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Approximating Dose and Risk in Dental CT and Cone Beam CT

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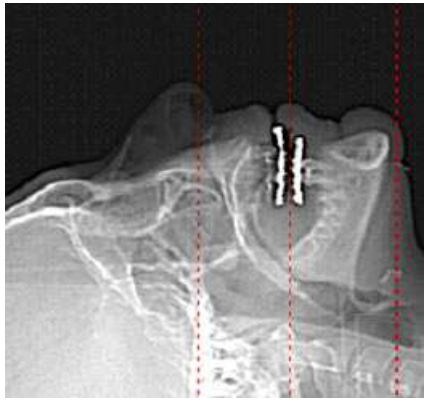
Image Diagnostic Technology Ltd

Dental (CB)CT Scans



- **Bony anatomy of Mandible, Maxilla or Both**
- **Useful for:**
  - **planning dental implants**
  - **maxillofacial surgery**
  - **TMJ and airway analysis**
  - **impacted and supernumerary teeth**
  - **root canals, root fractures etc**

- **High natural contrast**
- **High resolution**
- **Low dose**

Rationale

Clinicians want to know the ~~dose~~ risk (today)

It is better to have an answer that is roughly right than very precisely wrong

It is not good to have no answer at all.

Outline of Presentation

Main Topic:

- **How can we calculate doses quickly with sufficient accuracy for the task at hand?**

Underlying Topics:

- **Why do we care about radiation dose?**
- **How accurate do we need to be?**
- **What can we do if we only have limited information?**

IR(ME)R 6.2 Justification of Individual Medical Exposures

Must give appropriate weight to:

a) the specific objectives of the exposure

b) the total potential diagnostic or therapeutic benefits

c) the individual detriment that the exposure may cause

d) the efficacy, benefits and risks of available alternative techniques.

Annals of the ICRP

PUBLICATION 103

The 2007 Recommendations of the International Commission on Radiological Protection

Editor
J. VALENTIN

PUBLISHED FOR

The International Commission on Radiological Protection

by

ELSEVIER

ICRP 103:

“the combined detriment due to excess cancer and heritable effects remains unchanged at around 5% per Sv”

Effective Dose **is a way of describing the dose to a limited region in terms of the whole body dose that would result in the same risk to the patient**

“Effective dose is not recommended for epidemiological evaluations, nor should it be used for detailed specific retrospective investigations of individual exposure and risk.”

Risk varies with Age

Age group (years)	Multiplication factor for risk
<10	x 3
10-20	x 2
20-30	x 1.5
30-50	x 0.5
50-80	x 0.3
80+	Negligible risk

5.7% per Sievert at age 30

RADIATION PROTECTION N° 172 A report prepared by the SEDENTEXCT project 2011

www.sedentexct.eu

How accurate do we need to be?

A factor of 2 change in risk is unlikely to bring about a change in the patient's management.

A factor of 10 would be in line with estimates of risk in other areas.

Cancer: science and society and the communication of risk

Kenneth C Calman

BMJ VOLUME 313 28 SEPTEMBER 1996

This article is based on the Calum Muir lecture, delivered in Edinburgh in September 1996.

Table 2—*Descriptions of risk in relation to the risk of an individual dying (D) in any one year or developing an adverse response (A)*

Term used	Risk range	Example	Risk estimate
High	≥1:100	(A) Transmission to susceptible household contacts of measles and chickenpox[6]	1:1-1:2
		(A) Transmission of HIV from mother to child (Europe)[7]	1:6
		(A) Gastrointestinal effects of antibiotics[8]	1:10-1:20
Moderate	1:100-1:1000	(D) Smoking 10 cigarettes a day[9]	1:200
		(D) All natural causes, age 40[9]	1:850
Low	1:1000-1:10 000	(D) All kinds of violence and poisoning[9]	1:3300
		(D) Influenza[10]	1:5000
		(D) Accident on road[9]	1:8000
Very low	1:10 000-1:100 000	(D) Leukaemia[9]	1:12 000
		(D) Playing soccer[9]	1:25 000
		(D) Accident at home[9]	1:26 000
		(D) Accident at work[9]	1:43 000
		(D) Homicide[9]	1:100 000
Minimal	1:100 000-1:1 000 000	(D) Accident on railway[9]	1:500 000
		(A) Vaccination associated polio[10]	1:1 000 000
Negligible	≤1:1 000 000	(D) Hit by lightning[9]	1:10 000 000
		(D) Release of radiation by nuclear power station[9]	1:10 000 000

What do we mean by "the right answer"?

a) **Use ImPACT Spreadsheet to calculate Effective Doses**

b) **Use Monte Carlo methods to calculate Effective Doses**

c) **Use TLD measurements in a Rando phantom to calculate Effective Doses.**

Effective Dose (E)

$$E = \sum_T H_T w_T$$

H_T = Organ Equivalent Dose
w_T = Tissue weighting factor

Unit = (Sv) Sievert

Effective Dose is proportional to risk of fatal cancer

	w_T value ICRP103
Brain	0.01
Salivary glands	0.01
Skin	0.01
Thyroid	0.04
Oesophagus	0.04
Lung	0.12
Red bone marrow	0.12
Breast	0.12
Bone surface	0.01
Liver	0.04
Stomach	0.12
Colon	0.12
Ovary	0.08
Bladder	0.04
Testes	0.08
Remainder	0.12

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/ejrad

Effective dose range for dental cone beam computed tomography scanners

Ruben Pauwels[a,*], Jilke Beinsberger[a,1], Bruno Collaert[b,2], Chrysoula Theodorakou[c,d,3], Jessica Rogers[e,3], Anne Walker[c,3], Lesley Cockmartin[f,4], Hilde Bosmans[f,5], Reinhilde Jacobs[a,6], Ria Bogaerts[g,7], Keith Horner[d,8], The SEDENTEXCT Project Consortium[9]

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[f] Department of Radiology, University Hospital Gasthuisberg, Leuven, Belgium
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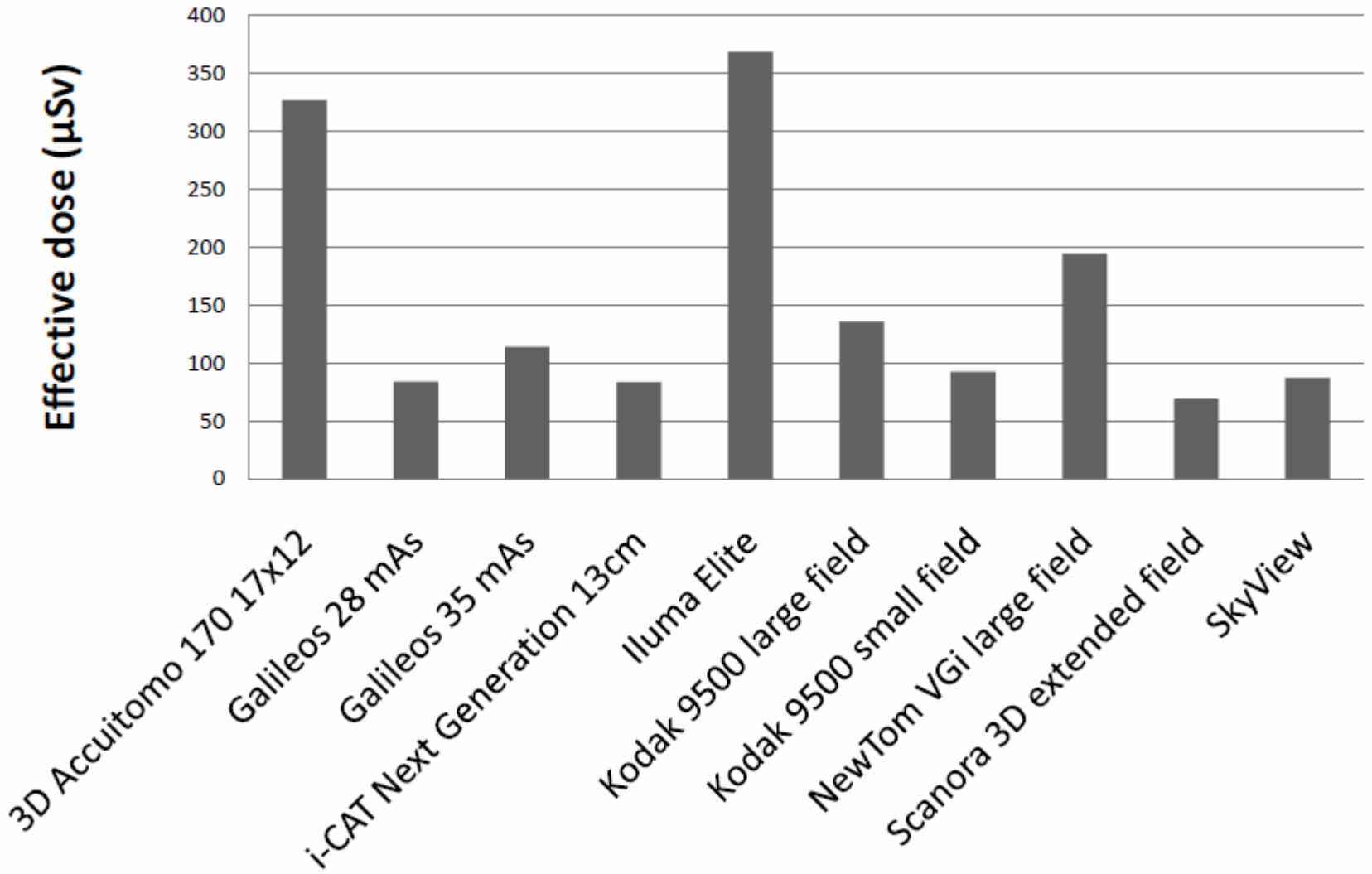
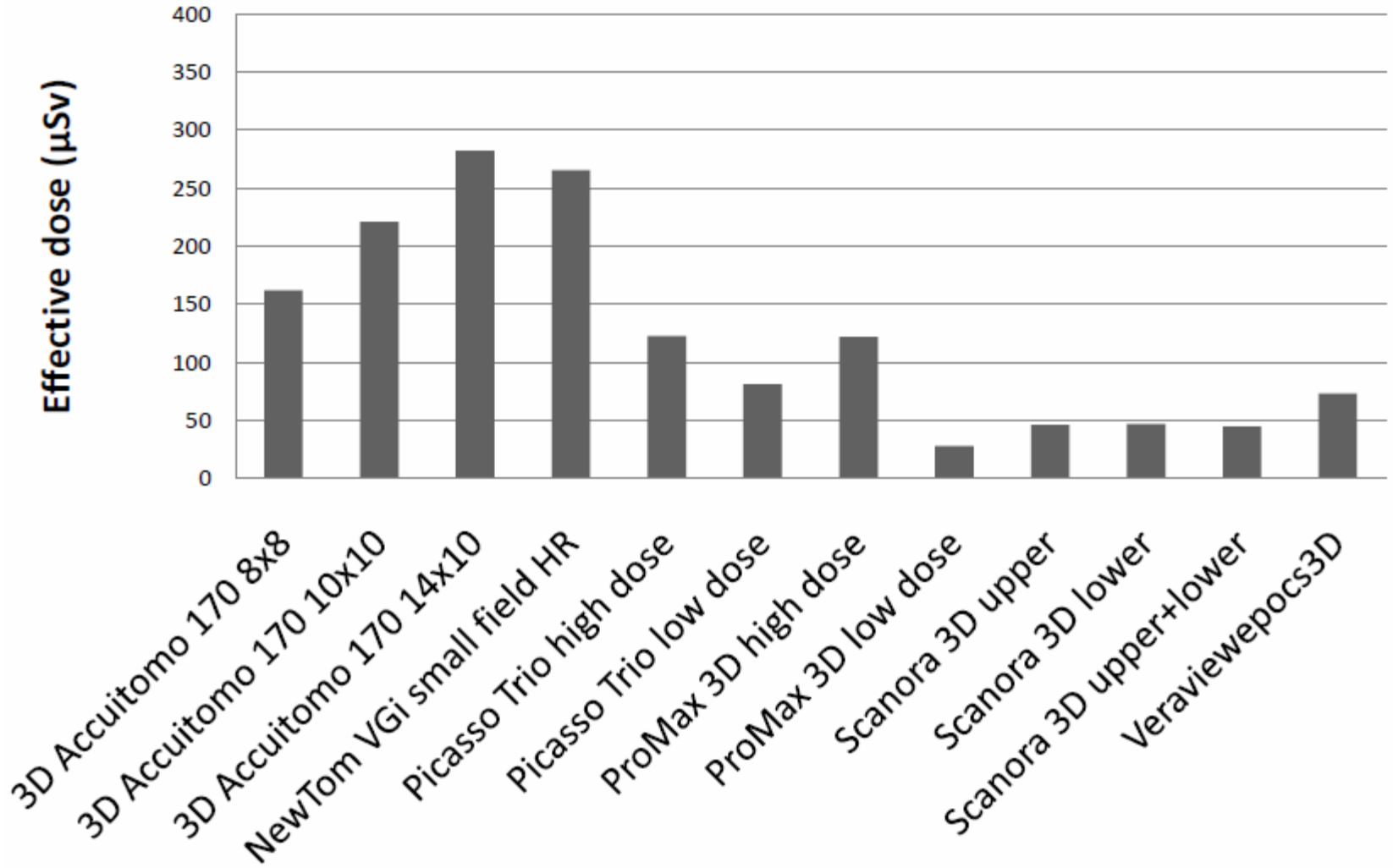
Eur J Radiol 81,2,267-271 (February 2012)

Effective dose for large field CBCTs

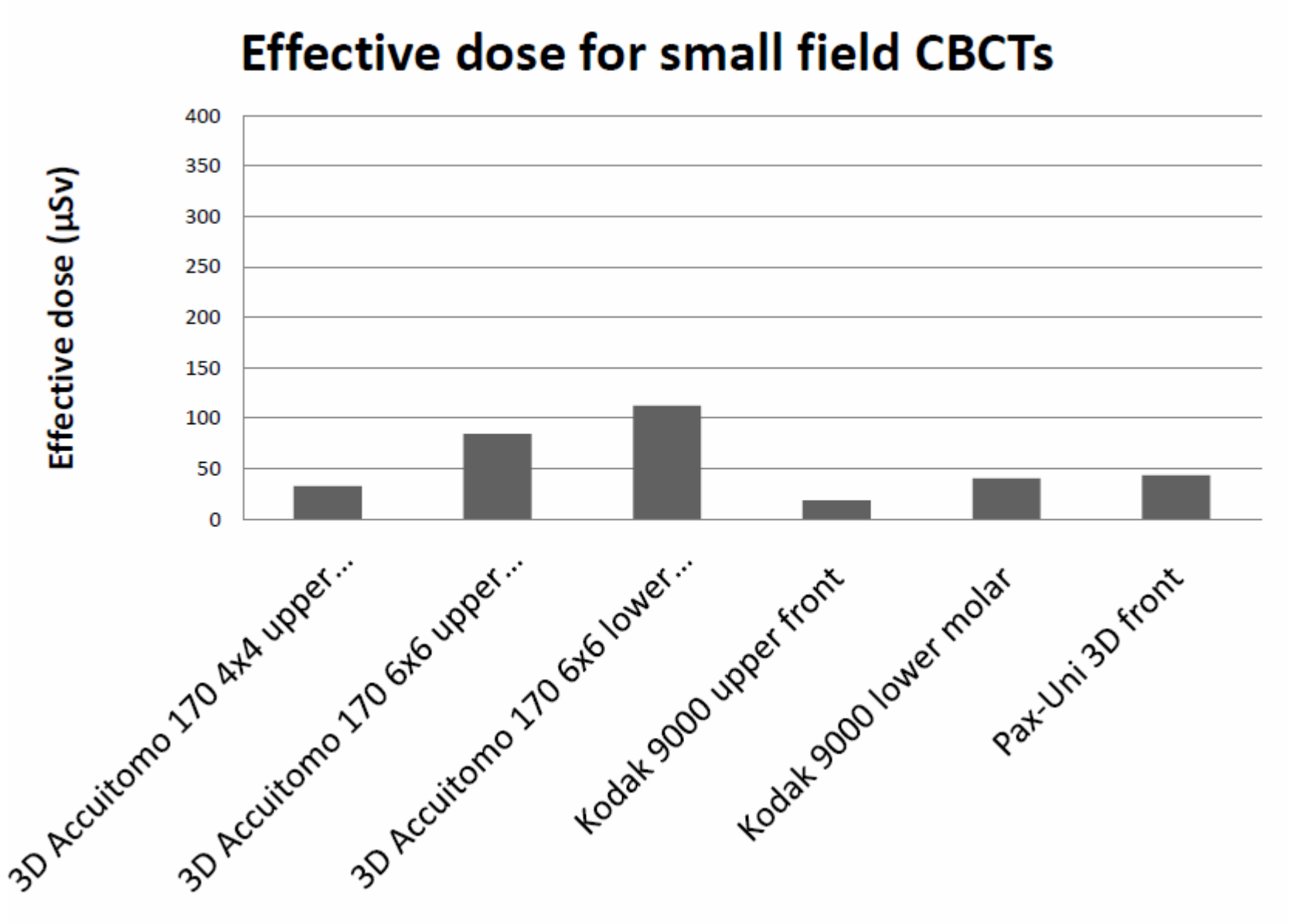


Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

Effective dose for medium field CBCTs



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

Estimating the Effective Dose from CT and CBCT scans

We can't measure the Effective Dose for every patient

The SEDENTEXCT report doesn't cover every situation

so

Use the DLP (if known)

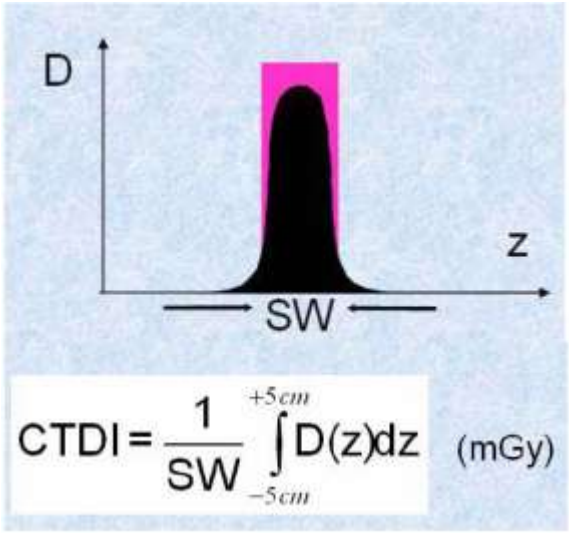
or

Use the DAP (?accuracy)

Dose Length Product (DLP)

DLP = $CTDI_{vol}$ x Irradiated Length

Effective Dose = DLP x F (where F is a conversion factor)



- **tables for F have been published**
- **works well for medical CT (± 40%)**

Conversion Factor F

Tab. 3.1
Average values f_{mean} of conversion factor (in mSv/mGy·cm) to convert from dose free-in-air on the axis of rotation into effective dose for different regions of the body and patient groups (beam quality: 125 kV, 9 mm Al-equivalent); demarcation of the body regions was made according to (Hidajat96/2) (see also fig. 3.1 - 3.3).

Body region	Adults		Children (7 year-old)		Babies (8 week-old)	
	(female)	(male)	(female)	(male)	(female)	(male)
Head	0.0022	0.0020	0.0028	0.0028	0.0075	0.0074
Neck	0.0051	0.0047	0.0056	0.0055	0.018	0.017
Chest	0.0090	0.0068	0.018	0.015	0.032	0.027
Upper abdomen	0.010	0.0091	0.020	0.016	0.036	0.034
Pelvis (*)	0.011	0.0062	0.018	0.011	0.045	0.025
Entire abdomen (*)	0.010	0.0072	0.019	0.014	0.041	0.031

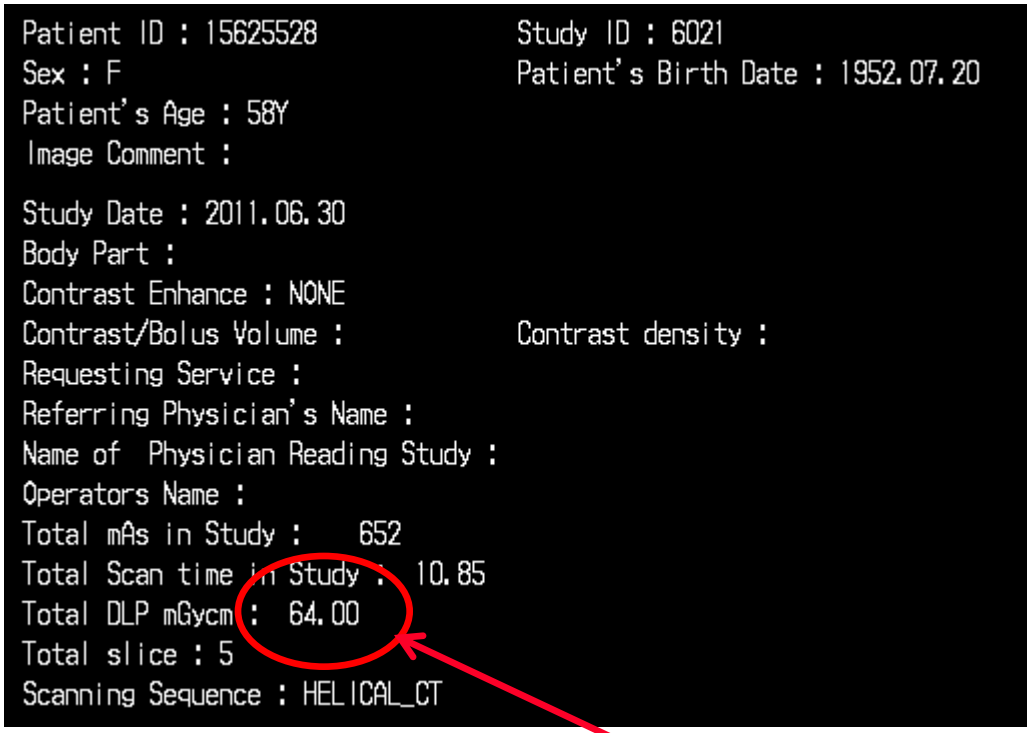
Table from "Radiation Exposure in Computed Tomography" edited by Hans Dieter Nagel
F can also by calculated from ImPACT CTDosimetry calculator www.impactscan.org

Roughly speaking, F = ~~0.002~~mSv / mGy.cm for Maxilla and ~~0.003~~mSv / mGy.cm for Mandible

2 µSv **3 µSv**

Accuracy: ±40%

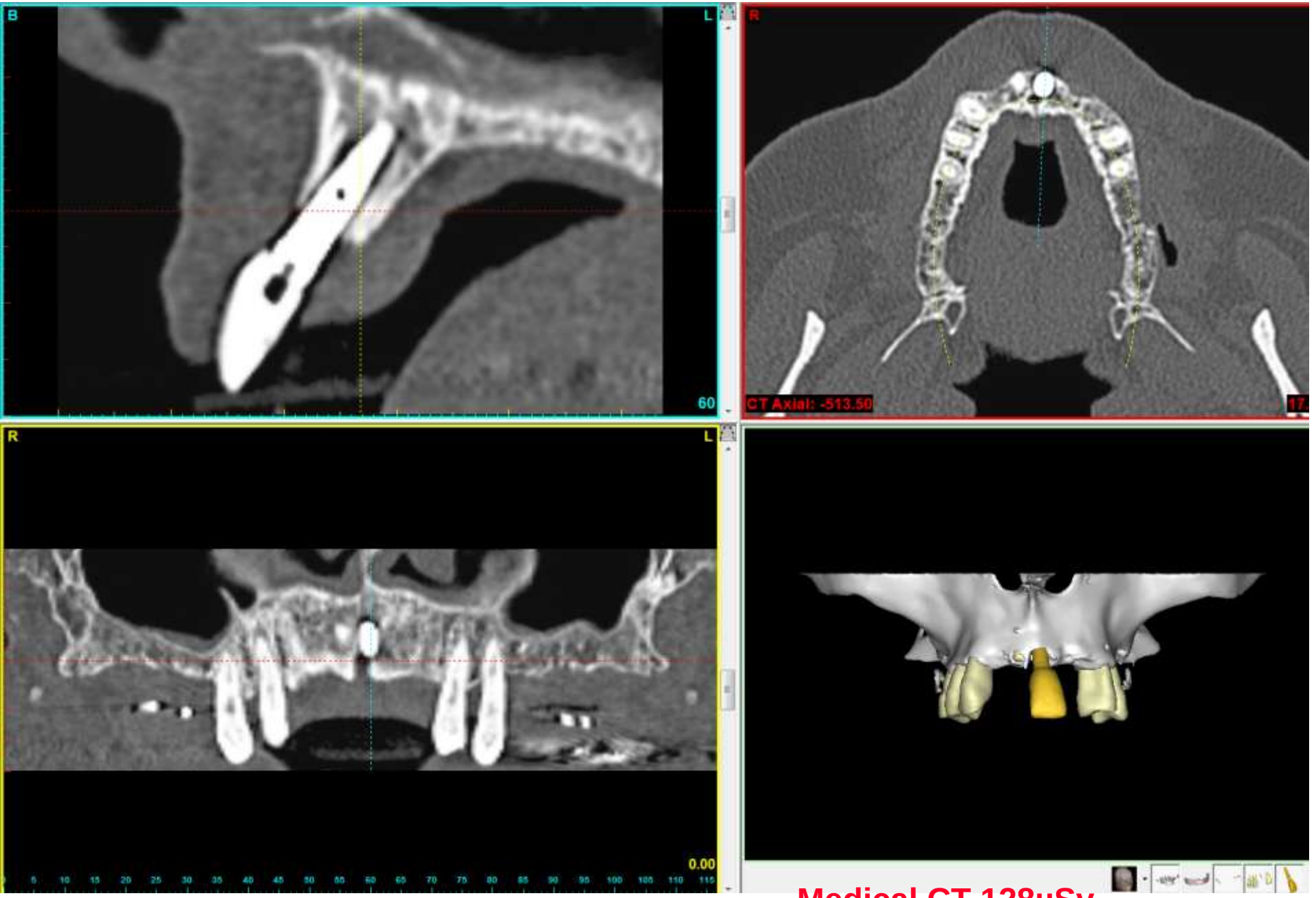
Effective Dose for Medical CT Scanners



Multiply DLP by 2 for Maxilla or 3 for Mandible to get the Effective Dose in microSieverts (µSv)

Accuracy: ±40%

Mx 128µSv ROUGHLY

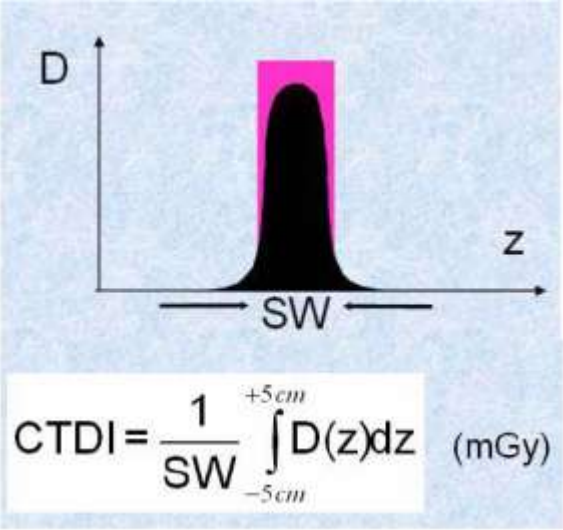


Medical CT 128μSv

Dose Length Product (DLP)

DLP = $CTDI_{vol}$ x Irradiated Length

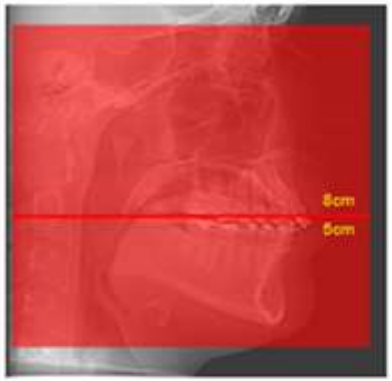
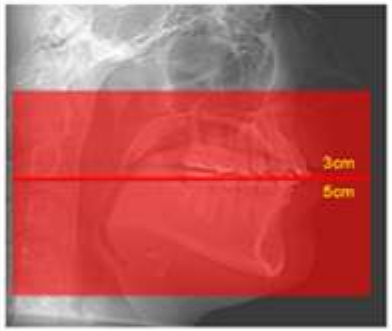
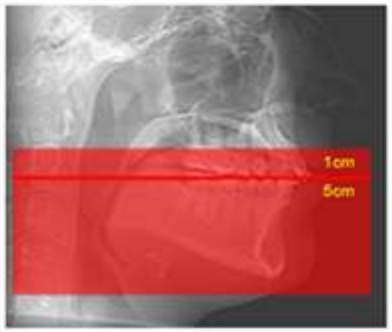
Effective Dose = DLP x F (where F is a conversion factor)



- **most CBCT manufacturers don't display $CTDI_{vol}$ (exception: J.Morita, NewTom)**
- **$CTDI_{vol}$ = <u>Effective Dose</u>**
  F x Irradiated Length
- **Can use $CTDI_{vol}$ to interpolate published data**

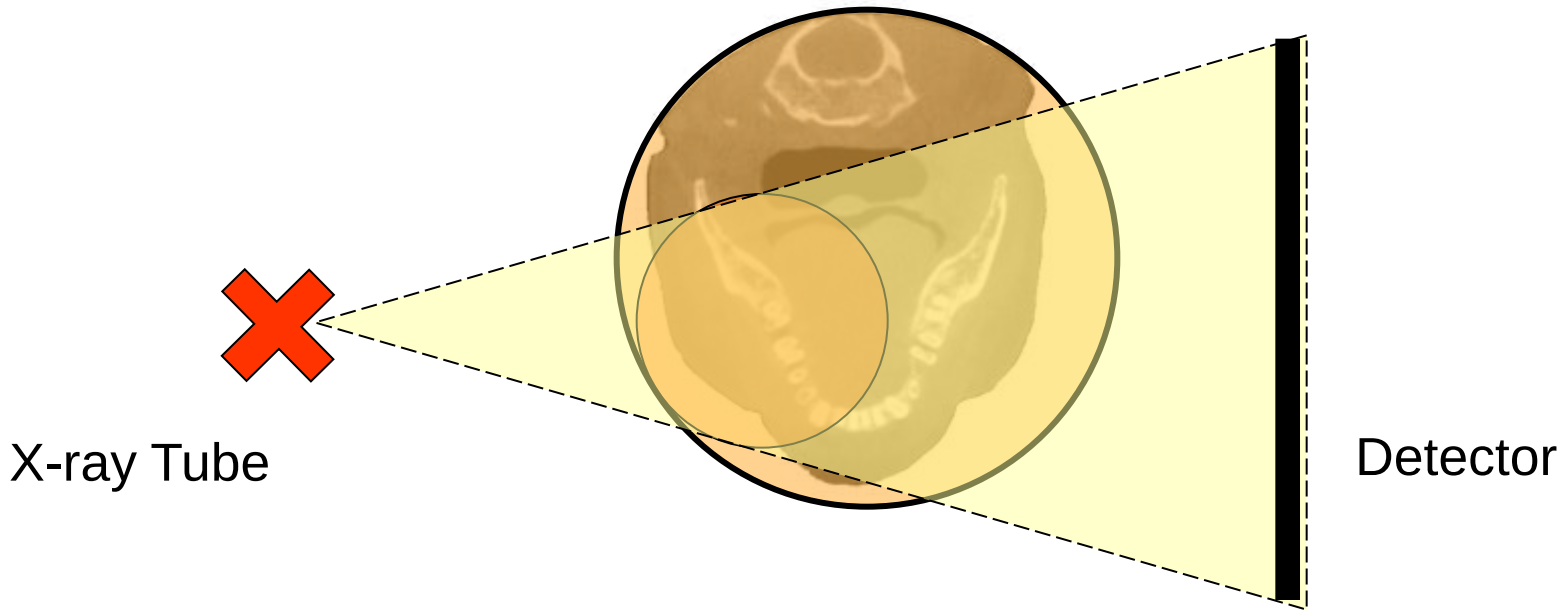
CBCT Scanners:

Effect of Reducing Beam Height

	Full face 13cm height x 16cm diameter 83 microSieverts
	Both arches 8cm height x 16cm diameter 56 microSieverts
	Mandible 6cm height x 16cm diameter 45 microSieverts

Effective Dose is (roughly) proportional to the DLP

Effect of Reducing Beam Width



- **Local Dose outside the imaged region is not zero**
- **Not clear that the Effective Dose is proportional to the DAP**

Cone Beam Computed Tomography

radiation dose and image quality assessments

Sara Lofthag-Hansen

Department of Oral and Maxillofacial Radiology
Institute of Odontology at Sahlgrenska Academy

UNIVERSITY OF GOTHENBURG

Gothenburg 2010

Table 5. Most commonly used exposure parameters in three specified regions and corresponding dose-are product (DAP) value and effective dose according to ICRP 60 (1991)

Region	*Volume size (mm x mm)*	*Tube voltage (kV)*	*Tube current (mA)*	*DAP value (mGy cm^2)*	*Effective dose (μSv)*
Upper jaw					
Cuspid	30 x 40	80	5.0–6.0	263–316	21–25
	40 x 40	75	4.0–5.0	260–325	21–26
	60 x 60	75	4.5–5.5	645–788	52–63
Lower jaw					
Second premolar–first molar	30 x 40	75–80	3.0–6.0	140–316	11–25
	40 x 40	75	4.0–6.0	260–390	21–31
	60 x 60	75	5.0–6.0	716–859	57–69
Lower jaw					
Third molar	30 x 40	75–80	3.0–6.5	140–342	11–27
	40 x 40	75–80	4.0–5.0	260–366	21–29
	60 x 60	75–80	4.5–6.0	645–967	52–77

Effective Dose (μSv) = 0.1 x DAP (mGy.cm2) for **Maxilla**
Effective Dose (μSv) = 0.15 x DAP (mGy.cm2) for **Mandible**
Effective Dose (μSv) = 0.125 x DAP (mGy.cm2) for **Mn & Mx**

VERY ROUGH – USE WITH CAUTION !

Effective Dose Calculator

Siemens Sensation 64 (Ludlow)

Accuitomo F170 (SEDENTEXCT)

Vol. 106 No. 1 July 2008

Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology

ORAL AND MAXILLOFACIAL RADIOLOGY Editor: Allan G. Farman

Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology

John B. Ludlow, DDS, MS, FDS RCSEd,[a] and Marija Ivanovic, PhD,[b] Chapel Hill, North Carolina
UNIVERSITY OF NORTH CAROLINA

Siemens Sensation 64 (32 row / 64 slice)

Both Jaws, 200 slices x 0.6 mm spacing

Collimation 32 x 0.6 = 19.2 mm

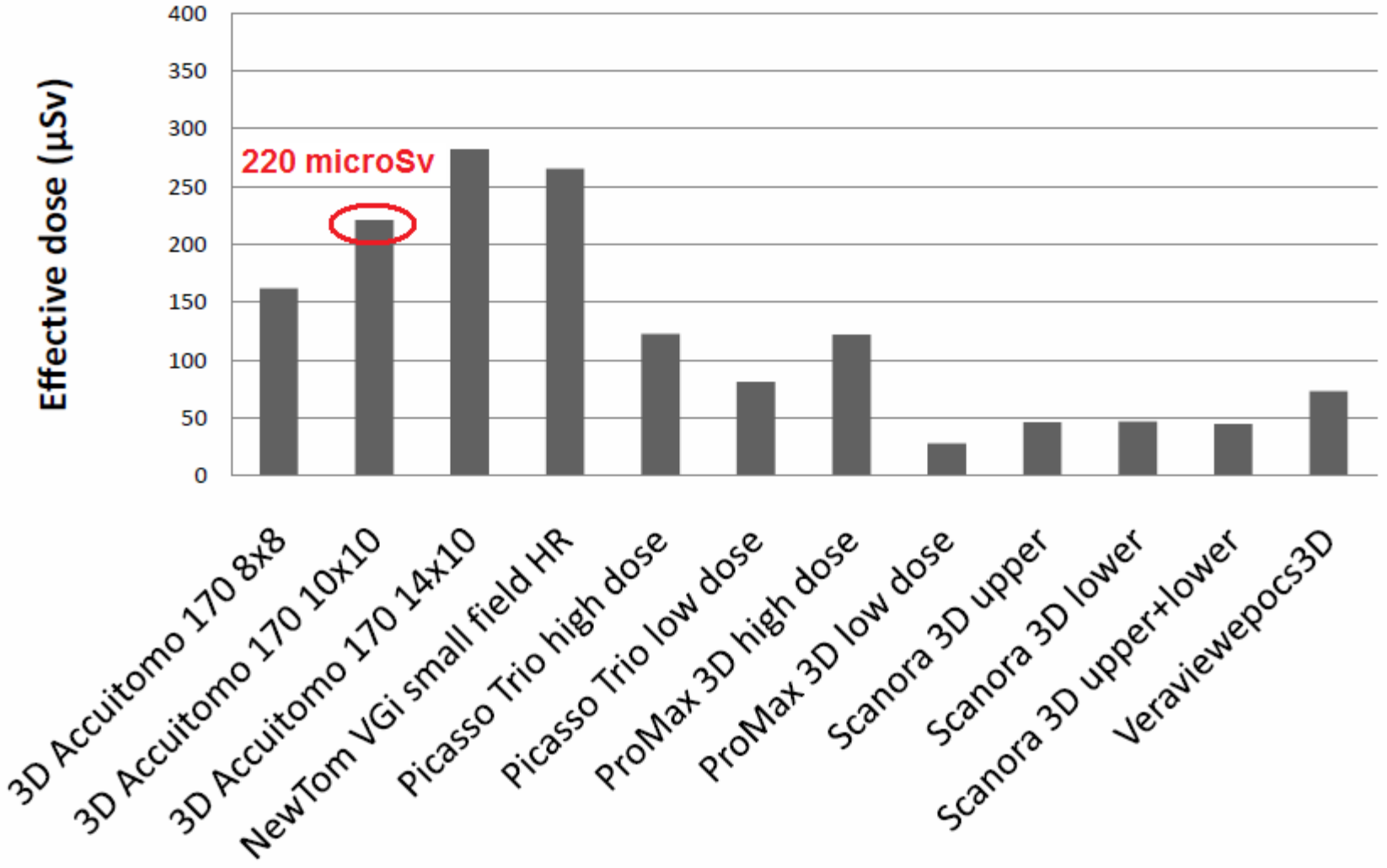
Effective mAs 90 (pitch = 0.9)

Effective Dose 860 microSv

Dosimetry of dental CBCT

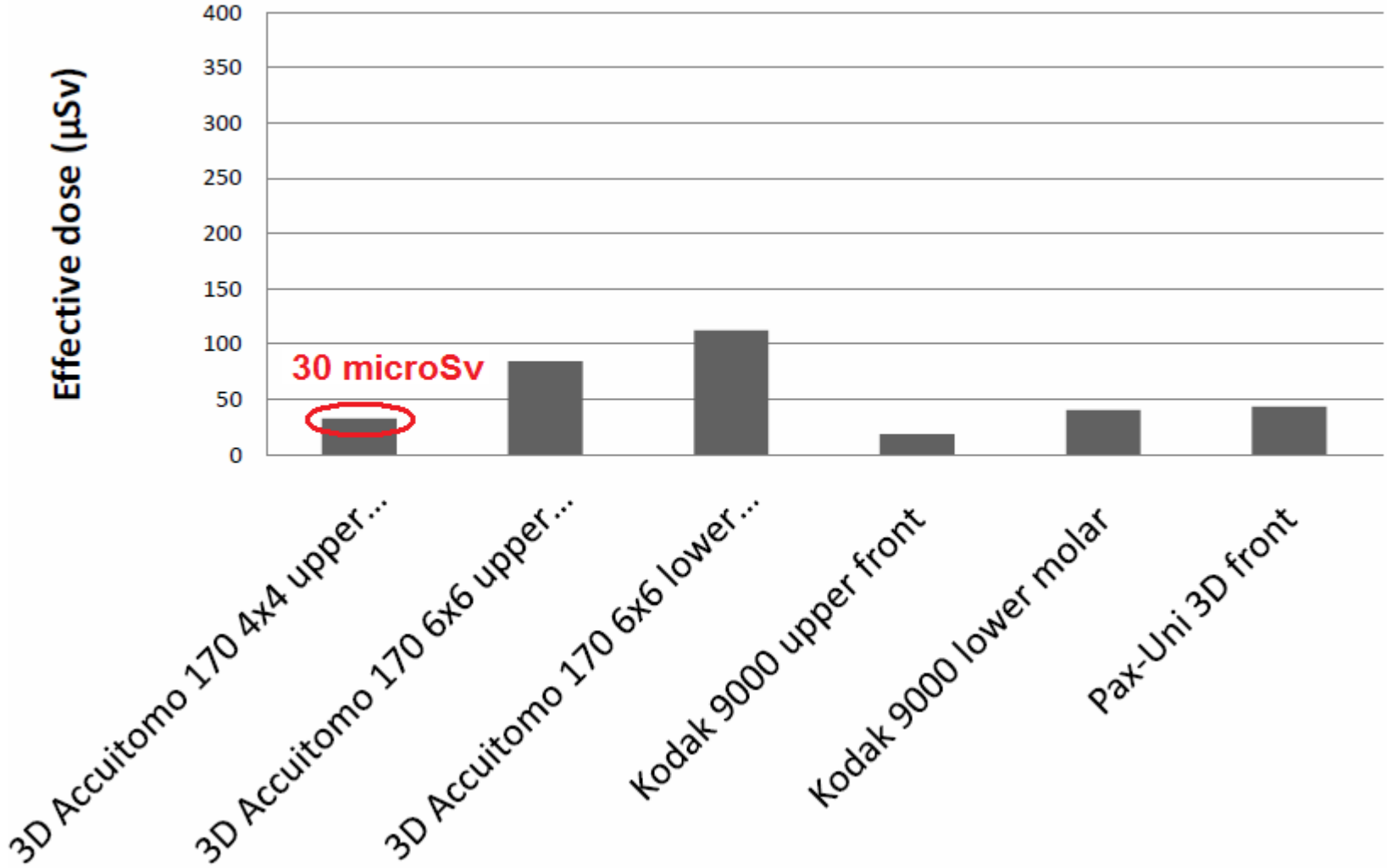
Presentation by
Prof. Ria Bogaerts
at SEDENTEXCT Workshop
on dental Cone Beam CT
Leeds, 31 March 2011

Effective dose for medium field CBCTs



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

Effective dose for small field CBCTs



Prof. Ria Bogaerts, Katholieke Universiteit Leuven, March 2011

DICOM headers for similar scans:

Accuitomo 10 x 10:

- **kV: 90.0**
- **mA: 5.0**
- **EXPTIME: 17.5s**
- **PIXEL: 250.0um**
- **SliceInterval: 0.250mm**
- **CTDIw: 6.88mGy**
- **DAP: 1820mGycm2**
- **DLP: 68.8mGycm**

Accuitomo 4 x 4:

- **kV: 90.0**
- **mA: 5.0**
- **EXPTIME: 17.5s**
- **PIXEL: 80.0um**
- **SliceInterval: 0.250mm**
- **CTDIw: 4.57mGy**
- **DAP: 402mGycm2**
- **DLP: 18.3mGycm**

Select Scanner | 26 Siemens Sensation 64 | details

Region: **Maxilla & Mandible** | **260 Dental**

	Suggested	Actual
Voltage (kVp):	120	120
Exposure (mAs):	45	90
Pitch:	0.9	0.9
CTDIvol (mGy):	22.40	22.40
Slices:		200
Spacing (mm):	0.3	0.6
VisibleLength (mm):	120	120
BeamWidth:	19.20	19.20
Overrun (mm):	17.28	17.28
IrradiatedLength (mm):	137.28	137.28
DLP (mGy.cm):	307.5	307.5
Dose (microSv):	793	793
RawRisk (1 in N):	22136	22136
Age (years):		60
AgeFactor:	.28	0.28
Risk (1 in N):	79058	80000

Select Scanner | 44 J.Morita Accuitomo 170 | details

Region: **Maxilla & Mandible** | **442 FOV 10cm**

	Suggested	Actual
Voltage (kVp):	90	90
Exposure (mAs):	87.5	87.5
Pitch:	0	0
CTDIvol (mGy):	6.88	6.88
Slices:		400
Spacing (mm):	0.25	0.25
VisibleLength (mm):	100	100
BeamWidth:	100.00	100.00
Overrun (mm):	0.00	0.00
IrradiatedLength (mm):	100.00	100.00
DLP (mGy.cm):	68.8	68.8
Dose (microSv):	194	194
RawRisk (1 in N):	90637	90637
Age (years):		60
AgeFactor:	.28	0.28
Risk (1 in N):	323703	300000

Select Scanner | 44 J.Morita Accuitomo 170 | details

Region:	Maxilla	445 FOV 4cm
	Suggested	Actual
Voltage (kVp):	90	90
Exposure (mAs):	87.5	87.5
Pitch:	0	0
CTDIvol (mGy):	4.57	4.57
Slices:		160
Spacing (mm):	0.25	0.25
VisibleLength (mm):	40	40
BeamWidth:	40.00	40.00
Overrun (mm):	0.00	0.00
IrradiatedLength (mm):	40.00	40.00
DLP (mGy.cm):	18.3	18.3
Dose (microSv):	32	32
RawRisk (1 in N):	550272	550272
Age (years):		60
AgeFactor:	.28	0.28
Risk (1 in N):	1965258	2000000

Conclusions

- **A knowledge-driven approach based on published data allows us to estimate Effective Dose and Risk for a number of makes and models of CT / CBCT scanners and a variety of scanning protocols**

- **Even if we don’t have all of the information.**

Thank You!

- **Any Questions?**