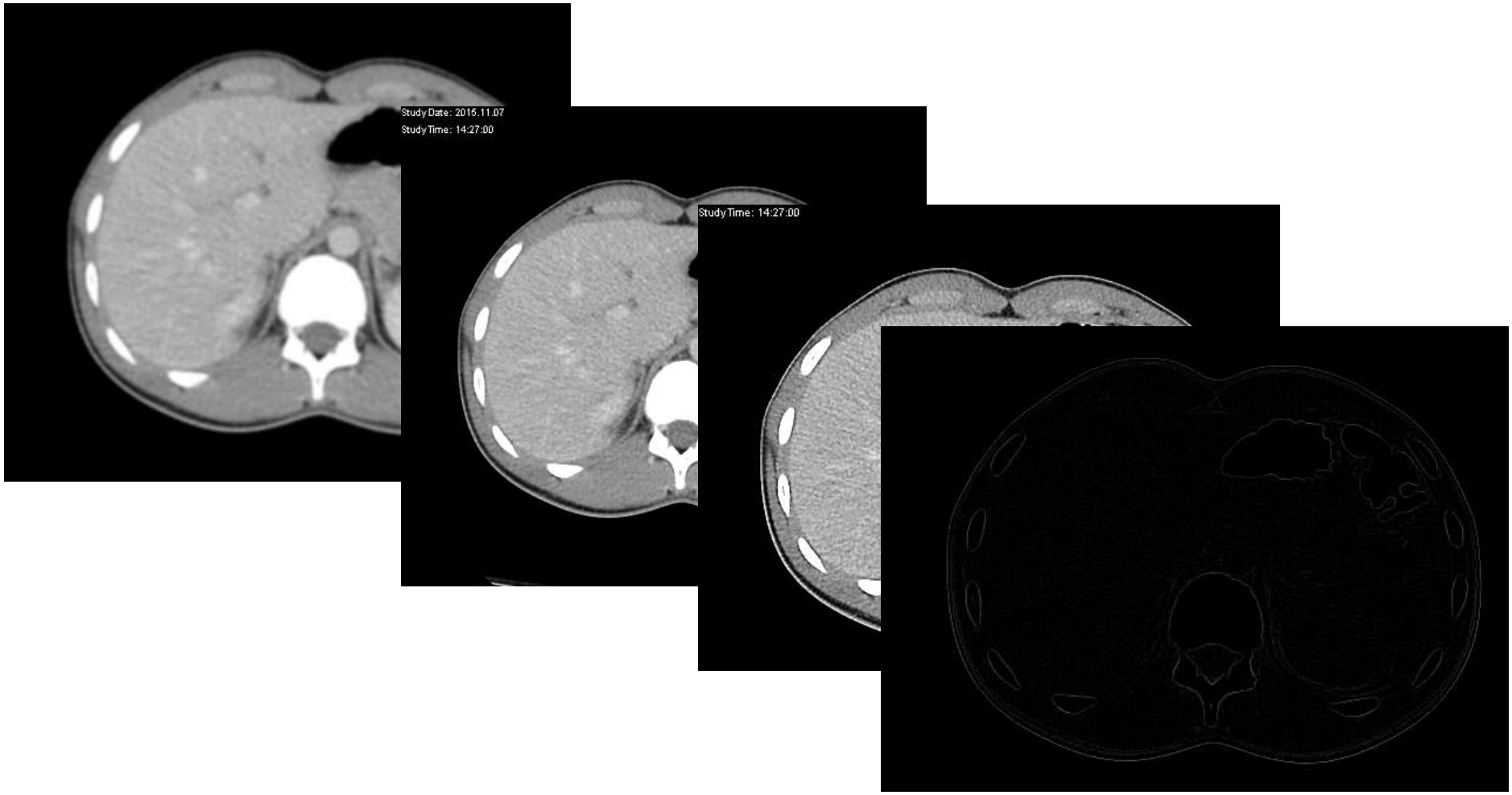
- **Filter Beispiele**



Imag. Chain - Kernel

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- **HiRes Kernel ➔ erhöhen Rauschen**
- **Cave: kein HiRes Kernel für „automated exposure control" (AEC)**

Lee, C. H., Goo, J. M., Ye, H. J., Ye, S.-J., Park, C. M., Chun, E. J., Im, J.-G. Radiation dose modulation techniques in the multidetector CT era: from basics to practice.Radiographics, 28(5):1451–1459, 2008.
URL http://dx.doi.org/10.1148/rg.285075075.

Imag.Chain - Kernel

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- **Kernel – können wir**
- **Dosis sparen???????**

- **YES WE CAN!!!!**
  - **Kinderradiologie Graz → neuer dosissparender Kernel eingeführt**

≈ 50 % Dosiseinsparung sollte möglich sein

Imag.Chain - Kernel

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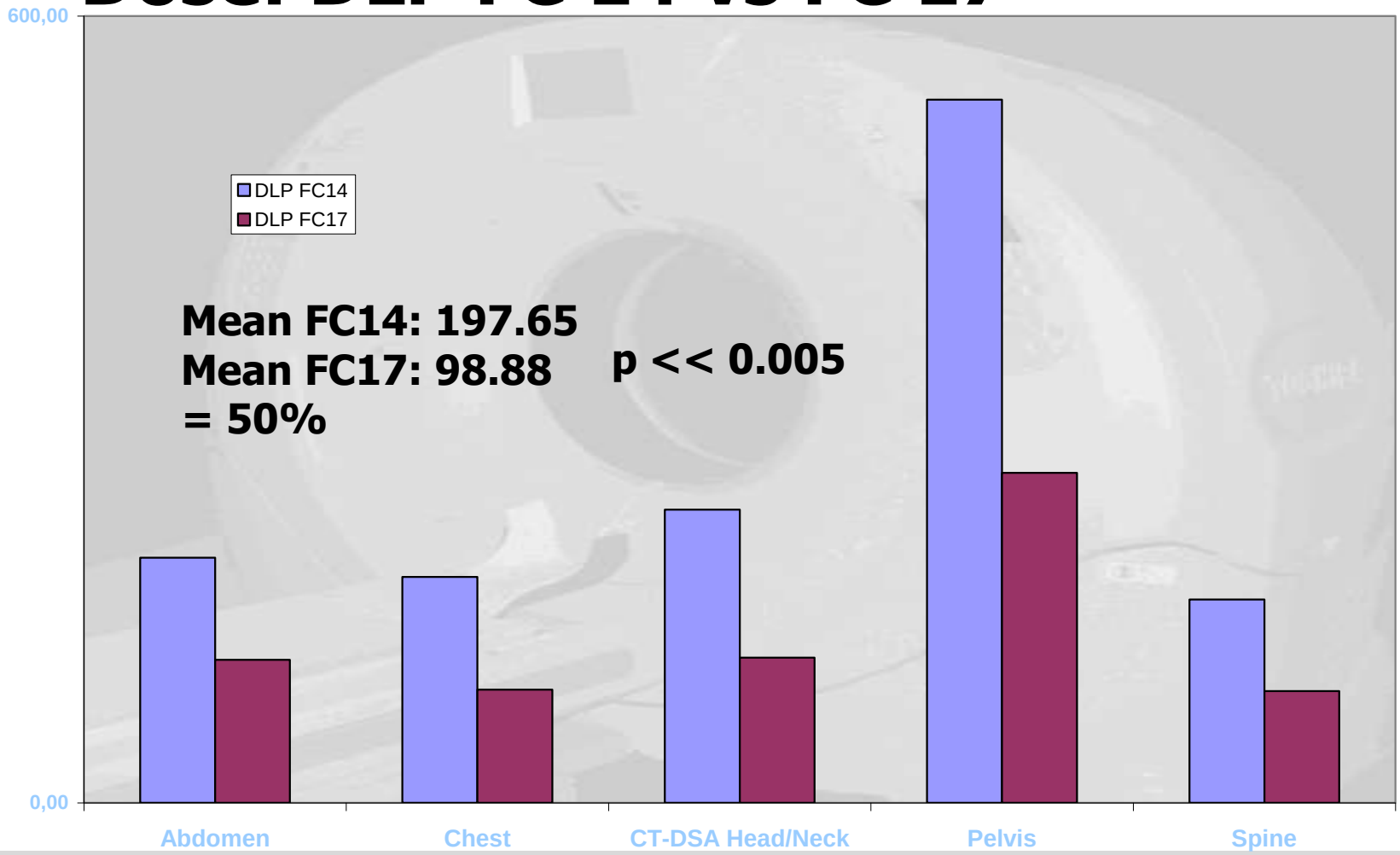
- **Dose: DLP FC 14 vs FC 17**



Imag. Chain – Rekonst.

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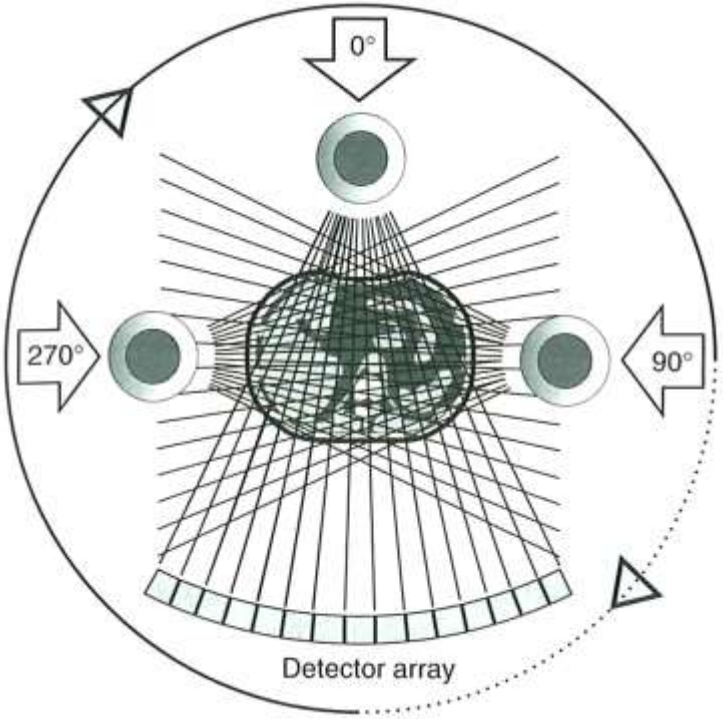
- Bisher im CT „Back Projektion" für Bildrekonstruktion verwendet



- Nun neue, statische Verfahren verfügbar – ↓Rauschen ➔Dosis↓

Dosis - Protokolle

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- **mAs:**
  Rogalla – Stöver Formula (kV=120):

mAs = (Gewicht (kg) +5) x f

Factor f:	Thorax	=1.0
	Abdomen/Becken	=1.5
	Schädel	=2-5

Dosis – Protokolle

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- **Absolute Dosisangaben unmöglich**
  - **CT Geräte unterschiedlich**
  - **Angaben können nicht von einer Maschine auf andere kopiert werden**
    - **ua Bauartunterschiede (Fokus-Achs-Abstand)**
    - **Unterschiedliche Werte für verschiedene Techniken (single slice, spiral, volume etc.)**
- **Allg. Richtlinien möglich**
- **Phantomstudien der eigenen Maschine notwendig (Kalibration)**

Dosis - Protokolle

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- **Image Gently / USA**
  - **Nun auch für 80 - 120 kV**
  - **Reduktionsfaktoren**
    - **Basieren an optimierter Untersuchung von Erwachsenen (??!!??)**

Image Gently

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Table I: mAs Reduction Factors for the Pediatric Body

Abdomen/	Abdomen/	Abdomen/	kVp	mA	Time (sec)	Pitch During Measured CTDIvol	Pitch During Clinical Exam	Adult SSDE					
Pelvis:	Pelvis:	Pelvis:	120	200	1	1,0	1,0	23					
AP Thickness (cm)	LAT Thickness (cm)	Effective Diameter (cm)	Mass (kg)	Age	*Limited* mAs Reduction Factor	*Moderate* mAs Reduction Factor	*Aggressive* mAs Reduction Factor	*Limited* mAs SSDE (mGy)	*Moderate* mAs SSDE (mGy)	*Aggres-sive* mAs SSDE (mGy)	*Limited* NB = Adult SSDE Estimated mAs	*Moderate* NB = 0.75 * Adult SSDE Estimated mAs	*Aggressive* NB = 0.5 * Adult SSDE Estimated mAs
10	14	11,8	4	newborn	0,52	0,39	0,25	23	17	11	104	77	50
11	16	13,3	10	1 yr	0,55	0,42	0,29	23	18	12	110	84	59
14	20	16,7	18	5 yr	0,62	0,50	0,39	23	19	15	123	100	78
16	25	20,0	33	10 yr	0,70	0,62	0,53	23	20	18	140	123	106
19	29	23,5	54	15 yr	0,80	0,74	0,68	23	21	20	160	148	137
22	32	26,5	65	20 yr	0,89	0,86	0,83	23	22	22	179	172	165
25	35	29,6	75	md adult	1,00	1,00	1,00	23	23	23	200	200	200
31	41	35,7	110	lg adult	1,21	1,28	1,35	23	25	27	242	256	270

http://www.imagegently.org/Procedures/Interventional-Radiology/Protocols

Image Gently

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	kVp	mA	Time (sec)	Pitch Abdomen	Pitch Thorax
Abdomen:	fill in	fill in	fill in	fill in	fill in

		Abdomen		Thorax	
PA Thickness (cm)	Approx Age	mAs Reduction Factor (RF)	Estimated mAs = BL x RF	mAs Reduction Factor (RF)	Estimated mAs = BL x RF
9	newborn	0,43	#WERT!	0,42	#WERT!
12	1 yr	0,51	#WERT!	0,49	#WERT!
14	5 yr	0,59	#WERT!	0,57	#WERT!
16	10 yr	0,66	#WERT!	0,64	#WERT!
19	15 yr	0,76	#WERT!	0,73	#WERT!
22	small	0,90	#WERT!	0,82	#WERT!
25	med adult	1,0	fill in	0,91	#WERT!
31	large	1,27	#WERT!	1,16	#WERT!

http://www.imagegently.org/Procedures/Interventional-Radiology/Protocols

Protokolle – Graz: kV

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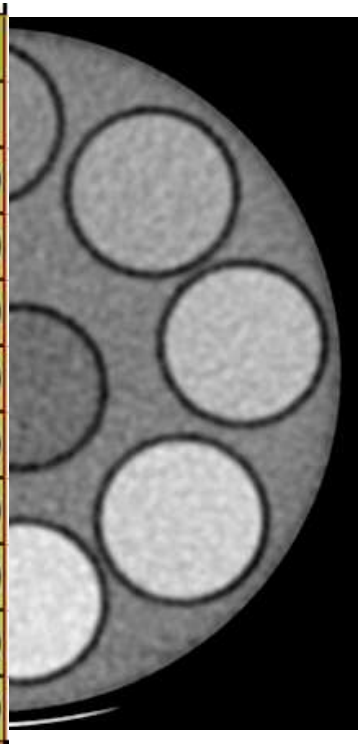
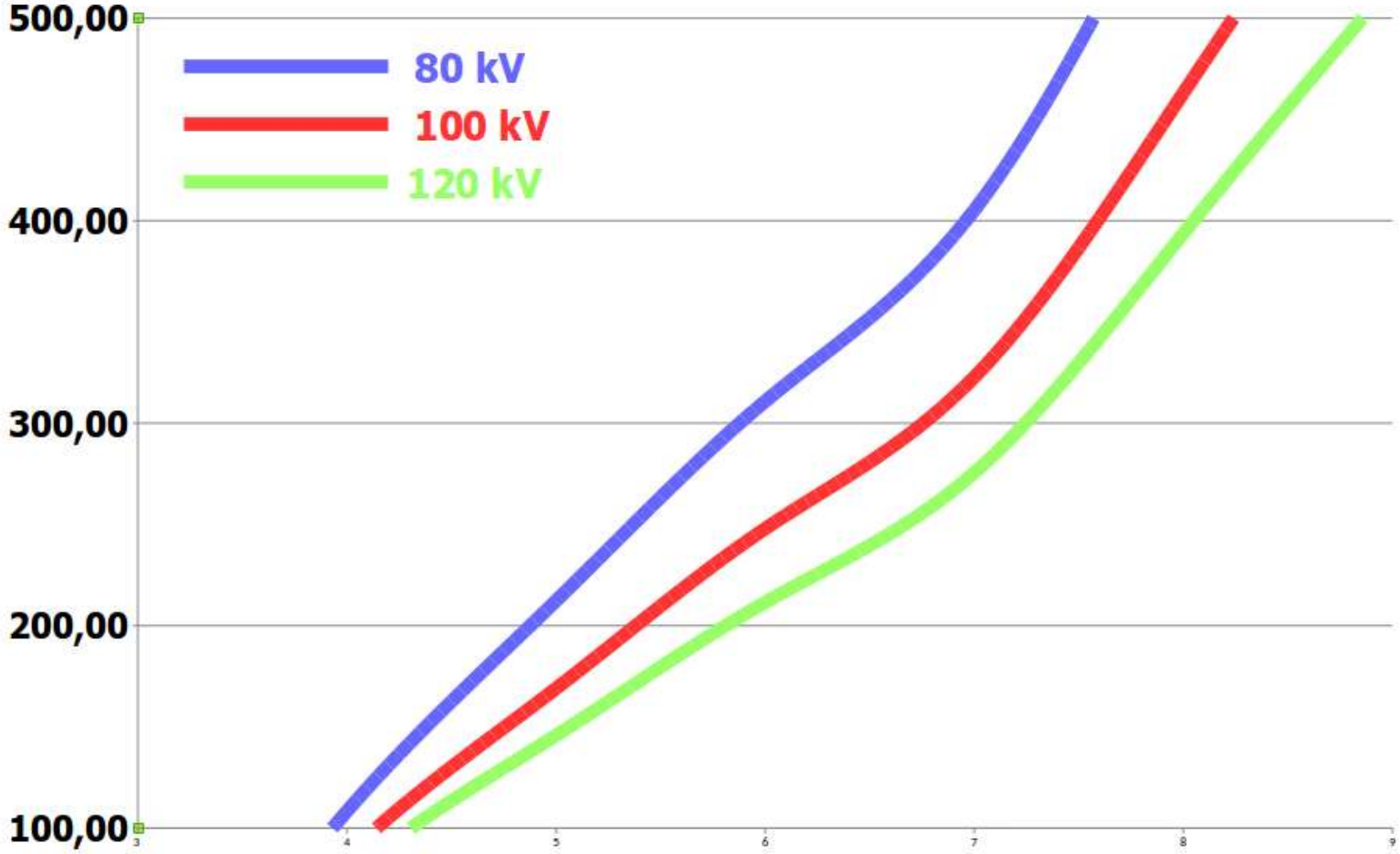
- **HU ändern sich in Abhängigkeit von kV**
  - **Scannen bei 80/100/120 kV gleiche Dosis**

		70mA	40mA	25mA
Phantom	Curve	80 kV	100 kV	120 kV
Air	1	-996,00	-992,00	-992,00
Fat	2	-142,50	-124,00	-113,70
Water	3	7,90	8,10	9,30
1	4	108,40	86,80	76,10
2	5	212,30	169,00	145,80
3	6	310,80	247,90	211,50
4	7	405,20	322,70	275,50
5	8	584,50	463,10	393,70
6	9	778,10	614,50	517,30



Protokolle – Graz: kV

Medical University of Graz



Protokolle – Graz: kV

- 1 – 2 (5)a: 80kV
- 2(5) – 14a: 100kV
  - Koronar CT: 100kV
- > 12a: 120kV
- Was ist mit Patienten nicht altersentsprechenden BMI?
  - Ca 30% weniger Dosis als altersüblich

Optimale Dosis???

- **Wie finden?**
  - **NB: Rauschen inverse proportional Schichtdicke**
  - **→ Halbe Schichtdicke → doppeltes Rauschen**
  - **Warum nicht für Optimierung verwenden??**

Optimale Dosis….

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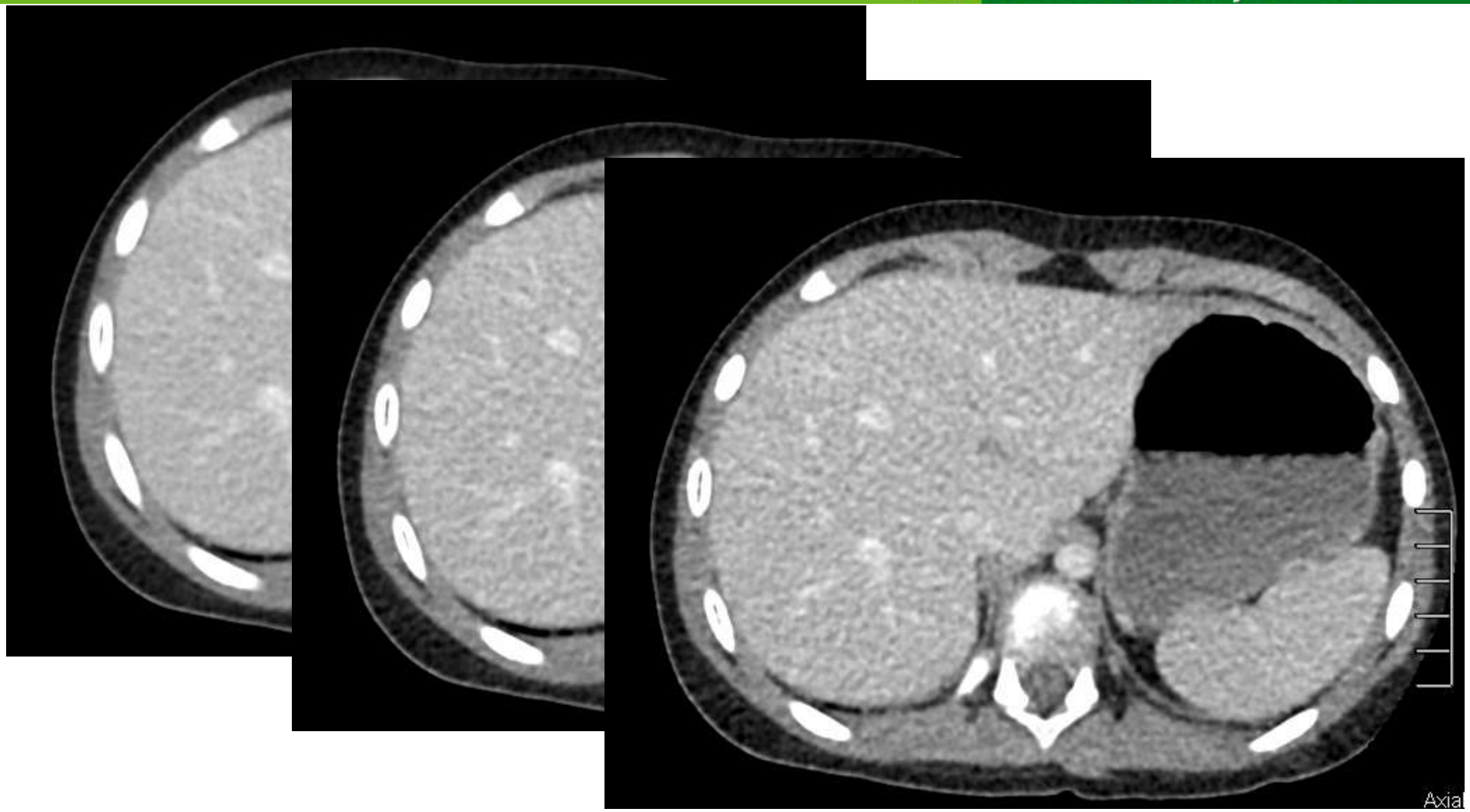

Image Quality – CT

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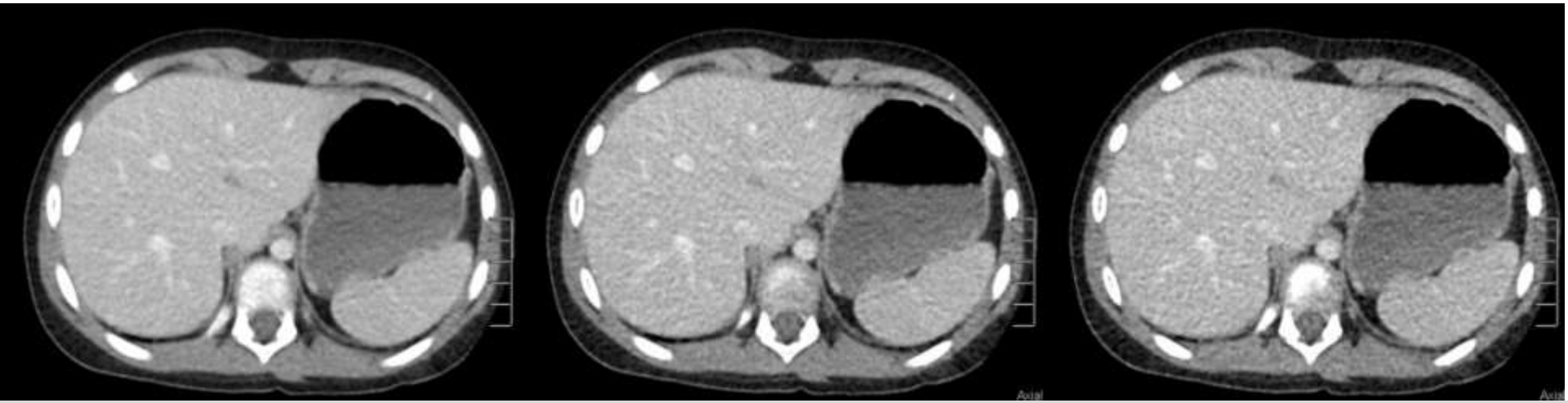
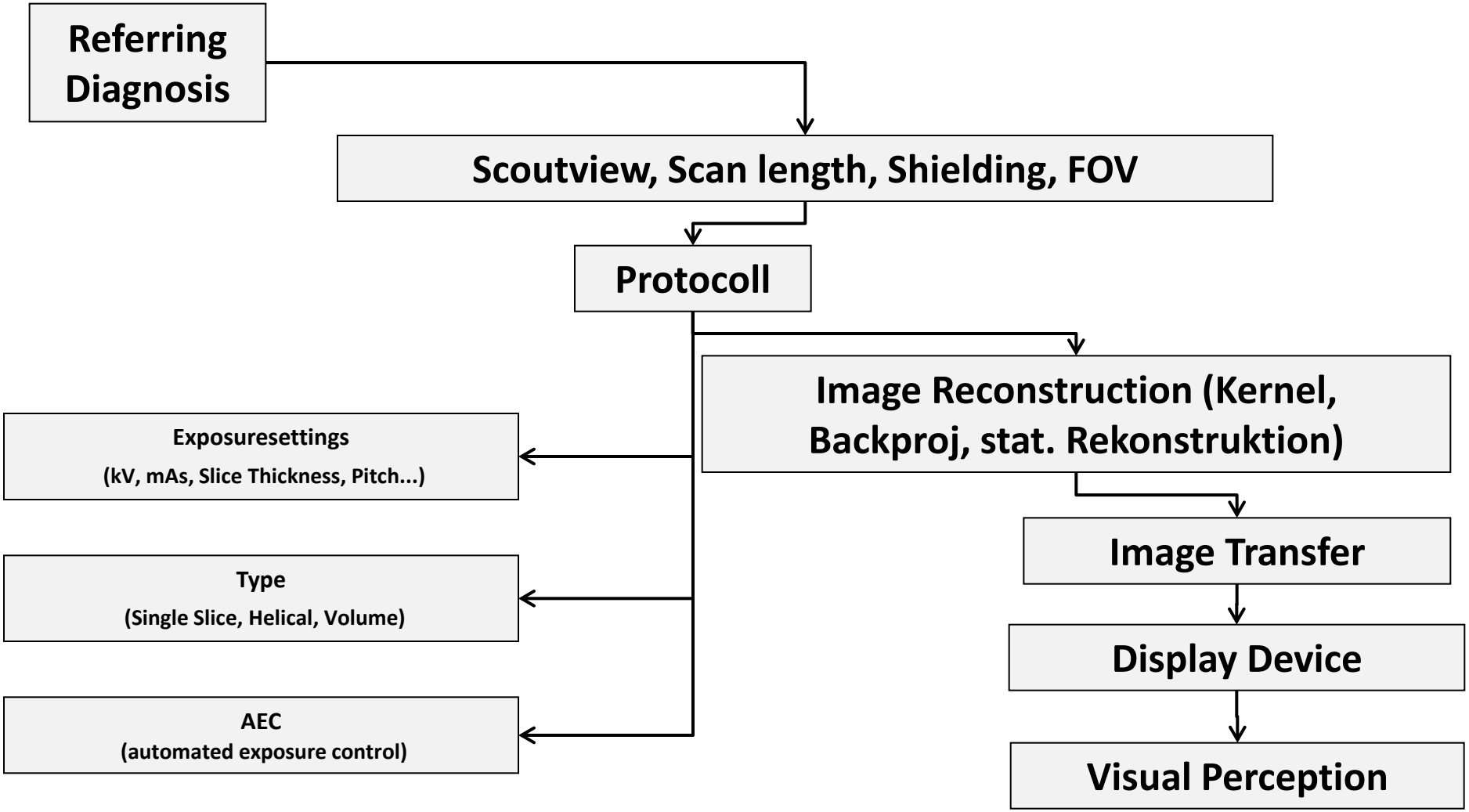
- **Sorantin‘scher „Halve Slice Thickness Approach“:**
  - **Bilder mit halber Schichtdicke ➔ Qualität gut ➔ nächste Untersuchung mit 20% Dosis🡻**
  - **Beginne von vorne!**



E.Sorantin, „Abdomen CT bei Kindern – Wann? Wie?“, Jena 2015

„Imaging Chain"-CT

Medical University of Graz



E.Sorantin, Pediatr Radiol. 2008, EJR 2011

Hypothese

- „Imaging Chain“:

60% Dosisreduktion mit JEDEM CT MÖGLICH

- JUST DO IT …..

Kontrastmittel…..

Medical University of Graz

Pediatric CT - Calculation i.v.CM, GFR, SSDE

		study date	17.05.2012
Patient	firstname surname		
age(years)	4	sex	female
flow (ml/s)	2,0	creatinine (mg/dl)	0,9
weight (kg)	30		
height (cm)	118	GFR(ml/min/1,73m²)	131,111
0,9% NaCl(ml/kg)	3		

Size-Specific Dose Estimates (SSDE) (Th. + Abd.)

	AP(mm)	LAT(mm)	32 PMMA corr.factor	16 PMMA corr.factor
	126,90	199,90		
summed		32,7	2,08	1,02

16 cm PMMA	CTDI vol	2,20	SSDE(mGy)	2,24	

contrast media volume (ml)				corrective factor	
Age <1a	2,5	IOMERON	neck	1,6	liver 0,8 2,2
Age 1-2a	2		chest	1,2	pelvis 2,2
Age >2age	1,5		Abdomen	2,8	kidneys 0,8 4,8

Organ	KM Volume 300mg/ml	KM Volume 350mg/ml (>40kg)	Delay	0,9%NaCl	comment
Head	45,0	use 300mg/ml	50,0	50,0	mastoiditis, sinus venous thrombosis, orbital phlegmon
Neck	45,0	use 300mg/ml	54,0	50,0	> 40kg Delay 70s
Chest	30,0	use 300mg/ml	27,0	50,0	> 40kg Delay 30s
Abdomen	45,0	use 300mg/ml	63,0	50,0	> 40kg Delay 70s
Liver arterial	30,0	use 300mg/ml	18,0	50,0	> 40kg Delay 25
Liver (late)	45,0	use 300mg/ml	49,5	50,0	> 40kg Delay 70s
PELVIS	45,0	use 300mg/ml	49,5	50,0	> 40kg Delay 70s
Kidney (arterial)	30,0	use 300mg/ml	18,0	50,0	> 40kg Delay 20s
kidneys (clearance)	45,0	use 300mg/ml	108,0	50,0	
CTA 1 system	30,0	use 300mg/ml	Bolustrackiung	50,0	
CTA 2 systems	45,0	use 300mg/ml	Bolustrackiung	50,0	
CTA carotis	45,0	use 300mg/ml	Bolustrackiung	50,0	
Head(brain death)	58,5	use 300mg/ml	20,0	50,0	diagnosis of brain dead

Kontrastmittel …

- **Bolus Tracking Treshhold:**
  - **80 kV** **280 HU (2-5a)**
  - **100 kV** **230 HU (5-12a)**
  - **120 kV** **200 HU (>12a)**
- **Achtung:**
  - **Liegt ROI am Anfang/Ende der Scans?**
  - **Wenn nicht Startverzögerung messen**
  - **Pitfall: Wann kommt Atemkommando?**

Kreativ

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- CTA und C ne Run“
  - z.B.: Tran

Zusammenfassung

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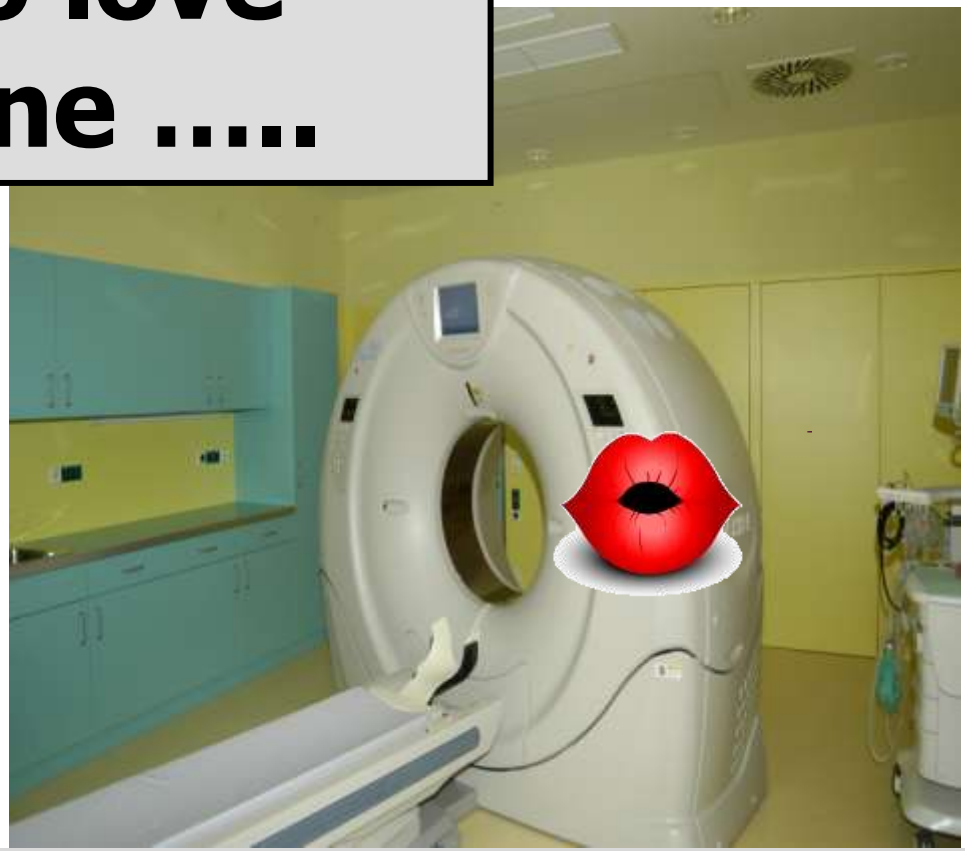
- **Simply speaking….**

You have to love your machine …..