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***Calculating the Patient Dose
from
Dental CT Scans***

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Dose Information available

The Radiation Protection Implications of the Use of Cone Beam Computed Tomography (CBCT) in Dentistry – What You Need To Know

J R Holroyd and A D Gulson

Examination	Effective patient dose (μSv)	Dose as a multiple of the dose from a typical panoramic exam
Panoramic	24 ⁶	1
Small FOV* CBCT	48 – 652 ⁷	2 – 27
Large FOV* CBCT	68 – 1073 ⁷	3 – 45
CT scan (dental program)	534 ⁷ – 2100 ⁸	22 – 88

* FOV = Field of view



CT Scanner Dosimetry

- Differences can be explained by:
 - The make and model of CT Scanner
 - The scanner settings used
 - The region scanned
- We designed our own dose optimized dental protocol for each CT Scanner type.



CT Scanner Types

IDT works with:

- More than 130 Hospitals
- More than 25 Scanner Types
- Multiple parameters per scanner



Issues that arise

- How do we know that the protocol that IDT designed was actually followed?
- How can we estimate the effective dose to the patient?
- From the DICOM header!



Toshiba DICOM Header

Attribute List

Group	Element	Description	Value
0x0008	0x0008	ImageType	ORIGINAL\PRIMARY\AXIAL
0x0008	0x0016	SOPClassUID	1.2.840.10008.5.1.4.1.1.2
0x0008	0x0018	SOPInstanceUID	1.2.392.200036.9116.2.6.1.48.1215677551.1257754672.5
0x0008	0x0022	AcquisitionDate	20091109
0x0008	0x0023	ImageDate	20091109
0x0008	0x0032	AcquisitionTime	171734.00075
0x0008	0x0033	ImageTime	171736.000036
0x000a	0x000a	Filename	H2850078
0x0010	0x0000	PatientGroupLength	72
0x0018	0x0000	AcquisitionGroupLength	216
0x0018	0x0022	ScanOptions	HELICAL_CT
0x0018	0x0050	SliceThickness	0.5
0x0018	0x0060	KVP	120
0x0018	0x0090	DataCollectionDiameter	240.00
0x0018	0x1100	ReconstructionDiameter	150.00
0x0018	0x1120	GantryDetectorTilt	+0.0
0x0018	0x1130	TableHeight	+22.00
0x0018	0x1140	RotationDirection	CW
0x0018	0x1150	ExposureTime	1000
0x0018	0x1151	XRayTubeCurrent	70
0x0018	0x1152	Exposure	70
0x0018	0x1210	ConvolutionKernel	FC30
0x0020	0x0000	ImageGroupLength	354
0x0020	0x0012	AcquisitionNumber	3
0x0020	0x0013	InstanceNumber	6
0x0020	0x0020	PatientOrientation	L\P
0x0020	0x0032	ImagePositionPatient	-75.0000\ -117.1875\ -604.0000
0x0020	0x0037	ImageOrientationPatient	1.0000\ 0.0000\ 0.0000\ 0.0000\ 0.0000\ 0.0000

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DICOM Header Interpretation

SIEMENS vs GE



Siemens DICOM Header

Attribute List

Group	Element	Description	Value
0x0008	0x2112	SourceImageSequence	
0x0009	0x0000	PrivateGroupLength	13078
0x0009	0x0010	PrivateCreator	SIEMENS CT VA1 DUMMY
0x0009	0x0011	PrivateCreator	GEIIS
0x0009	0x1110		
0x000a	0x000a	Filename	IMG00019
0x0010	0x21c0	PregnancyStatus	4
0x0018	0x0050	SliceThickness	0.75
0x0018	0x0060	KVP	120
0x0018	0x0090	DataCollectionDiameter	500
0x0018	0x1100	ReconstructionDiameter	150
0x0018	0x1110	DistanceSourceToDet...	1040
0x0018	0x1111	DistanceSourceToPati...	570
0x0018	0x1120	GantryDetectorTilt	0
0x0018	0x1130	TableHeight	183
0x0018	0x1140	RotationDirection	CW
0x0018	0x1150	ExposureTime	750
0x0018	0x1151	XRayTubeCurrent	80
0x0018	0x1152	Exposure	120
0x0018	0x1160	FilterType	0
0x0018	0x1170	GeneratorPower	9
0x0018	0x1190	FocalSpots	0.7
0x0018	0x1210	ConvolutionKernel	H60s
0x0019	0x0010	PrivateCreator	SIEMENS CT VA0 COAD
0x0019	0x10b0		6
0x0020	0x0012	AcquisitionNumber	5
0x0020	0x0013	InstanceNumber	20
0x0020	0x0032	ImagePositionPatient	.74 853515625\ 283 853515625\ 110

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GE DICOM Header

Attribute List

Group	Element	Description	Value
0x0010	0x0000	PatientGroupLength	90
0x0018	0x0000	AcquisitionGroupLength	430
0x0018	0x0022	ScanOptions	HELICAL MODE
0x0018	0x0050	SliceThickness	0.625000
0x0018	0x0060	KVP	120
0x0018	0x0090	DataCollectionDiameter	320.000000
0x0018	0x1100	ReconstructionDiameter	153.000000
0x0018	0x1110	DistanceSourceToDet...	949.075012
0x0018	0x1111	DistanceSourceToPati...	541.000000
0x0018	0x1120	GantryDetectorTilt	0.000000
0x0018	0x1130	TableHeight	170.000000
0x0018	0x1140	RotationDirection	CW
0x0018	0x1150	ExposureTime	1460
0x0018	0x1151	XRayTubeCurrent	50
0x0018	0x1152	Exposure	2
0x0018	0x1160	FilterType	MEDIUM FILTER
0x0018	0x1170	GeneratorPower	6000
0x0018	0x1190	FocalSpots	0.700000
0x0018	0x1210	ConvolutionKernel	BONE
0x0018	0x9305	RevolutionTime	0.8000000119
0x0018	0x9306	SingleCollimationWidth	0.625
0x0018	0x9307	TotalCollimationWidth	20
0x0018	0x9309	TableSpeed	13.2812498
0x0018	0x9310	TableFeedPerRotation	10.625
0x0018	0x9311	SpiralPitchFactor	0.53125
0x0019	0x0000	PrivateGroupLength	294
0x0019	0x0010	PrivateCreator	GEMS_ACQU_01
0x0019	0x0012		

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DICOM Header Interpretation

- Some values not explicit
- Need to be deduced
- Example of Siemens
- Exposure equivalent Effective mAs
- $\text{Effective mAs} = \text{mA} \times \text{rotation time} / \text{pitch}$
- This can be used to calculate the pitch



SIEMENS mAs

- IDT set mA = 80
- Hospitals used mA=53
- DICOM Header: Exposure = 80
- However, the radiographer cannot specify mA directly
- mAs can be directly manipulated



DICOM Header Summary

- Useful Dose information
- Same DICOM Tag interpreted differently
- DICOM Conformance Statement
- Some data are not directly available



Patient Dose Calculation

$$\text{Effective Dose} = \text{DLP} * F$$

F is a factor to convert from DLP to Effective Dose

- Need to estimate F and DLP



Estimation of F

- Data by Hans Dieter Nagel, taken from *Radiation Exposure in Computer Tomography* page 18
- Collect data from ImPACT Spreadsheet



Radiation Exposure in Computed Tomography

**Fundamentals, Influencing Parameters, Dose Assessment,
Optimisation, Scanner Data, Terminology**

Edited by Hans Dieter Nagel



Estimation of 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

(*) without direct irradiation of gonads of male patients



Estimation of F

Second Method:

- Calculate Effective Dose and DLP for each scanner type using ImPACT Spreadsheet
- Take the ratio of Effective Dose to DLP for different anatomical regions

Gives reasonable agreement with previous table



Dose Length Product (DLP)

- Given by explicit Dose Report (e.g. GE)
- Recorded manually by the radiographer
- Estimated using our Dose Calculation Spreadsheet if IDT's protocol has been followed.



GE Dose Report

Accession Number: 373718

10 Jun 2009

Patient ID: 14910164

LightSpeed VCT

Exam Description: CT Facial bones

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	17.000-192.000	15.20	161.45	Head 16
Total Exam DLP:				161.45	



IDT Dose Calculator



How does it work

- $DLP = CTDI_{vol} * \text{Scan Length}$

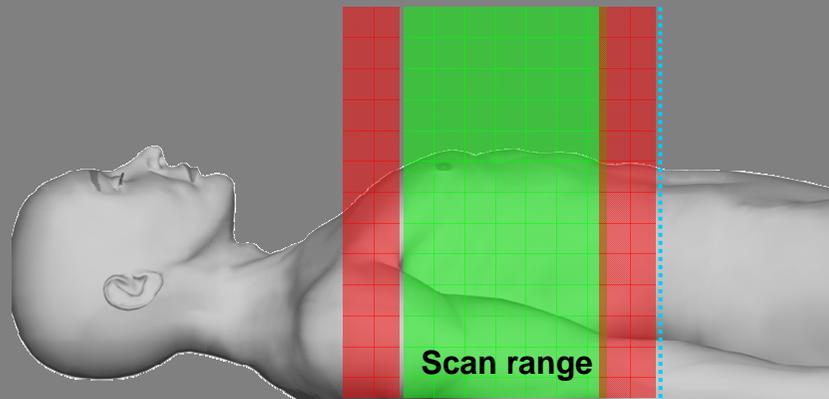
So need to estimate $CTDI_{vol}$ and Scan Length



CTDIvol

- If IDT protocol was followed, CTDIvol will be constant for a given scanner
- CTDIvol is often displayed on the scanner screen (but not always stored in the DICOM header) so ask radiographer to report it
- Can estimate CTDIvol from ImPACT Spreadsheet

Scan Length: Overrun



$$L = \text{Length imaged} + \text{Overrun}$$

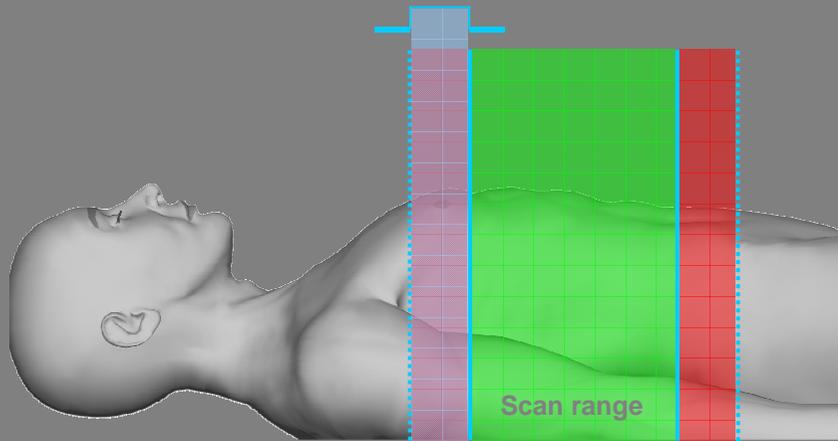
Courtesy of Siemens



Scan Length

- Overrun of about 1 rotation before and after imaged region depending on scanner
- Overrun very important in Dental CT
- Can be up to double the dose
- Hence important to get collimation right.
- Potential problem with >64 slices/rot...
- Can estimate the overrun for some scanner types (using IDT's protocol)

Overrun: Siemens Definition has a solution



Technologie conventionnelle



Limits of DICOM Header approach

- DICOM fields not always filled in
- DICOM tags used differently from one manufacturer to another
- Difficult to find the right DICOM conformance statement
- Lack of information in the conformance statement



Limits of Dose Calculator approach

- Only works for fixed protocols
- If protocol was not respected, we need to manually enter the necessary parameters into ImPACT Spreadsheet.
- Overrun needs to be estimated for different scanner types



MSCT Scanners Published Results

	Scanner	Region	Measured CTDIvol (mGy)	ImPACT CTDIvol (mGy)	Weighting Factors	Measured Dose (μ Sv)	ImPACT Dose (μ Sv)
Loubelle Thesis 2008	Sensation 16	Mandible			ICRP103	420	300
	Sensation 16	Whole Head	2.5	2.1	ICRP103	120	170
Ludlow & Ivanovic 2008	Sensation 64	Whole Head		13	ICRP60	453	370
	Sensation 64	Whole Head		13	ICRP103	860	390
Swennen, Schutyser, Hausamen 2006	Sensation 64	Whole Head		13	ICRP60	930	810



Cone Beam CT Scanners

- Have implemented a Dose Calculator for the i-CAT
- Need to know how to interpret i-CAT DICOM headers



i-CAT Classic Header

Attribute List

Group	Element	Description	Value
0x0008	0x0008	ImageType	ORIGINAL\PRIMARY\AXIAL
0x0008	0x0012	InstanceCreationDate	20091124
0x0008	0x0016	SOPClassUID	1.2.840.10008.5.1.4.1.1.2
0x0008	0x0018	SOPInstanceUID	1.2.826.0.1.3680043.2.594.17198.25136.1753.19413.153E
0x0008	0x0022	AcquisitionDate	20091124
0x0008	0x0023	ImageDate	20091124
0x0008	0x0032	AcquisitionTime	092614
0x000a	0x000a	Filename	Barker, Tom 24_11_20090001.dcm
0x0018	0x0050	SliceThickness	0.3
0x0018	0x0060	KVP	120
0x0018	0x1063	FrameTime	67
0x0018	0x1110	DistanceSourceToDet...	698.3127
0x0018	0x1111	DistanceSourceToPati...	479.661
0x0018	0x1120	GantryDetectorTilt	0.0
0x0018	0x1140	RotationDirection	CW
0x0018	0x1151	XRayTubeCurrent	18
0x0018	0x1530	DetectorPrimaryAngle	332
0x0018	0x1531	DetectorSecondaryAngle	692.099487304688
0x0020	0x0012	AcquisitionNumber	
0x0020	0x0013	InstanceNumber	1
0x0020	0x0020	PatientOrientation	LVP
0x0020	0x0032	ImagePositionPatient	0.000000\0.000000\0.150000
0x0020	0x0037	ImageOrientationPatient	1.000000\0.000000\0.000000\1.000000\0.000000\0.000000
0x0020	0x1041	SliceLocation	-0.150000
0x0028	0x0002	SamplesPerPixel	1
0x0028	0x0004	PhotometricInterpretation	MONOCHROME2
0x0028	0x0008	NumberOfFrames	1
0x0028	0x0010	Rows	534

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i-CAT Dose Information

A weighted average of the following papers:

- Theodorakou C, Pauwels R, Walker A et al, SEDENTEXCT Project Consortium 2009
- Roberts JA, Drage NA, Davies J, Thomas TW, BJR, 82:35-40, 2009
- Loubele M, PhD Thesis, Leuven 2008
- Ludlow JB, Ivanovic M, Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 106:106-114, 2008



i-CAT Dose Calculator



Conclusions

We can use DICOM Header

- To know what protocol has been used
- To calculate the Effective Dose
- To know if the protocol has been optimised for dose
- To improve the protocols