Medical Council
Comhairle na nDochtúirí Leighis
The Medical Council Regulates the Medical Profession in Ireland

Diagnostic Reference Levels

Position Paper

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Introduction:

Statutory Instrument 478 of 2002 was enacted into Irish Law on 15/10/2002. This legislation transcribes the provisions of EC Council Directive 97/43 Euratom on health protection of individuals against the dangers of ionising radiation in relation to medical exposures into Irish law. In the statutory instrument the Medical Council is required to promote the establishment and use of diagnostic reference levels (DRLs) for radio-diagnostic examinations.

This position paper seeks to identify the issues involved in the establishment and use of DRLs in this country.

Definitions:

"Diagnostic reference levels" means dose levels in medical radio- diagnostic practices or, in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied.

SI 478 of 2002:

11. 1. The Medical and Dental Councils shall promote the establishment and the use of standard diagnostic reference levels for radio diagnostic examinations as referred to in sub paras. 4.1(a), (b), (c) and (e).

4.1. These regulations shall apply to the following medical exposure:

(a) the exposure of patients as part of their own medical diagnosis or treatment;
(b) the exposure of individuals as part of occupational health surveillance;
(c) the exposure of individuals as part of health screening programmes;
(d) the exposure of healthy individuals or patients voluntarily participating in medical or biomedical, diagnostic or therapeutic, research programmes;
(e) the exposure of individuals as part of medico-legal procedures.

Please note that SI 478 excludes the exposure of individuals as part of research programmes from the ambit of DRLs. Exposures in medical research have been examined by the European Commission in a guidance note published in 1998 (20).

97/43 Euratom:
Article 6 (5)
Member states shall ensure that appropriate local reviews are undertaken whenever diagnostic reference levels are consistently exceeded and that corrective actions are taken when appropriate.

General Comments:
The International Commission on Radiological Protection (ICRP) has produced a useful advisory document on DRLs (1). The following comments are extracted from this ICRP document.
Objective of a DRL: The objective of a DRL is to help avoid radiation dose to the patient that does not contribute to the clinical purpose of the image. This is accomplished by comparison between the numerical value of the DRL and the mean or other appropriate value observed for a suitable *reference group* of patients or a suitable reference phantom. A DRL is not applied to individual patients.

DRLs should be applied with flexibility to allow higher doses when indicated by sound clinical judgment

The guiding principles for setting a DRL are:

(a) The regional , national or local objective is clearly defined , including the degree of specification of clinical and technical conditions for the medical imaging task
(b) The selected value of the DRL is based on relevant regional, national or local data.
(c) The quantity used for the DRL can be obtained in a practical way.
(d) The quantity used for the DRL is a suitable measure of the relative change in patient tissue doses and, therefore, of the relative change in patient risk for the given medical imaging task.
(e) The manner in which the DRL is to be applied in practice is clearly illustrated.

It is clear that a DRL is a form of benchmark against which practice in relation to medical exposure is evaluated. A suitable parameter derived from the exposures of a sample of standard sized patients (or phantoms) is compared to the DRL to identify atypical practice.
If, as the 97/47 Euratom suggests, a medical exposure practice is reviewed against the local value of the DRL then a practice leading to an 'outlier' in the relevant distribution can be identified. Once identified these practices should be optimized to ensure that the dose distribution is altered and consequently the DRL value will change accordingly. Therefore, DRL values themselves are not fixed in stone but are subject to refinement as the system evolves.
It is worth noting that DRL values have generally been set at the upper level of acceptability of patient dose. It is clear, however, that if radiation levels in an exposure are too low then the intended clinical outcome is not achieved and the radiation is 'wasted'. In future, perhaps, DRL values will encompass an upper and lower threshold.
In summary, a DRL is a level set for a **standard** procedure, for **groups** of standard sized patients or a standard phantom and **not** for individual exposures and individual patients.

Diagnostic Radiology (Plain Film):

The dose distribution in diagnostic radiology is usually skewed with a long tail at the higher end of the scale. It has been recommended (2) that the 75^{th} percentile of the dose distribution is an appropriate level for the DRL. The use of this percentile is a pragmatic first approach to identifying those situations most in need of investigation.

DRLs can be established using a TLD on the patient's skin to measure entrance surface dose including backscatter. An alternative method is to measure the Dose-Area- Product using a DAP meter. The balance of convenience lies with the DAP meter approach but the availability of these devices has been limited up to now. This situation will change as SI 478 requires that new X-ray equipment, if appropriate, should have a DAP meter fitted at installation.

It should be noted that image receptor technology has altered considerably in the recent past with the introduction of computed radiography and direct digital radiography. As the use of these technologies become more widespread patient dose distributions will be altered and consequently the adopted values for the DRLs will also have to be reviewed and adjusted as appropriate.

While there is a wide range of data available on patient dose values in this country there is a relative paucity of published papers on the subject. Therefore, in the first instance, considerable reliance will have to be placed on published data from U.K. and European sources. This approach is open to criticism as it is acknowledged (3) that practice and equipment use in this country may not be comparable with that in other states.

Table 1 contains DRL values (4) derived from data obtained in Irish hospitals.

Table 1.

Examination	Projection	DRL per view
Chest	PA	0.3 mSv
Abdomen	AP	6 mSv
Pelvis	AP	7 mSv
Lumbar Spine	AP	8 mSv
Lumbar Spine	Lateral	24 mSv
Lumbar Spine	LSJ	46 mSv

Table 2 contains DRL values (3) for intravenous urography from Irish hospitals.

Table 2.

Examination	DRL (Total study)
IVU	**12 Gy.cm^2**

In the case of examinations, other than the IVP, the above DRL values represent the entrance surface dose at the point of intersection of the beam axis with the surface of a standard sized patient. The DRL value for the IVP is the total dose- area- product for the examination.

Table 3 contains some further DRL values (5) derived from UK data.

Table 3.

Examination	Projection	DRL per view
Chest	Lateral	1.5 mSv
Thoracic Spine	AP	5.1 mSv
Thoracic Spine	Lateral	16.2 mSv

As has already been stated the DAP values are a more convenient method of establishing DRLs. A list of DRL values (18) based on DAP readings from the UK are contained in Table 4.

Table 4.

Examination	Projection	DRL per view $Gy.cm^2$
Chest	PA	0.12
Abdomen	AP	3.1
Pelvis	AP	2.7
Lumbar Spine	AP	1.6
Lumbar Spine	Lateral	2.8
Lumbar Spine	LSJ	2.9

Diagnostic Imaging (Fluoroscopy):

Because of the likely variability of the X-ray entrance beam at the body surface it has been accepted that the DAP value is most appropriate parameter for DRL values in fluoroscopy.

Table 5 contains DRL values (6) obtained from data accumulated in Irish Hospitals.

Table 5.

Study	DRL (Total study)
Barium Enema	47 $Gy.cm^2$
Barium Meal	17 $Gy.cm^2$

Table 6 contains a DRL value (18) for a barium follow through examination derived from data collected in the UK

Table 6.

Examination	DRL (Total study)
Barium Follow Through	14 $Gy.cm^2$

Table 7 contains DRL values for a range of more complex procedures derived from data collected in the UK.

Table 7.

Examination	DRL	Source
Femoral Angiogram	33 $Gy.cm^2$	(18)
ERCP	19.0 $Gy.cm^2$	(18)
Venography – Leg	5.0 $Gy.cm^2$	(18)
MCU	17 $Gy.cm^2$	(18)
Hysterosalpinogram	4 $Gy.cm^2$	(18)
Nephrostogram	13 $Gy.cm^2$	(18)
Small Bowel Enema	50 $Gy.cm^2$	(18)
T-Tube Cholangiogram	10 $Gy.cm^2$	(18)
Water soluble enema	31 $Gy.cm^2$	(18)
Water soluble swallow	11 $Gy.cm^2$	(18)
TIPPS	237 $Gy.cm^2$	(7)
TIPS follow up	93 $Gy.cm^2$	(7)
Central Line Insertion	10 $Gy.cm^2$	(7)
Abdominal Angiogram	132 $Gy.cm^2$	(7)
Renal Angiogram	93 $Gy.cm^2$	(7)
Mesenteric Angiogram	145 $Gy.cm^2$	(7)

Interventional Radiology and Cardiology:

The establishment of DRL values in Interventional Radiology and Cardiology is particularly difficult as these studies, by their very nature, are generally non-standard and therefore do not come within the definition of DRLs.

Research programmes sponsored by the EC have been investigating the establishment of reference levels in these areas (8) and have concluded that for complex procedures reference levels must include DAP values, fluoroscopy times and total number of images acquired. This approach, it is argued, will allow optimisation and also minimise the incidence of skin injuries. For example, in a recent Spanish study (9) the following values are indicated for the DRL for interventional cardiology:

DAP = 99 $Gy.cm^2$
Fluoroscopy Time = 9.5 minutes
Number of Images = 981

Data from UK studies may be used to arrive at an initial estimate of DRL values, based on DAP readings alone, for a limited number of procedures (18). These data are presented in Table 8

Table 8

Procedure	DRL $Gy.cm^2$
Biliary Drainage	54
Biliary Intervention	50
Hickman Line	4
Oesophageal dilation	16
Pacemaker insertion	27
Coronary Angiogram	36

Computed Tomography:

The principal dosimetric quantity used in CT is the computed tomography dose index (CTDI). This parameter can be measured with a suitable pencil dosimeter and quantifies the radiation output of the system during a complete revolution of the tube.

Measurements may be made free-in-air or alternatively in Perspex phantoms Reference dosimetry in CT is based on measurements in two standard Perspex phantoms, namely, a 16 cm diameter cylinder for head exposures and a 32 cm diameter cylinder for body exposures.

The combination of measurements made at the centre (c) and 10 mm below the surface (p) of the phantom leads to the following two reference dose values.

Weighted CTDI for a single slice

$CTDI_w = 1/3\ CTDI_{100,c} + 2/3\ CTDI_{100,p}$

The 100 subscript denotes measurements made with a 100 mm pencil probe and the p subscript represents an average of measurements at four different locations around the periphery of the phantom.

Dose-length product for a complete examination

$DLP = {}_nCTDI_w \times A \times t \times n \times T$

Where the n subscript indicates that the CTDI is normalised for mAs, A is the mA, t is the total irradiation time, n is the number of slices acquired simultaneously and T is the nominal slice thickness.

If there are a number of scan sequences in the examination then they are all summed to get a total DLP for the examination.

Initial reference dose levels in CT have been proposed based on measurements made in a number of European countries (12). These reference levels are contained in Table 9

Table 9.

Examination	CTDIw (mGy)	DLP(mGy.cm)	Phantom
Routine Head	60	1050	Head
Face and Sinuses	35	360	Head
Vertebral Trauma	70	460	Body
Routine Chest	30	650	Body
HRCT Lung	35	280	Body
Routine Abdomen	35	780	Body
Liver and Spleen	35	900	Body
Routine pelvis	35	570	Body
Osseus pelvis	25	520	Body

A recent study (13) performed in Northern Ireland , where CT practice should be comparable to that in the Irish Republic, indicates that these reference levels are generally applicable in this region.

The measurements required to establish $CTDI_w$ and DLP values, while not intrinsically complex, can be tedious. However, on some new scanners these values are computed automatically and are displayed on the control monitor once the scanning parameters have been selected. It is extremely important that these displayed values be verified at acceptance testing as some manufacturers correct $CTDI_w$ values for selected pitch, contrary to the EC recommendation. Furthermore, in the US it has been customary to use the FDA definition for $CTDI_w$ which is at variance with the EC one and hence it needs to be established clearly which parameter is being displayed on the monitor. These issues are fully examined in a recent publication on CT quality control (14).

It should be noted also that the reference levels in Table 8 are, in the main, based on data from single slice CT machines. As the use of multi-slice machines becomes more widespread it is likely that these values will have to be adjusted to take account of the potential for increased dose levels in multi-slice CT examinations.

Mammography:

In European guidelines (15) on image quality a reference level of 10 mGy surface dose per view is proposed.
Entrance surface dose measurements present some difficulty in mammography as the placing of a TLD chip on the skin surface causes a marked image artefact which has a significant effect on diagnostic efficacy. It is possible to measure entrance kerma outside the breast area and correct this for backscatter but this approach is prone to some considerable error.
For a range of technical reasons it is not possible to use DAP meters on mammography machines.

The most convenient DRL for mammography is an estimation of mean glandular dose to a standard Perspex phantom – 4cm thick.
This phantom based DRL is 2 mGy per view in the UK (7).
Details of the measurements involved in deriving mean glandular dose values are contained in the literature (15)
In the UK there is also a recommendation that mean glandular dose measurements be measured on a representative sample of patients for each facility.

Modern mammography X-ray machines contain a range of selectable anode coatings and filter materials. Each of the settings used in clinical practice should be evaluated against the DRL value.

Nuclear Medicine:

In diagnostic nuclear medicine DRLs are expressed in terms of administered activities (MBq) rather than absorbed dose (2).

The DRL values are not based on the 75^{th} percentile but on the administered activity necessary for a good image on well- adjusted equipment during a standard procedure.

In diagnostic nuclear medicine, while the DRL is not expected to be exceeded in standard procedures, the DRL should be approached as closely as possible to produce optimised images. As technology improves these DRL values will also need to be adjusted.

Over the recent years there have been some surveys of nuclear medicine clinical practice conducted in Irish hospitals. None of the data derived from these surveys have, as yet, been published in the literature. Practice here closely reflects that in the UK. Therefore it seems reasonable to propose that the UK DRL values, in this speciality, should be used in this country.

Table 10 contains the UK DRL (16) values for a range of nuclear medicine procedures.

Table 10.

Radionuclide	Pharmaceutical	Investigation	DRL (MBq)
Cr-51	Red blood cells	Red cell volume	0.8
Cr-51	Red blood cells	Ed cell survival and sequestration	4
Cr-51	EDTA	GFR	3
Ga-67	Citrate	Infection/inflammation imaging	150
Kr-81m	Gas	Lung Ventilation	6000
Tc-99m	Pertechnetate	Thyroid Imaging	80
Tc-99m	Pertechnetate	Stomach and Salivary gland imaging	40
Tc-99m	Pertechnetate	Meckel's diverticulum	400
Tc-99m	Pertechnetate	Lacrimal drainage	4 (each eye)
Tc-99m	MAA	Lung Perfusion	100 200 SPECT
Tc-99m	Phosphates Phosphonates	Bone Imaging	600 800 SPECT
Tc-99m	DTPA	Renal Imaging	300
Tc-99m	DMSA	Renal Imaging	80
Tc-99m	MAG-3	Renal Imaging	100
Tc-99m	Colloid	Liver Imaging	80 200 SPECT
Tc-99m	Colloid	Bone marrow Imaging	400
Tc-99m	Colloid	Lymph Node Imaging	40
Tc-99m	Colloid	GI Bleed	400
Tc-99m	Iminodiacetates	Biliary Imaging	150
Tc-99m	Denatured red cells	Spleen Imaging	100
Tc-99m	Red blood cells	GI Bleed	400
Tc-99m	Red blood cells	Cardiac Blood Pool	800
Tc-99m	Exametazine labelled white cells	Infection/ Inflammation Imaging	200
Tc-99m	Sestamibi	Parathyroid Imaging	900
Tc-99m	Sestamibi	Tumour Imaging	900
Tc-99m	Sestamibi	Myocardial Imaging	300 400 SPECT
Tc-99m	Exametazine	Cerebral Perfusion	500
Tc-99m	Leukoscan	Infection/Inflammation	750
Tc-99m	Technegas	Lung Ventilation	40
Tc-99m	CEA	Tumour imaging	750
Tc-99m	HIG	Infection/Inflammation	200
Tc-99m	Tetrofosmin	Parathyroid Imaging	900
Tc-99m	Tetrofosmin	Myocardial Imaging	300 400 SPECT

Table 10 (contd)

Radionuclide	Pharmaceutical	Investigation	DRL (MBq)
Tc-99m	ECD	Brain Imaging	500
In-111	DTPA	Cisternography	30
In-111	White blood cells	Infection/inflammation	20
In-111	Oncoscint	GI Tumour Imaging	150
In-111	Pentreotide	Somatostatin receptor imaging	110 220 SPECT
I-123	MIBG	Neuroectodermal tumour imaging	400
I-131	Iodide	Thyroid Uptake	5
I-131	Iodide	Thyroid metastases	400
I-131	MIBG	Neuroectodermal Tumour imaging	20
Xe-133	Gas	Lung Ventilation	400
Tl-201	Chloride	Non-specific Tumour Imaging	150
Tl-201	Chloride	Thyroid tumour imaging	80
Tl-201	Chloride	Myocardial Imaging	80
Tl-201	Chloride	Parathyroid Imaging	80
F-18	FDG	Tumour Imaging	400
F-18	FDG	Myocardial Imaging	400

It should be noted that these DRL values are prescribed for standard sized patients. If the adult patients are of a non-standard size, i.e. less than 50 kg or greater than 90 kg then the injected activities need to be adjusted to allow for this variation. A pro-rata adjustment by patient weight is the simplest method to allow for patient size variation. [A patient of 100 Kg would be injected with the relevant activity value from Table 9 multiplied by 100/70].

Paediatric Reference Levels:

For the purpose of this paper children are defined as those aged up to and including 15 years old. Sixteen year olds and upwards are classified as adults.

In the UK the majority of X-ray examinations on children are undertaken in general hospitals where the level of expertise and interest in paediatric imaging is very variable. Furthermore, it is unlikely that the special requirements for paediatric examinations have been taken into account in the selection and operation of X-ray equipment. (7)

A major problem with data collection from paediatric patients is the range of patient sizes within any age band.

The EC has provided reference doses for a standard 5 year old (weight 19 kg) but not for other ages (17). The European data revealed a very wide variation in measured dose for individual patients because of the wide range in speed of film-screen systems in use and the relatively poor optimisation of technique.

At present there are no published data from paediatric exposures in Irish hospitals although this is likely to change in the near future. However, some data are available from a group in the Mater Hospital (21). These data are derived from practice in dedicated paediatric facilities and are included in Table 11.

Studies performed in UK hospitals have revealed a clear relationship between dose and patient age and for this reason the NRPB recommends the adoption of reference levels for a range of patient ages. Five standard sizes of children were chosen by the NRPB representing 0, 1, 5, 10, 15 year olds. (18)

Table 11 contain DRL values obtained from paediatric practice in UK (18) and Irish hospitals (21)

Table 11

Examination	Patient Age (yrs)	Irish DRL μGy	UK DRL μGy
Abdomen AP	1	330	
	5	752	700
	15		2600
Chest AP/PA	0		70
	1	57	90
	5	53	150
	10	66	
	15	88	100
Pelvis AP	0		210
	1	265	
	5	475	
	10	807	730
	15	892	1320
Skull AP	5		1370
Skull Lat	5		820

Table 12 contains DRL values on more complex paediatric examinations derived from UK data (18)

Table 12

Examination	Patient Age (yrs)	UK DRL mGy.cm2
MCU	0	400
	1	900
	5	1100
	10	2100
	15	4700
Barium Meal	0	700
	1	2000
	5	2000
	10	4500
	15	7200
Barium Swallow	0	800
	1	1600
	5	1300
	10	2700
	15	4600

Initial European reference doses for CT examinations in paediatric patients are provided in (19) and are listed in Table 13.

Table 13

Examination	Patient Age (yrs)	CTDIw (mGy)	DLP per examination (mGy.cm)
Brain	<1	40	300
	5	60	600
	10	70	750
Chest	<1	20	200
	5	30	400
	10	30	600
Chest (HRCT)	<1	30	50
	5	40	75
	10	50	100
Upper Abdomen	<1	20	330
	5	25	360
	10	30	800
Lower Abdomen & Pelvis	<1	20	170
	5	25	250
	10	30	500

The injected activities in paediatric nuclear medicine should be based on the adult reference levels adjusted for patient weight. However a minimum activity of $1/10^{th}$ of the adult value should be used to ensure that imaging times are acceptable in young children. (2).

Testing Compliance:
To establish conformity with the respective DRL value the relevant parameter should be logged on a sample of 10 patients and its mean value compared to the DRL. If is not possible to accumulate data on 10 patients then smaller sample sizes can be used once the mean patient weight is in the range 65 – 75 kg (18). In institutions where the procedures are conducted in a number of different rooms the verification process will have to be replicated in each room.

In the case of paediatric patients smaller sample sizes (2 or 3) could be used to determine conformity to the DRL for each patient size.

It should be emphasised that measuring devices used in the hospitals to perform the compliance measurements need to be subjected to rigorous quality control procedures. In particular, if TLD chips are used to measure entrance surface dose then the TLD batch must be selected to ensure that the batch variance together with any uncertainty in the calibration factor is within a 10% error margin. Similarly, DAP meters need to be checked to ensure that they yield results to within a 10% error margin. [DAP meters fitted to under couch tubes need to be adjusted to make allowance for attenuation in the table top and mattress material.]

Activity calibrators used in nuclear medicine to measure injected activities also need to have their calibration factors checked for accuracy with a suitable calibration source. Injected activity should be measured to an accuracy of 10%.

Conclusion:

The data presented in this paper are an initial attempt at establishing local DRL values. As has been already mentioned the published data from Irish sources is very sparse and hence a great deal of reliance has been placed on data of UK or European origin. The recommended DRL values need to be scrutinised carefully to ensure that they are appropriate for practice in Irish hospitals.

A number of hospitals in this country have been accumulating patient dose data for some time in an effort to optimise procedures. These data could form the basis for a refinement of the proposed DRL values. To facilitate this process a national centre needs to be established to collate the data and to establish consistent protocols for the collection of such data. This collating service is performed by the NRPB in the UK and is the source of 95% of the data on the comprehensive patient dose surveys performed in that jurisdiction. Clearly, the Department of Health and Children would have to provide the modest funding needed for this service.

When the DRL values have been adopted it would be prudent to establish a review of the adopted values in parallel with the compliance verification process. Patient dose levels are in a state of flux at present because of the introduction of new image receptor technology (CD, DR) both in radiography and in fluoroscopy. Furthermore, the more widespread use of multi- slice CT machines is likely to have a significant effect on patient dose. This review process could also come within the remit of the national collating service.

The bulk of new X-ray apparatus installed henceforth in this country will be fitted with DAP meters. It would seem appropriate, therefore, to establish DRL values in terms of dose-area-product values, where feasible, for all X-ray examinations in the future.

DRL References

1. Diagnostic Reference Levels in Medical Imaging: Review and Additional Advice. ICRP web site. http://www.icrp.org/educational_area.htm accessed 14/10/03
2. EC Radiation Protection Report 109. Guidance on Diagnostic Reference Levels (DRLs) for Medical Exposure. 1999.
3. Investigation into patient doses for intravenous urography and proposed Irish diagnostic reference levels. Carroll E.M., Brennan P.C. Eur. Radiol. 2003; 13(7): 1529 – 1533
4. Reference dose levels for patients undergoing common diagnostic examinations in Irish Hospitals. Johnson D.A., Brennan P.C. Brit. J. Radiol 2000; 73: 396 – 402.
5. Doses to patients from Medical X-ray Examinations in the UK – 1995 review. NRPB – R-289 1996
6. Radiation Doses for barium enema and barium meal examinations in Ireland: potential diagnostic reference levels. Carroll E.M., Brennan P.C. Brit J. Radiol. 2003; 76: 393 – 397.
7. Guidelines on Patient Dose to promote the optimisation of protection for diagnostic medical exposure. NRPB Docs. 1999: 10
8. DIAMOND: A European approach to establish and use reference levels in fluoroscopy guided procedures. In Radiological Protection of patients in diagnostic and interventional radiology. IAEA Malaga , 2001
9. Skin dose and dose-area product values for interventional cardiology procedures. Vano E., Gonzalez L., et al. Brit. J. Radiol. 2001: 74; 48-55
10. A study of radiation doses in interventional radiology. McParland B.J. Brit. J. Radiol. 1998; 71 : 175 – 185
11. Dose – area product measurements in a range of common orthopaedic procedures and their possible use in establishing local diagnostic reference levels.
12. Quality Criteria for Computed Tomography. EUR 16262 , EC (1999)
13. Application of draft European Commission reference levels to a regional CT dose survey. Clarke J., Cranley K., et al, Brit J. Radiol. 2000; 73: 43-50
14. Computed Tomography X-ray Scanners. IPEM Report 32, Part III. (2003).
15. The commissioning and routine testing of mammographic X-ray machines. IPEM Report 59 (2nd Ed.) 1994.
16. Notes for guidance on the clinical administration of radiopharmaceuticals and use of sealed radioactive sources. Administration of radioactive substances advisory committee (ARSAC) December 1988.
17. European guidelines on quality criteria for diagnostic radiographic images in Paediatrics. EUR 16261 EN (1996).
18. Doses to patients from medical X-ray examinations in the UK – 2000 review. Hart D., Hillier M.C., Wall B F. NRPB – W14 (2002)
19. Reference Dosimetry for CT in the UK. Shrimpton P.C., Wall B.F. Radiological Protection of Patients in Diagnostic and Interventional Radiology. IAEA Malaga 2001.
20. Guidance on medical exposures in medical and biomedical research. EC Radiation Protection 99 (1998).
21. Paediatric reference levels. Private Communication. Byrne B., Kenny P.A.