Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

Population Dose from CT Scanning: 2009

Health Service Executive

January 2011

Executive Summary of Results

The Health Services Executive (HSE) has a legal obligation, under Article 12 of the European Commission Medical Exposures directive (1997)[1] and Article 22.6 of Statutory Instrument 478 (2002)[2], to collect and publish statistics on population dose levels from the use of medical ionising radiation. In 2008 the Population Dose Sub-Committee of the National Radiation Safety Committee[3] decided to select Computed Tomography (CT) as the first modality to survey in relation to population dose.

The survey commenced in April 2010. All CT scanners, both public and private, on the HSE register of ionising radiation installations were surveyed and great credit is due to all those who participated, with a 100% response achieved. A selected subset of examinations was selected for survey in line with recommendations from the European Commission[7], with the addition of the Thorax&Abdomen&Pelvis scan due to anecdotal evidence of high frequency. Additional information was obtained from the 2008 Baseline clinical audit questionnaire, as carried out by the Health Service Executive's Taskforce on the Implementation of the SI 478[4].

The 2008 Audit report[4] recorded 59 Radiologists per million of the population compared to 50 in the UK and the European average of 89[7] It also noted 315 radiographers per million of the population compared to 310 in the UK and the European average of 400[7].

This survey found there to be 15 scanners per million of the population, which is broadly in line with the number in other European countries. There were 211,728 CT scans performed in 2009 for the examinations surveyed; 27% CT Brain, 20% Thorax&Abdomen&Pelvis (TAP), 24% Abdomen&Pelvis examinations and 29% from C-Spine, Thorax and High Resolution Thorax examinations combined.

The Collective Effective Dose to the population from these CT scans was found to be 1368manSv, of which less than 1% is attributed to those under 15 years of age. The 1368manSv is a 17% increase on the 2006 figure reported by the RPII. The increase may be due, in part, to the difference in scan types included in the 2006 and 2009 surveys, although are in keeping with international evidence of increasing use of CT, and the trend for increasing collective effective dose from CT over time[24,25,26].

The Dose per Caput from CT scans surveyed (Collective effective dose averaged over the population) is 0.32mSv. This could be compared with that of other countries surveyed in recent years where the Dose per Caput from CT was found to be between 0.74mSv (Canada 2006[21]) and 1.46mSv (USA 2006[20]). However, care must be taken interpreting international comparisons given the variation in study design and CT examinations selected for survey.

Introduction

The HSE has a legal obligation, under Article 12 of the European Commission Medical Exposures directive (1997)[1] and Statutory Instrument 478 (2002)[2], to collect and publish statistics on population dose levels from the use of medical ionising radiation on an annual basis.

In 2008 the Population Dose Sub-Committee[3] of the National Radiation Safety Committee recognised that it would not be practicable to produce a report annually to cover all modalities. Thus it was decided to deal with a specific modality annually on a five year cycle basis. The first modality selected is Computed Tomography (CT). This was selected based on the findings of the 2006 report of the Radiological Protection Institute of Ireland (RPII) "Radiation Doses Received by the Irish Population"[5], that CT contributed 56% of the dose from medical exposure, while only accounting for approximately 10% of total examinations carried out (RPII, 2006), and similar in proportion of population dose to that in other European studies (fig 1).

It was also noted that the proportion of population dose from medical exposure attributable to CT is increasing, as has been demonstrated in European surveys (RP-154). CT technology is developing at a rapid pace, resulting in the development and use of higher number slice scanners and the use of CT for a wider range of diagnostic puposes.

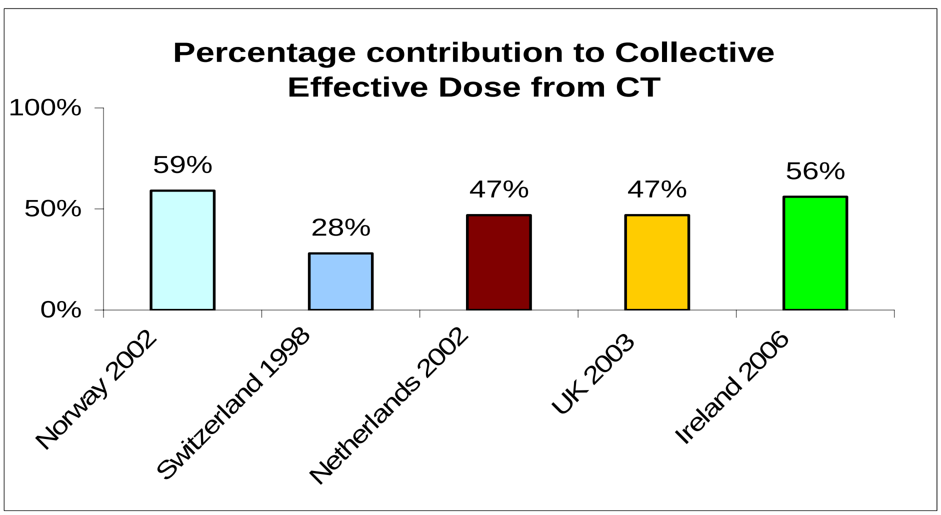

Figure 1. Contribution to collective population dose from CT examinations up to 2006.

This report is the first modality specific survey on total collective dose contributed from Computed Tomography (CT) in Ireland. The study is confined to the diagnostic use of CT scanners, and did not collect data pertaining to the use of CT in other areas, such as Radiotherapy, PET, Nuclear Medicine or Dental Cone Beam CT.

The Dose Reference Level (DRLs) for CT examinations were approved by the Medical Council in 2004[6], and were based on European surveys published in 1999 in which many of the scanners surveyed were single slice scanners, and so may not be relevant to modern multi-slice systems. To assist individual sites in setting their own local DRLs and with dose optimization, for CT examinations the results of the Population Dose CT Survey have been communicated back to each participating site to assist in optimisation of protocols and in setting local Diagnostic Reference Levels.

Methodology

To assist member states with the implementation of Article 12 the European Commission published European Guidance on Estimating Population Doses from Medical X-ray Procedures[7]. This document has been useful to the Population Dose Sub-Committee in formulating methodology and in reporting on population dose.

Numbers of radiologists and radiographers where CT scans are used

The 2008 Baseline clinical audit questionnaire [4] provided data on the numbers of staff associated with the use of all ionising radiation equipment, and this data is a useful comparison to that reported by other European countries as reported in RP-154[7].

CT Scanning Equipment and Locations

The register of all ionising radiation for both public and private installations in Ireland is held by the HSE, and provided data on the numbers and locations of CT scanners Ireland. The survey relates to doses from selected CT examinations for the twelve month period January to December 2009.

Survey Design

A subset of examinations for adults, and for paediatrics where relevant, was included in the survey. The subset of examinations was chosen based on the recommendations of the European Commission in RP-154[7] while taking into consideration changes in CT referral patterns seen in Ireland in recent years. In particular anecdotal evidence for a significant increase in Thorax/Abdomen/Pelvis scans was considered and this scan referral type was included in the survey.

In total six scan types were selected for survey of the adult population; CT Head, Neck, Thorax, Hi Resolution Thorax, Abdomen/Pelvis and Thorax/Abdomen/Pelvis. For the paediatric population a subset of the two most frequently requested examinations, Head and Abdomen/Pelvis were selected for survey.

The survey form (Appendix A) was sent to the CEO, Clinical Specialist Radiographer in CT and the Practitioner in Charge at each location, and requested data on patient and examination frequency, CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) (Appendix B). Both of these dose parameters are recorded by modern CT scanners and are displayed alongside the patient image. Where DLP was not available on older CT scanner models the $CTDI_{vol}$ was used as an estimate of patient exposure.

The number of patients who had a CT examination was surveyed, along with the number of examinations performed. Where multiple body part examinations were recorded as a single examination the patient frequency and examination frequency were expected to be identical. Where participating sites were able to provide examination frequency but unable to provide information on the number of patients irradiated an estimate of patient frequency was made, based on the ratio of patient to examination frequency from other similar participating sites.

In order to ensure that the data returned was validated internally before submission the survey required the signature of the CEO, the Radiologist-in-charge, and the Radiation Protection Adviser (RPA) as well as that of the individual responsible for completing the survey form.

Verification of the data originally submitted was made with the participating site where the original data indicated a dose significantly lower or higher than the Medical Council approved dose reference level or where the DLP appeared inconsistent with the $CTDI_{vol}$ provided.

Effective Dose Determination

Irish statutory instruments SI 125(2000)[8] and SI478 (2002)[2] enact the European Council Directives 96/29[9] and 97/43/EURATOM[1] which take into account the 1990 recommendations of the International Commission on Radiological Protection (ICRP)[10] on protection against the risks associated with ionising radiation. However, in recent years the ICRP have revised their view of the radio-sensitivity of some organs, most notably Breast and Gonads and published their most recent recommendations ICRP-103 in 2005[11]. The European Commission is revisiting the Directive 97/43/EURATOM[1] in light of these revised recommendations.

There are several published reference values for the conversion of DLP to estimated Effective Dose[12,13,14,15]. The conversion factor chosen reflects work carried out on modern CT scanners by Christner et al[12] taking into account ICRP-103. This work was followed on by Alesso and Phillips[13] to include Paediatric conversion factors (Appendix C). It is hoped that in this way the data collected is future proofed against changes to European guidance based on ICRP-103[11]. However, the conversion factor used needs to be taken into consideration when comparing the estimated effective dose with that of other studies, or with Dose Reference Levels.

RP-154[7] outlines the various methods used in European countries for estimation of effective dose for CT, for the purposes of population dose and states that uncertainties can lie in the range of 20-50% even when they are based on extensive surveys of current radiology practice in the country concerned.

Population Dose

The Effective Dose from each examination was determined from the DLP where DLP was available. For the two sites for which DLP was not available the average effective dose surveyed was attributed to the site. The Average Effective Dose per scan type was then used to contribute to the determination of Population Dose

Population dose is reported as the annual Collective Effective Dose manSv and Dose per Caput as recommended by RP-154[7].

The collective dose is defined as the sum of the average effective dose for each examination times the frequency of each examination.

The Dose per Caput is defined as the collective dose average over the whole population

The population for 2009 has been taken as the same as that from the 2006 Census 4,429,848[16] which also provides a breakdown of the population figure into adults and children under 15.

Results

The survey commenced in April 2010, with responses requested by 28th May 2010. 65 facilities with CT scanners were surveyed and a 100% response rate was achieved.

Numbers of radiologists and radiographers where CT scans are used

The 2008 Baseline Clinical Audit[4] identified the number of Radiologists, Radiographers and other medical specialties involved in the use of ionising radiation. In Ireland non-radiology specialties are not directly involved in the delivery of CT examinations and so are not discussed here.

The European Average[7] number of radiologists per million of the population is 89 compared to 54 in Ireland reported by the 2008 Survey. The Irish figure is broadly in line with that of the UK, at 50 per million of the population reported in 2002. The European average[7] number of radiographers per million of the population is 401 compared to 315 in Ireland as reported in 2008. The Irish figure is in line with that of the UK, as reported in 2002[7] of 310 radiographers per million of the population.

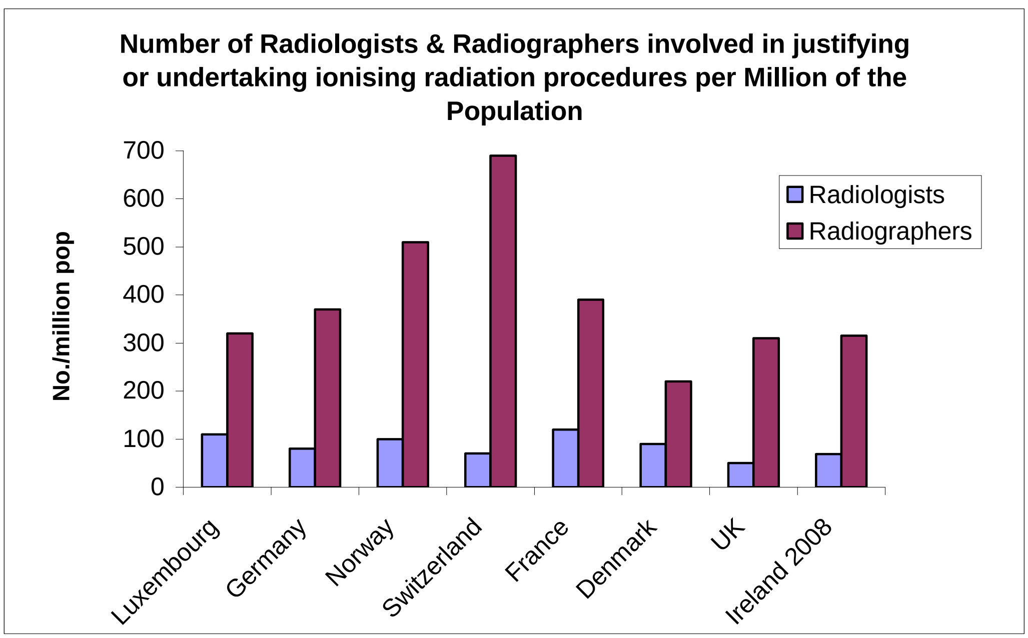

Figure 2 Number of radiologists and radiographers per million of the population

Number of CT scanners for the population

There were 65 CT scanners in Ireland in 2009, which is 15 CT scanners per 1,000,000 of the population in Ireland. This is lower than ,or broadly in line with, that reported for many other European countries[7] from surveys undertaken between 1998 and 2003 (figure 3).

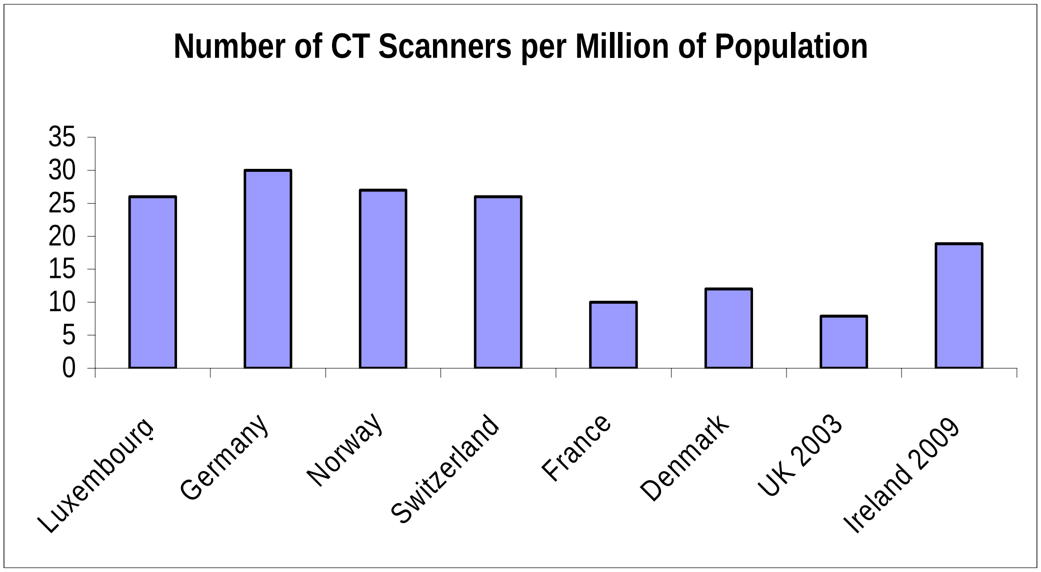

Figure 3. Number of CT scanners per million of the population across Europe[7]

<u>Number of CT scans per annum</u>

RP-154[7] reports on the number of CT examinations per year per 1000 of the population.

Data on number of Thorax/Abdomen/Pelvis (TAP) examination is sparce across the EU and is not recommended in RP-154[7] as one of the CT examinations to include in population dose surveys. However RP-154[7] figures relate to studies carried out between 1998 and 2003, and anecdotal evidence suggests that the TAP examination is now one of the most frequently requested examinations in Ireland, particularly in the context of oncology. The TAP examination was included in this first survey of CT use in Ireland.

A comparison of the examinations per 1000 of the population across Europe with that found in the survey can be seen in figure 4. The results validate the inclusion of the TAP in the survey with 10 examinations per 1000 of the population carried out in 2009, compared to 11 abdomen/pelvis scans and 7 Thorax scans per 1000 of the population.

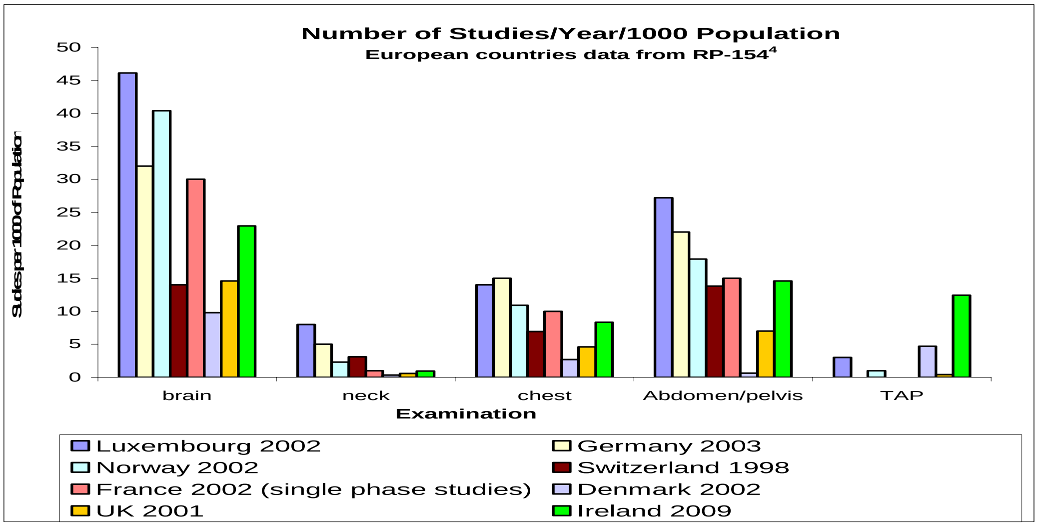

Figure 4. Number of CT scans per annum per 1000 of the population.

Average Effective Dose from CT Scans

The data provided on DLP, converted to Effective Dose (mSv) per scanner was averaged and the average Effective Dose per scan type is shown in Figure 5. For all scan types included in the survey the average effective dose (mSv) is lower than the European average. The high dose from the TAP scan taken in conjunction with the number of such scans per 1000 of the population justifies the inclusion of this scan type in the survey.

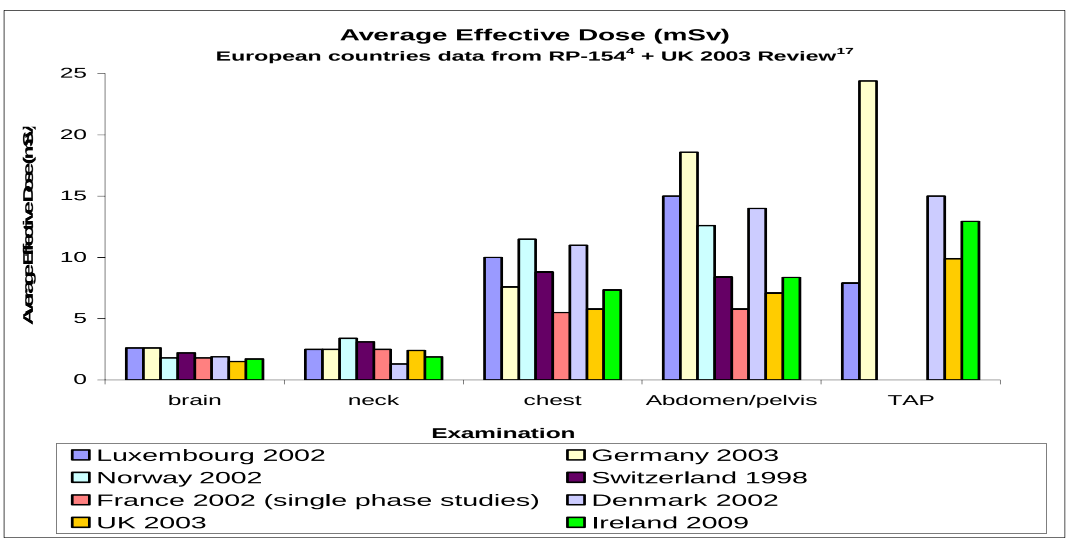

Figure 5. Average Effective Dose (mSv) across Europe.

The increase in average dose for Thorax examinations and Thorax/Abdomen/Pelvis due to the use of the chosen conversion factor relative to those recommended in RP-154[7] is illustrated in figure 6. The most significant change is seen for scans including the thorax due to the increased radiosensitivity of breast tissue recognised in ICRP-103.

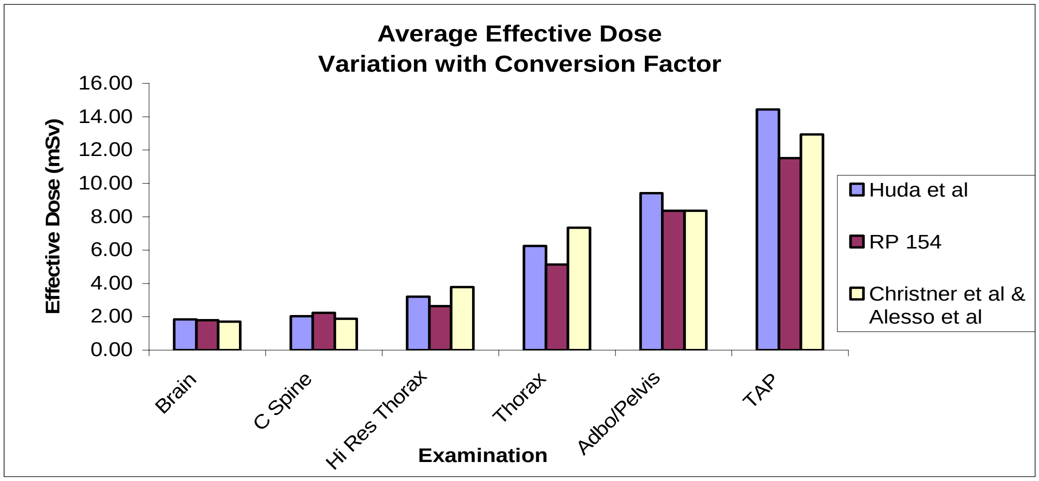

Figure 6.Variation in Average Effective Dose from the results of the 2009 CT scanning population dose survey, for each scan type using conversion factors; referenced in RP-154[7], published in 2008 by Walter Huda[15], and those published by Christner et al[12] and Alesso et al 2010[13]

Diagnostic Reference Levels for CT

The Irish Diagnostic Reference Levels for CT scans were approved by the Medical Council in 2004[6] and were based on data from European surveys, many of which were carried out some years previously. The Diagnostic Reference Level is the dose level not expected to be exceeded for standard procedures, for standard size patients, when good and normal practice regarding diagnostic and technical performance is applied. The DRL is generally determined as the 75th Percentile of the effective dose distribution delivered for each examination.

This survey did not consider a detailed analysis of examination protocols. Figure 7 illustrates that the 75th Percentile from the survey is lower, or on a par, with the Medical Council DRLs and those of the UK[18].

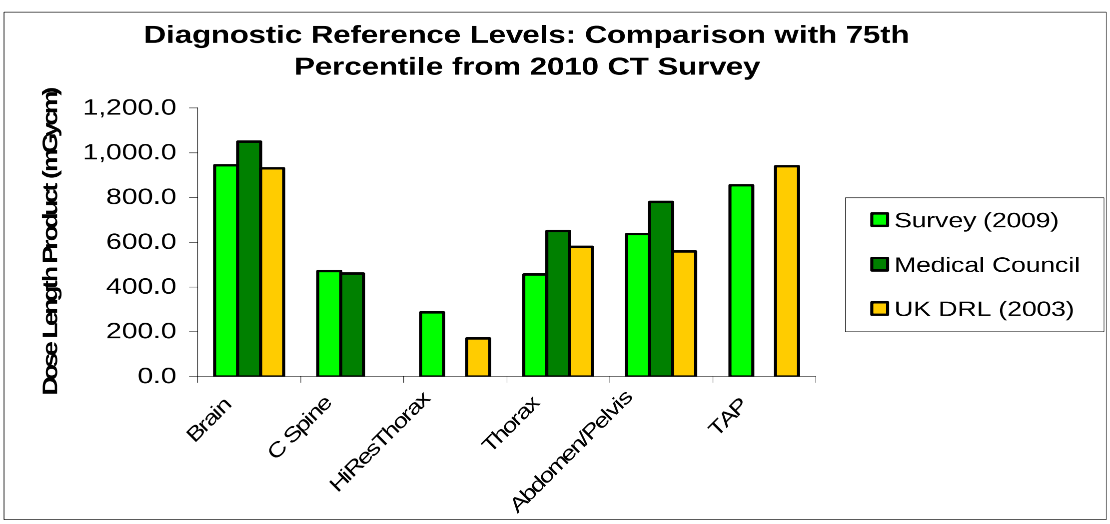

Figure 7. Diagnostic Reference Levels and comparison to the 75 Percentile of the Effective Dose per examination in the 2009 survey.

Population Dose

The average effective dose (mSv) per scan combined with the frequency of the scan type has been used to determine the population dose from CT scans.

The Collective Effective Dose (CED) to population as a whole from CT scans was found to be 1368manSv, an increase on the 1165manSv reported by the RPII in 2006. Of the total collective dose 1355.2manSv is attributed to the adult population and 12.4manSv, less than 1% of the total, to the paediatric population. However, this figure for CED must be considered an underestimate given that a small subset of examinations was selected for survey. There is no national figure for the total number of patients undergoing a CT scan, and so it was not possible to extrapolate a Collective Dose from all CT examinations, or to approximate the level of underestimation of the CT CED from the survey.

Taking the CED for all other medical procedures from the 2006 report[5], this translates to a total CED from all medical procedures for 2009 of 2044manSv, of which 67% is attributable to CT Scans compared to 56% reported in 2006. This can be compared to the most recent UK report which found 68% of the CED was attributed to CT[27].

The 2006 report[5] did not include TAP scans, although did include routine Abdomen and other examinations which were excluded here. The difference in the scan types chosen surveyed may account, in part, for the increase in dose to the population from CT over the three years. However, an increase might be expected in light of evidence from other countries of a continuing trend for higher CT usage, with Norway[24] reporting a 29% increase in CED from CT between 1993 and 2002, and CT scans in the USA increasing from 62 million scans in 2006[25] to 69 million scans in 2007[26].

Excluding the low collective dose attributed to the paediatric population the Dose per Caput was found to be 0.31mSv per head of the population, an increase on the 0.27mSv per head of the population reported by the RPII in 2006. The dose per caput to the paediatric population was found to be 0.01mSv.
Taking the other medical doses as the same as the 2006 report[5], this translates to a Dose per Caput for all medical exposures to be 0.48 mSv. In comparison the most recent UK report found the UK dose per caput from all medical and dental examinations to be 0.405mSv[27].

Figures 8 and 9 illustrate the breakdown of scan type in terms of patients scanned and contribution to the overall collective dose. It is clear that the Brain scan is the most frequently performed examination at 37% but contributes only 10% to the collective dose.

The TAP examination represents 20% of the examinations performed, while contributing over 40% to the Collective Dose to the Population.

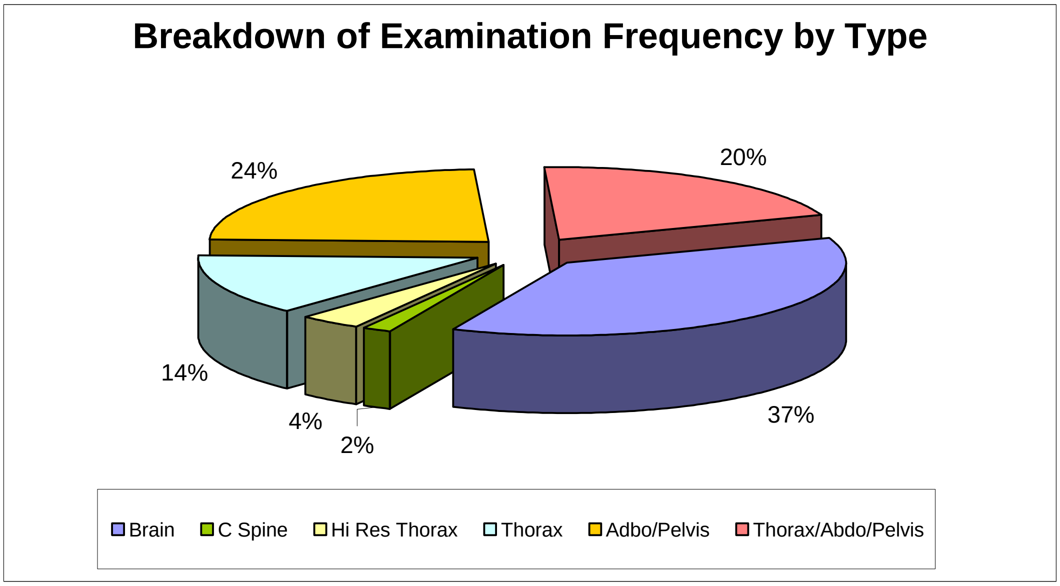

Figure 8. Contribution by scan type to the total number of scans performed for the subset of examinations surveyed.

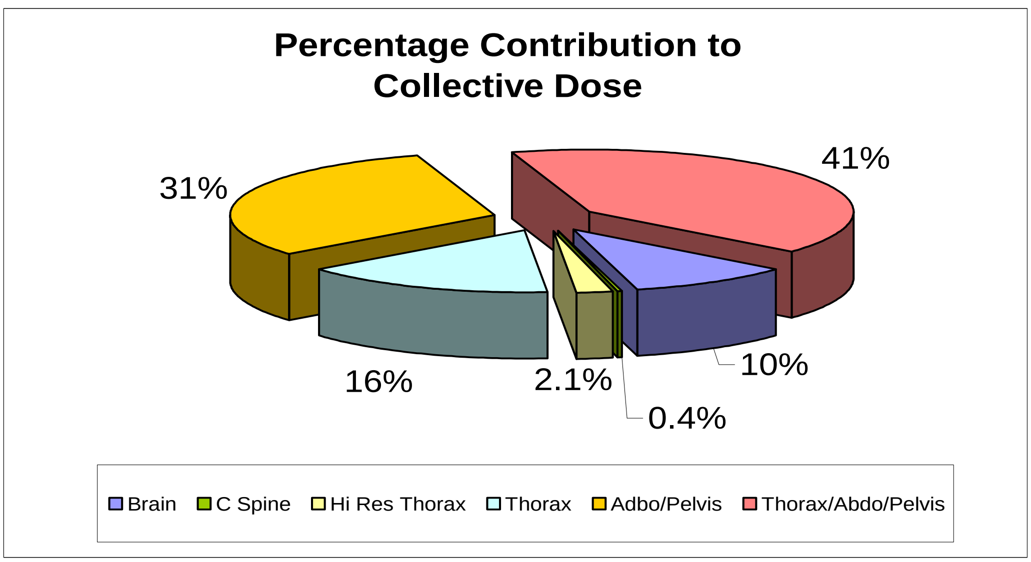

Figure 9. Contribution by scan type to the 2009 Collective Dose from CT scans.

Figures 10 and 11 illustrate a broad comparison with population dose from CT with that of other countries. This comparison must be treated with some caution. There is no internationally recognised standard examination dataset for surveying population from CT, or a standard extrapolation of surveyed data to all CT examinations. This survey includes TAP examinations and has not attempted to extrapolate the collective dose from the surveyed examinations to a total collective dose from all CT scans nationally. It is, therefore, not directly comparable to international studies [17,20,21,22,27]. However, in a broader context the comparison may be useful, and so is included here.

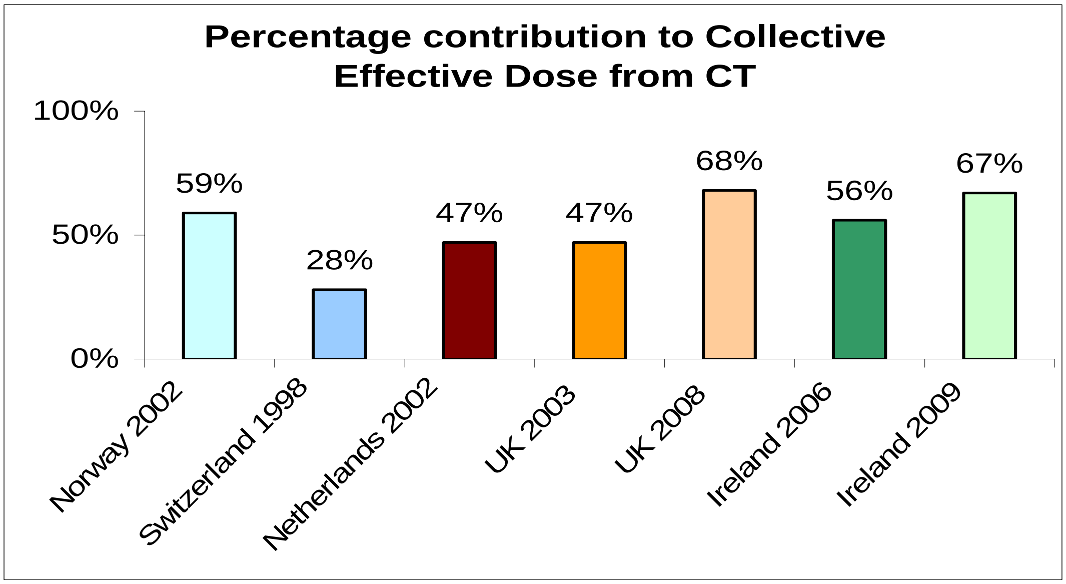

Figure 10. Comparison of the contribution of CT to Collective Dose from Diagnostic Medical examinations from the 2009 survey with that of other countries[4].

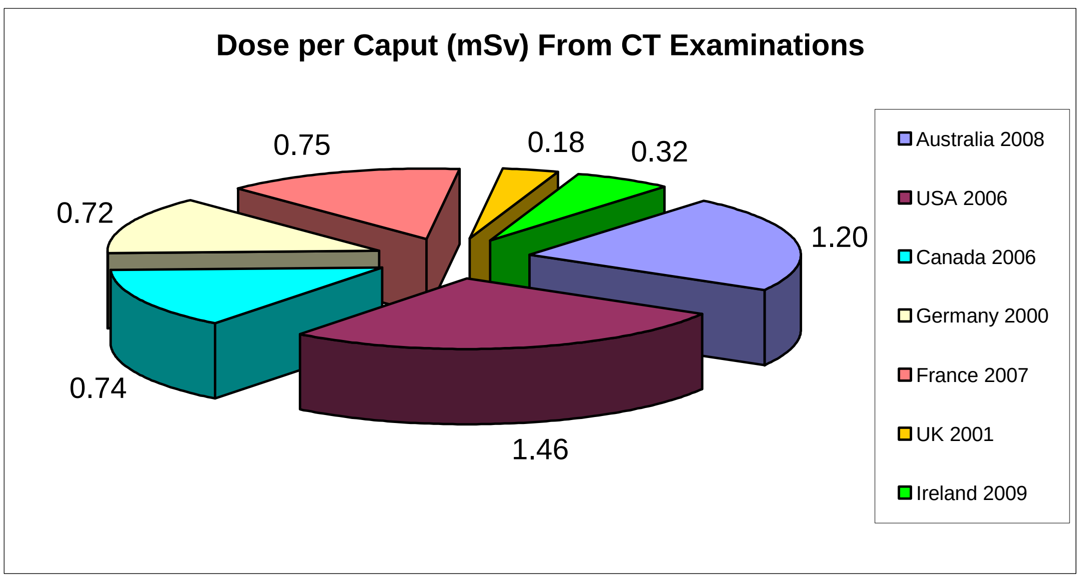

Figure 11: Comparison of 2009 dose per caput from CT with that of UK[17], Australia[19], USA[20], Canada[21] France[22] and other European Countries[7]

Recommendations for Future Surveys

While collecting data considerable difficulty was found in obtaining accurate figures for multi-organ part examinations, in particular the TAP. In most cases this data was not recorded by the holder, rather the number of examinations for each body part was recorded. In the main the TAP frequency per 1000 of the population is an estimate based on manual collation of data, for a period of time in 2009 chosen by the location as practicable, and extrapolated to a full year. Using this estimated frequency the TAP scan appears to be the largest contributor to collective dose and accurate data on frequency is of importance in determining overall collective dose to the population.

1. **It is recommended that holders are requested to record patient numbers by scan type rather than body part for all referred examinations.**

Difficulty was encountered in restricting DLP data collection to that of average sized patients. Many sites had to rely on retrospective collation of data without access to patient height and weight demographics available with the image study. This led to the inclusion of specific clinical cases that had additions to a routine scan, or patients of unusual size included in the estimates of average DLP at the site.

2. **It is recommended that routine audit of local Average DLP and Diagnostic Reference Levels, for average sized patients, and be considered by all holders. This should be extended to cover all CT examinations that may be included in future population dose surveys.**

The underestimation of dose to the population, by virtue of collating data on outmoded examinations or exclusion of newer techniques, may be of concern. Cervical spine and high resolution thorax examinations were found to contribute only 2.5% of the total collective dose from CT.

3. **It is recommended that these low frequency examinations be excluded from future surveys, while newer techniques such as CT Kidneys, Urether and Bladder (CTKUB), CT Pulmonary Angiography (CTPA) and CT Cardiology are considered for inclusion.**

It is hoped that the HSE National NIMIS project, with a national Radiology Information System for HSE hospitals might be in a position to assist with collation of population dose.

4. **It is recommended that the NIMIS Project is advised of the importance of collating accurate data examination frequency and dose data for future Population Dose surveys.**

It was not possible to extrapolate the collective dose from the examinations surveyed to a total effective dose from CT, as accurate figures for total number of CT scans performed are not available.

5. **It is recommended that the total number of patients undergoing a CT examination is collected in the next CT Population Dose Survey, to allow extrapolation of the surveyed data. This recommendation is dependent on recommendation 1.**

References

1. Council Directive 97/43/Euratom June 1997 on the health protection of individuals against the dangers of ionisng radiation in relation to medical exposure and repealing Directive 84/466/Euratom.
2. S.I No. 478 of 2002. European Communities (Medical Ionising Radiation Protection) Regulations 2002. EEC Directive 97/43/Euratom. Health Protection of Individuals agains the dander of Ionising Radiation in relation to Medical Exposures.
3. Annual Report 2008. HSE National Radiation Safety Committee
4. Quality Assurance Reference Centre (UK). Formal Baseline Clinical Audit of Current Practice in Medical Ionising Radiation Protection as required under Statutory Instrument 478 (2002). HSE National Radiation Safety Committee.
5. Radiation Doses Received by the Irish Population. Radiological Protection Institute of Ireland May 2008.
6. Medical Council. "Diagnostic Reference Levels Position Paper" Adopted by Medical Council 3 September 2004
7. European Guidance on estimating population doses from medical x-rays. Radiation Protection No. 154. European Commission 2008
8. S.I. No 125 of 2000. Radiological Protection Act, 1991 (Ionising Radiation) Order, 2000
9. Council Directive 96/29/Euratom May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiaiton.
10. The 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Annals of the ICRP, Vol 21, No. 1-3.
11. The 2007 recommendations of the International Commission on Radiological Protection ICRP Publication 103, Annals of the ICRP vol 37
12. Christner JA, Kofler JM McCullough CH. Estimating Effective Dose for CT Using Dose–Length Product Compared With Using Organ Doses: Consequences of Adopting International Commission on Radiological Protection Publication103 or Dual-Energy Scanning. AJR 194:881-889 2010
13. Alesso AM, Phillips GS. A pediatric CT dose and risk estimator, Pediatr Radiol 2010
14. 2004 European guidelines on quality criteria for computed tomography EUR 16262 EN
15. Huda W et al. Converting Dose-Length Product to Effective Dose at CT, Radiology 248(3):995-103, 2008
16. Census 2006 Principal Demographic Results, 2007 Central Statistics Office.
17. Hart D, Wall BF. Radiation exposure of the UK population from medical and dental x-ray examinations. Chilton, NRPB-W4 (2002).
18. Shrimpton, PC, Hillier MC, Lewis MA, Dunn M. Doses from Computed Tomography (CT) Examinations in the UK – 2003 Review, NRPB-W67 (2005)

19. Hayton A, Wallace A, Edmonds K, Tingey D. Application of the European DOSE DATAMED methodology and reference doses for the estimate of Australian MDCT effective dose (mSv). In Proceedings of the third European IRPA Congress 2010.

20. Recommendations of the National Council on Radiation Protection and Measurements. "Ionizing Radiation Exposure of the Population of the United States", NCRP Report 160, 2009

21. Chen, J Moir D. An estimation of the annual effective dose to the Canadian population from medical CT examinations. J Radiol Prot. 30 (2010) 131-137

22. Etarde C, Aubert B, Sinno-tellier S. Medical Exposure of the French Population 2007 In Proceedings of the third European IRPA Congress 2010

23. G. Bongartz, S.J. Golding, A.G. Jurik, M. Leonardi, E. van Persijn van Meerten, R. Rodríguez, K. Schneider, A. Calzado, J. Geleijns, K.A. Jessen, W. Panzer, P. C. Shrimpton, G. Tosi. European Guidelines for Multislice Computed Tomography 2004

24. Borretzen I, Lysdahl KB, Olerud HM Diagnostic radiology in Norway—trends in examination frequency and collective effective dose. Rad Prot Dos 2007;124(4):337-347.

25. Brenner DJ and Hall EJ. Computed Tomography – An Increasing Source of Radiaiton Exposure. N Engl J Med 2007;357:2277-2284

26. Berrington et al, Projected Cancer Risks from Conputed Tomography Scans Performed in the United States in 2007. Arch Intern Med 2009; 169(22):2071-2077

27. Hart, D, Wall BF, Hillier MC, Shrimpton PC. "Frequency and Collective Dose for Medical and Dental X-ray Examinations in the UK, 2008". Health Protection Agency HPA-CRCE-012, 2010

Appendix A

CT Population Dose Survey 2010, this form is available on line at http://www.hse.ie/eng/about/Who/Population%20Dose.html

Unique Hospital Number: ____________________

Complete a separate page for every machine:

Machine manufacturer: _______________

Make: ___________________________ **Model:**_______________

Data collected relates to the time frame from (date) ___/____/___ to (date): ___/___/___

Adults: (16 and over)

Sum of all Scans to be recorded	Number of Patients in 2009.	Number of Exams in 2009	Average KVp per Exam	Average CTDIvol (mGy)	Average DLP (mGycm)
Brain					
Cervical Spine					
Hi Res Thorax					
Thorax					
Abdomen/Pelvis					
Thorax/Abdo/Pelvis					

Paediatrics (where applicable):

Age 10 – 15 inclusive:

Sum of all Scans to be recorded	Number of Patients in 2009.	Number of Exams in 2009	Average KVp per Exam	Average CTDIvol (mGy)	Average DLP (mGycm)
Brain					
Abdomen/Pelvis					

Age 5 - 9 inclusive:

Sum of all Scans to be recorded	Number of Patients in 2009.	Number of Exams in 2009	Average KVp per Exam	Average CTDIvol (mGy)	Average DLP (mGycm)
Brain					
Abdomen/Pelvis					

Age 1 - 4 inclusive:

Sum of all Scans to be recorded	Number of Patients in 2009.	Number of Exams in 2009	Average KVp per Exam	Average CTDIvol (mGy)	Average DLP (mGycm)
Brain					
Abdomen/Pelvis					

Age newborn up to one year:

Sum of all Scans to be recorded	Number of Patients in 2009.	Number of Exams in 2009	Average KVp per Exam	Average CTDIvol (mGy)	Average DLP (mGycm)
Brain					
Abdomen/Pelvis					

Completed forms must be returned no later than Friday 28th May 2010

Appendix A

CT Population Dose Survey 2010, this form is available on line at http://www.hse.ie/eng/about/Who/Population%20Dose.html

Hospital Information

Hospital Name ____________________________

Completed by (Name): ____________________________

Job Title ____________________________

Signed: ____________________________

Date: ____________________________

RPA / MPE (name) ____________________________

Signed: ____________________________

Date: ____________________________

Practitioner in Charge (name) ____________________________

Signed: ____________________________

Date: ____________________________

CEO (name): ____________________________

Signed: ____________________________

Date: ____________________________

Return completed pages one and two to:

Email Rachel.brennan1@hse.ie

Or by post to:

Private and Confidential
Rachel Brennan
Medical Exposure Radiation Unit
HSE
Mill Lane
Palmerstown
Dublin 20

Tel 01-6201826

Completed forms must be returned no later than Friday 28th May 2010

Appendix B

Taken from Radiation Protection154 (reference 7)

The CT pitch factor for a scan sequence is the ratio of the distance (Δd, mm) moved by the patient support in the z direction between consecutive serial scans or per 360º rotation in helical scanning, and the product of the nominal section thickness (T, mm) and the number (N) of simultaneous tomographic sections from a single rotation (IEC 2003).

$$CT\ pitch\ factor = \frac{\Delta d}{N \times T} \qquad (1)$$

Volume radiographic exposure (C_{vol})

The volume radiographic exposure (C_{vol}, mAs) describes in helical scanning the average radiographic exposure over the total volume scanned. The C_{vol} is defined as follows:

$$C_{vol} = \frac{C}{CT\ pitch\ factor} \qquad \text{(mAs)} \quad (2)$$

Computed Tomography Dose Index (CTDI)

The principal dosimetric quantity used in CT is the computed tomography dose index (CTDI, mGy). This is defined as the integral along a line z perpendicular to the tomographic plane of the dose profile (D(z)) for a single axial scan, divided by the product of the number of tomographic sections N and the nominal section thickness T (Shope):

$$CTDI = \int_{-\infty}^{+\infty} \frac{D(z)}{N \times T} dz \qquad \text{(mGy)} \ (3)$$

where:

D(z) is the dose profile along a line z perpendicular to the tomographic plane, where dose is reported as absorbed dose to air (mGy);

N is the number of tomographic sections produced simultaneously in a typically a 360° rotation of the x-ray tube;

T is the corresponding nominal tomographic section thickness (mm)

In practice, a convenient assessment of CTDI can be made using a pencil ionisation chamber with an active length of 100 mm so as to provide a measurement of $CTDI_{100}$ expressed in terms of absorbed dose to air (mGy). Such measurements may be carried out free-in-air on, or parallel with, the axis of rotation of the scanner ($CTDI_{100(air)}$, or in abbreviation $CTDI_{air}$), or at the center ($CTDI_{100(center)}$) and 10 mm below the surface ($CTDI_{100(peripheral)}$) of standard CT dosimetry phantoms; in practice $CTDI_{100(peripheral)}$ is determined as the average of four values of $CTDI_{100}$ measured at evenly distributed positions around the dosimetry phantom:

Appendix B

$$CTDI_{100} = \int_{-50mm}^{+50mm} \frac{D(z)}{N \times T} dz \qquad \text{(mGy) (4)}$$

$CTDI_{air}$ is the $CTDI_{100(air)}$ measured at the isocenter (center-of-rotation) of the scanner in the absence of a phantom and patient support.

For the phantom measurements two homogeneous cylindrical phantoms with diameters of 160mm (standard CT head phantom) and 320mm (standard CT body phantom) are used. The height of the cylinders is at least 140mm and the material is PMMA. Holes with matching PMMA plugs are available in the phantoms for inserting a pencil ionisation chamber with an active length of 100 mm at the center and 4 equally spaced peripheral positions.

Measurements of CTDI in the standard head or body CT dosimetry phantom may be used to provide an indication of the average CTDI over a tomographic section produced with a single axial scan. On the assumption that dose in a particular phantom decreases linearly with radial position from the surface to the centre, then the average CTDI within a tomographic section (Leitz) is approximately the weighted $CTDI_{100}$ ($CTDI_w$):

$$CTDI_w = \frac{1}{3} \times CTDI_{100(center)} + \frac{2}{3} \times CTDI_{100(peripheral)} \qquad \text{(mGy) (5)}$$

The volume $CTDI_w$ ($CTDI_{vol}$) then describes the average dose over the total volume scanned in a sequential or helical sequence (IEC 2003):

$$CTDI_{vol} = \frac{CTDI_w}{CT\ pitch\ factor} \qquad \text{(mGy) (6)}$$

The subscript 'n' is sometimes used to denote when measurements of CTDI have been normalised to unit radiographic exposure (mAs):

$${}_nCTDI = \frac{CTDI}{C} \qquad \text{(mGy/mAs)} \quad (7)$$

where C is the radiographic exposure (mAs). Values of ${}_nCTDI$ vary with tube voltage and beam shaping filter, and also section thickness due to the effect of overbeaming, most notably for the smallest section thickness and 4-slice scanners. The beam shaping filter in use might depend on the selected field-of-view (e.g. a dedicated filter for small field scanning) or the anatomy to be scanned (e.g. a dedicated filter for body or head scanning). Elevated values of ${}_nCTDI$ at narrow section thickness, for a certain tube voltage and beam shaping filter, indicate a reduced geometric efficiency.

Dose Length Product (DLP)

Monitoring of the dose-length product (DLP, mGy.cm) provides control over the volume of irradiation and the overall exposure for an examination. The DLP depends on the $CTDI_{vol}$ and the length of the exposed range.

$$DLP = CTDI_{vol} \times L \quad \text{(mGy cm)} \qquad (8)$$

where:

L is the scan length (cm) limited by the outer margins of the exposed scan range (irrespective of pitch). For a helical scan sequence, this is the total scan length that is exposed during (raw) data acquisition, including any additional rotation(s) at either end of the programmed scan length that are necessary for data interpolation. Note that the DLP is derived from values of $CTDI_{vol}$ for either the standard head CT dosimetry phantom or the standard body CT dosimetry phantom. DLP's for different sequences are only additive if they refer to the same type of CT dosimetry phantom.

METHODS OF DOSE ASSESSMENT TO CHECK COMPLIANCE WITH THE CRITERIA

Comparison of performance against the criteria for each particular type of examination requires assessment of the values of the reference dose quantities associated with the technique typically used when scanning a standard-sized adult patient. In the absence of a well-defined scanning protocol, typical dosimetric practice should be determined on the basis of the mean results derived for a sample of at least 10 patients for each procedure.

Appendix C

DLP to Effective Dose
Conversion Factors

	Newborn			1 year old			5 year old		10 year old			Adult		
	RP-154(7)	Huda (15)	**Alesso (13)**	RP-154(7)	Huda (15)	**Alesso (13)**	RP-154(7)	**Alesso (13)**	RP-154(7)	Huda (15)	**Alesso (13)**	RP-154(7)	Huda (15)	**Alesso (13)**
head	0.011	0.0115	**0.0130**	0.0067	*0.0070*	***0.0080***	0.004	***0.0050***	0.0032	*0.0034*	***0.0040***	0.0021	*0.0022*	**0.0020**
neck	0.017	0.0156	**0.0230**	0.012	*0.0110*	***0.0150***	0.011	***0.0100***	0.0079	*0.0072*	***0.0070***	0.0059	*0.00540*	**0.00500**
chest	0.039	0.0474	**0.0570**	0.026	*0.0316*	***0.0380***	0.018	***0.0260***	0.013	*0.0158*	***0.0190***	0.014	*0.017*	**0.02**
abdopelvis	0.049	0.0523	**0.0500**	0.03	*0.0320*	***0.0310***	0.02	***0.0210***	0.015	*0.0160*	***0.0150***	0.015	*0.016*	**0.015**
trunk	0.044	0.0543	**0.0490**	0.028	*0.0345*	***0.0310***	0.019	***0.0210***	0.014	*0.0173*	***0.0150***	0.015	*0.019*	**0.017**