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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

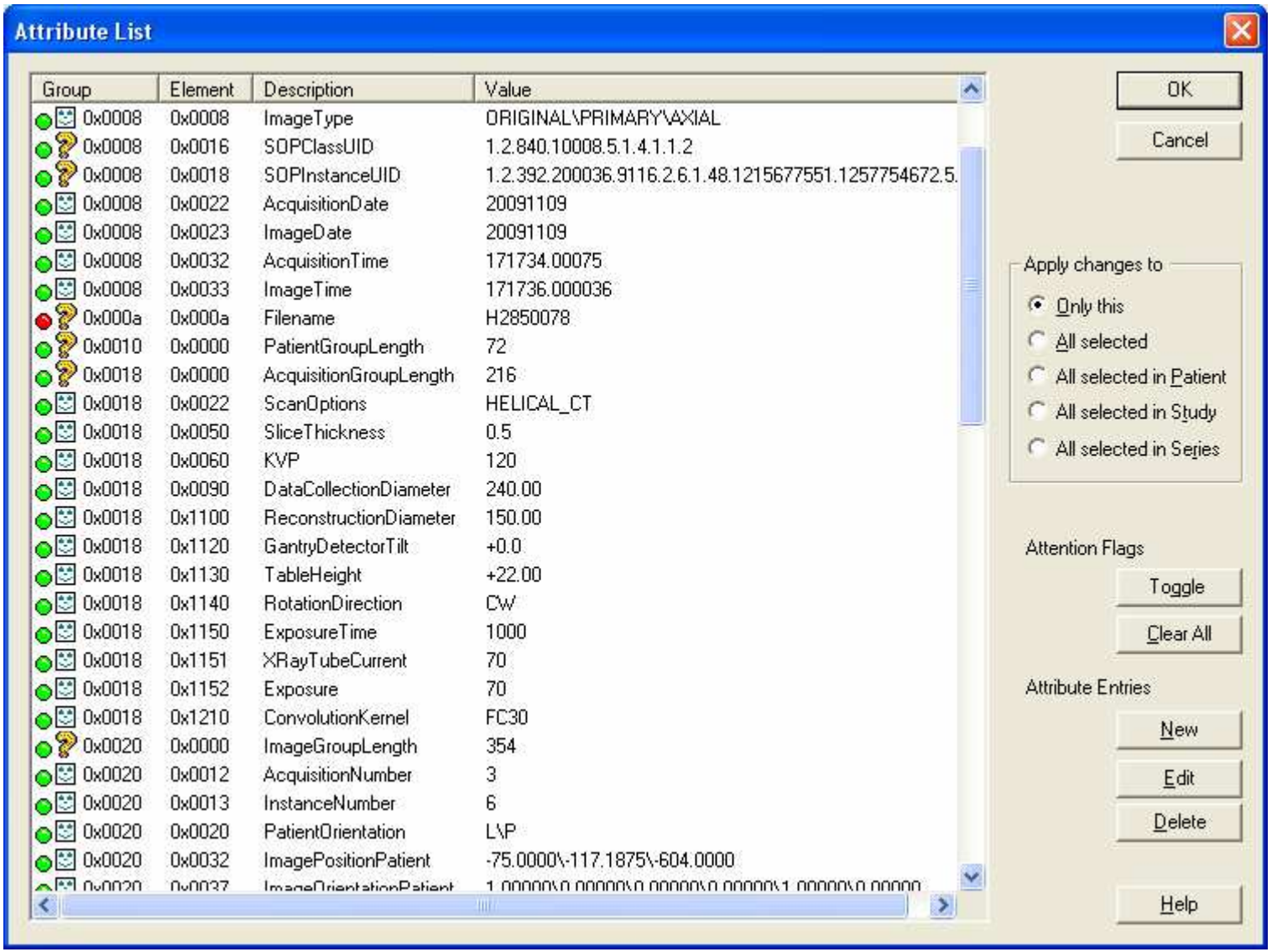
IDT works with:

- 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!

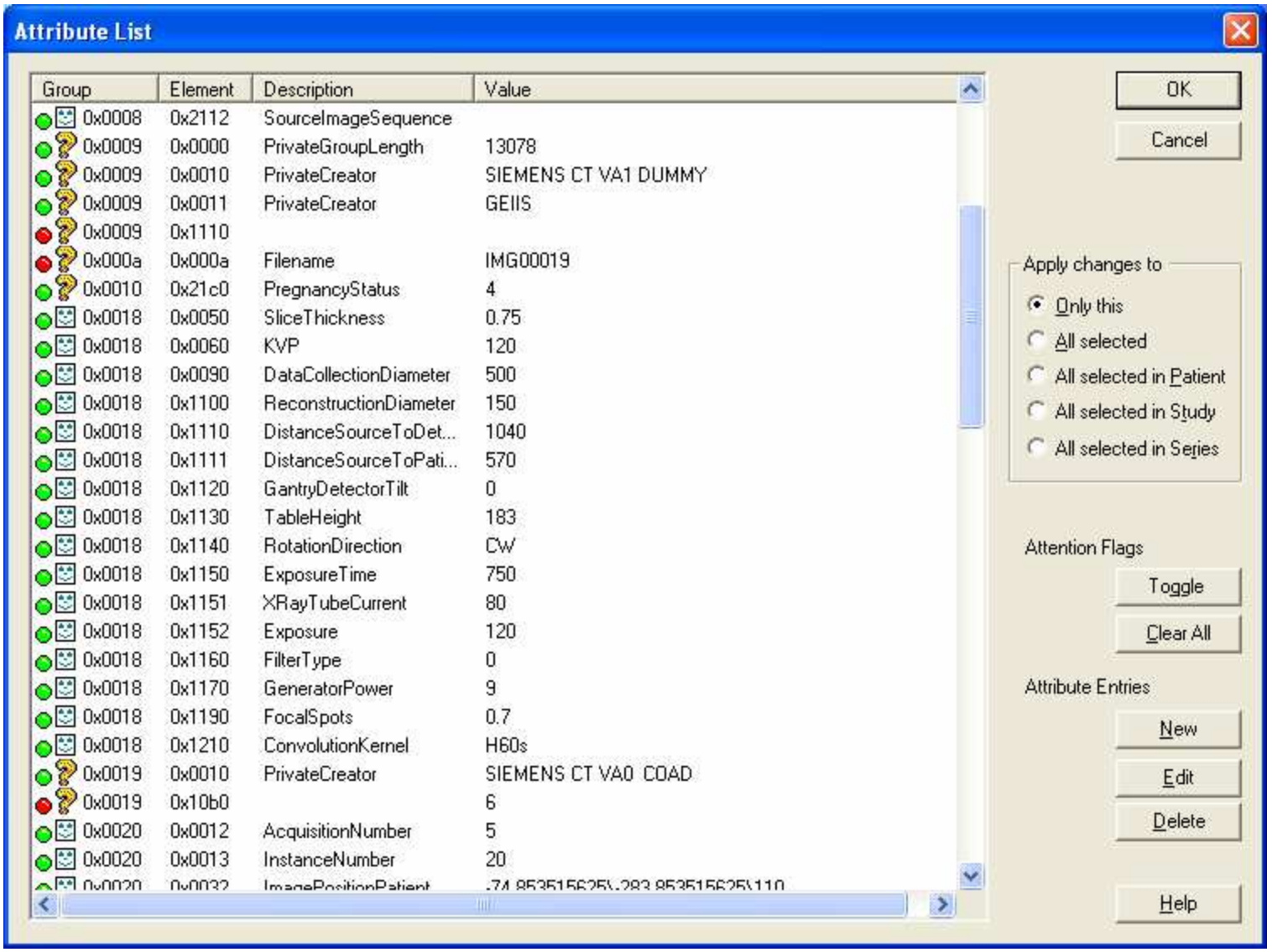
Toshiba DICOM Header



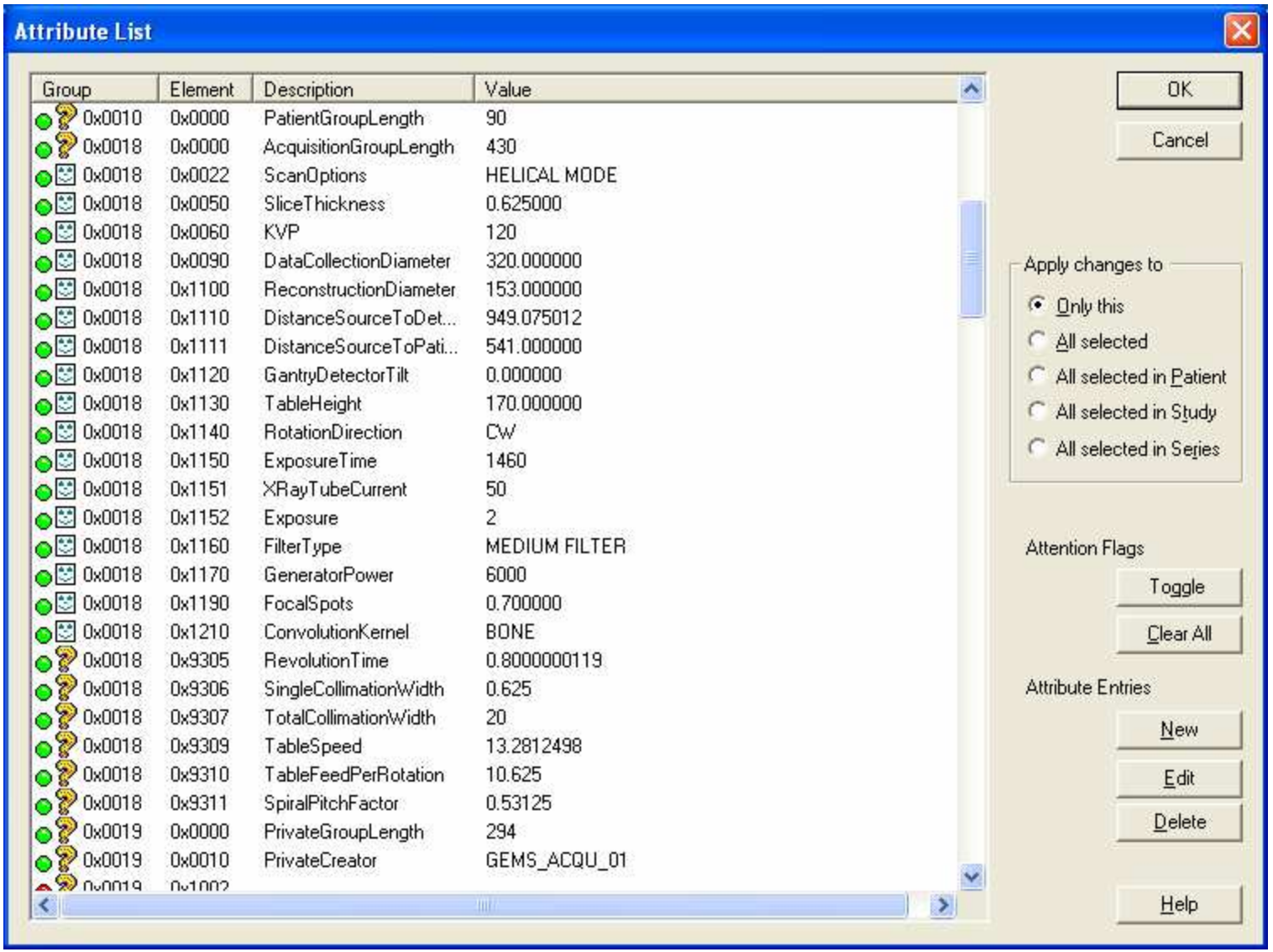
DICOM Header Interpretation

SIEMENS vs GE

Siemens DICOM Header



GE DICOM Header



DICOM Header Interpretation

- Some values not explicit
- Need to be deduced
- Example of Siemens
- Exposure equivalent Effective mAs
- Effective mAs = mA x rotation time / 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

Effective Dose = 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

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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

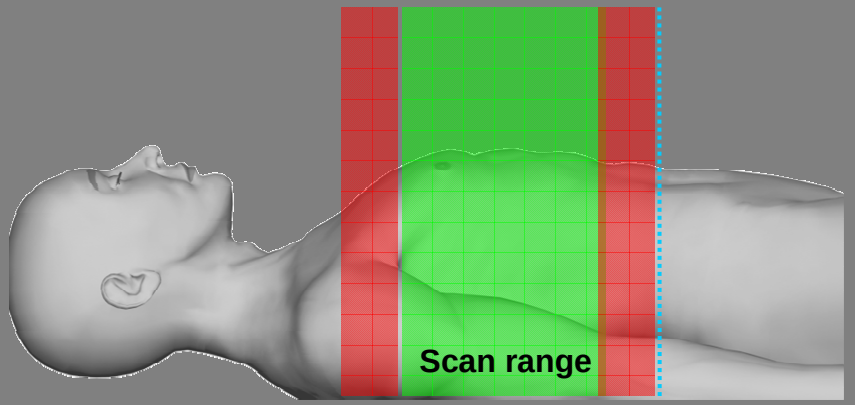
- DLP = CTDIvol * Scan Length

So need to estimate CTDIvol 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: Overun



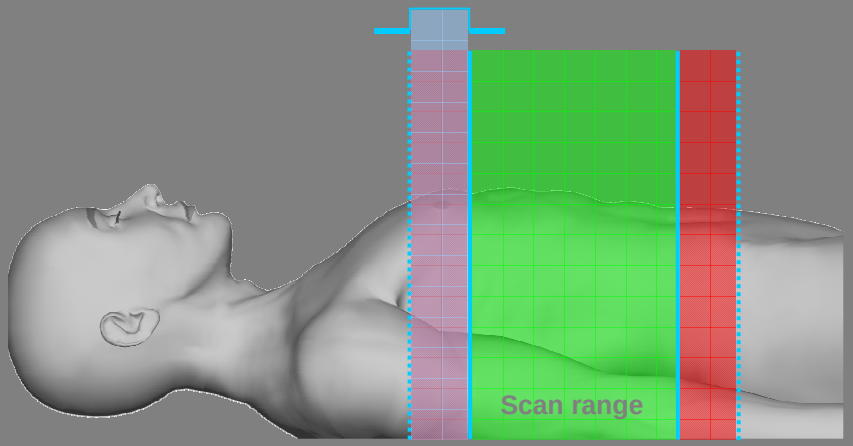
L = Length imaged + Overun

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

Courtesy of Siemens

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

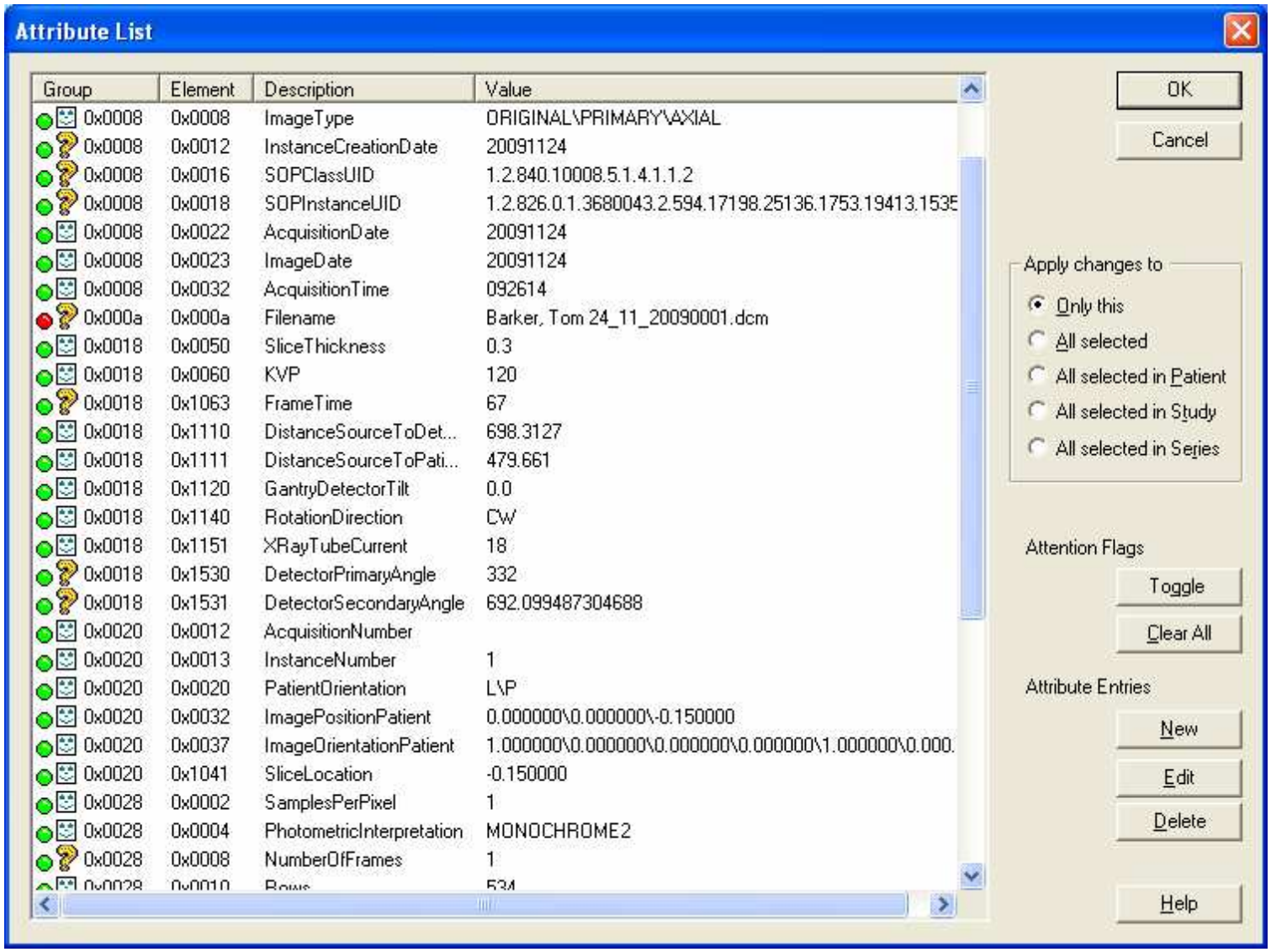
MSCT Scanners Published Results

	Scanner	Region	Measured CTDIvol (mGy)	ImPACT CTDIvol (mGy)	Weighting Factors	Measured Dose (µSv)	ImPACT Dose (µSv)
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



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