PiDRL

EUROPEAN DIAGNOSTIC REFERENCE LEVELS FOR PAEDIATRIC IMAGING

WORKSHOP

October 15–17, 2015

Lisbon School of Health Technology/
Escola Superior de Tecnologia da Saúde de Lisboa
Lisbon, Portugal

BOOK OF ABSTRACTS

coordinated by the
ESR
EUROPEAN SOCIETY OF RADIOLOGY

ESCOLA SUPERIOR DE TECNOLOGIA DA SAÚDE DE LISBOA

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TABLE OF CONTENTS

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coordinated by the EUROPEAN SOCIETY OF RADIOLOGY

EFRS European Federation of Radiographer Societies

EFOMP

STUK

ESPR European Society of Paediatric Radiology

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WELCOME MESSAGE

Dear colleagues,

On behalf of the PiDRL Project, I am delighted to extend warm greetings to everyone attending this workshop. PiDRL is intended to agree on a methodology for establishing and using diagnostic reverence levels (DRLs) for paediatric imaging, and update and extend the European DRLs to cover more types of examinations. The main task is to develop European guidelines on DRLs for paediatric imaging covering a wide range of procedures such as plain radiography, fluoroscopy, CT and fluoroscopically-guided interventional procedures. We have organised this workshop to subject the draft European guidelines to comments and critical review from a larger audience. We will also discuss a range of topics pertaining to difficulties and opportunities in the field of optimisation of radiation protection of paediatric patients.

The organising committee has worked hard to develop a stimulating scientific programme. This event provides a unique opportunity for all participants to exchange ideas and share their knowledge and experience. Moreover, I hope you will take some time to explore the beautiful city of Lisbon. There are many exciting places to visit and a variety of restaurants to enjoy Portuguese cuisine.

I would like to express my sincere thanks to the Lisbon School of Health Technology (ESTeSL) for providing generous support and hosting the PiDRL Workshop at their premises. Special thanks also go to everybody who has been involved in the creation of the PiDRL Workshop and has contributed to organizing this meeting. Last but not least, thank you for attending the PiDRL Workshop!

Prof. John Damilakis
PiDRL Project Scientific Coordinator

PROGRAMME

DAY 1 Thursday, OCTOBER 15

13:00–13:05 **Welcome by host – Lisbon School of Health Technology (ESTeSL)**
João Lobato (ESTeSL President, PT)

13:05–13:15 **00 - Welcome by ESR and presentation of EuroSafe Imaging context**
Guy Frija (ESR, Chair of EuroSafe Imaging Steering Committee, FR)

ROUND TABLE 1:
PiDRL Project Presentation
Moderators: Peter Vock (ESR, CH), Graciano Paulo (EFRS, PT)

13:15–13:30 **01 - Welcome – Overview of the PiDRL Project**
John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

13:30–13:45 **02 - The importance of European guidance for the establishment and use of DRLs for paediatric imaging**
Georgi Simeonov (European Commission, LU)

13:45–14:00 **03 - WP1: Development of the European PiDRL guidelines**
Hannu Järvinen (STUK, FI)

14:00–14:15 **04 - WP2: Update and expansion of European DRLs in paediatric imaging**
John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

14:15–14:30 **Discussion**

ROUND TABLE 2:
Current Status in DRLs for Paediatric Imaging in European Countries
Moderators: John Damilakis (ESR, Scientific Coordinator of PiDRL, GR), Annalisa Trianni (Udine University Hospital, DICOM Working Group 2, IT)

14:30–14:50 **05 - Summary of DRLs in European countries for paediatric imaging based on the DDM2 data and the results of the PiDRL specific questionnaire**
Hannu Järvinen (STUK, FI)

14:50–15:10 **06 - Radiographic and fluoroscopic paediatric DRLs:**
Data from the literature
Virginia Tsapaki (EFOMP, GR)

15:10–15:40 ***Coffee break***

15:40–16:00 **07 - The current situation of dose and DRLs for fluoroscopically guided procedures in children**
Claudio Granata (ESPR, IT)

16:00–16:20 **08 - CT paediatric DRLs: Data from the literature**
Shane Foley (EFRS, IE)

16:20–16:40 **09 - Paediatric imaging and the establishment of European DRLs**
Virginia Tsapaki (EFOMP, GR)

16:40–17:00 **Discussion**

17:00–17:20 **10 - The establishment of CT DRLs in Portugal**
Moderator: Raija Seuri (STUK, FI)
Speaker: Joana Santos (Coimbra Health School, PT)

ABSTRACT PRESENTATIONS:
National Developments of Paediatric DRLs
Moderators: Erich Sorantin (ESPR, AT), Andreas Jahnen (LIST, LU)

17:20–17:28 **11 - A decade of pediatric DRLs in France: Assessment and perspectives**
David Célier (Institut de Radioprotection et de Sûreté Nucléaire, FR)

17:28–17:36 **12 - Implementation of Diagnostic Reference Levels for children in Dutch clinical practice**
Harmen Bijwaard (National Institute for Public Health and the Environment - RIVM, NL)

17:36–17:44 **13 - Impact of new national diagnostic reference levels (DRL) for pediatric CT examinations**
Hannu Järvinen (Radiation and Nuclear Safety Authority - STUK, FI)

17:44–17:52 **14 - Patient radiation doses and reference levels in paediatric interventional radiology**
Bouchra Habib Geryes (Hôpital Universitaire Necker Enfants Malades, FR)

17:52–18:00 **15 - Initial paediatric LDRLs at the main public hospital in Malta for common paediatric examinations**
Maria Busuttil (University of Malta, MT)

18:00–18:08 **16 - Establishment of national Diagnostic Reference Levels (DRLs) for pediatric patients**
Sotirios Economides (Greek Atomic Energy Commission, GR)

18:08–18:16 **17 - PiDRLs for dental lateral cephalograph – study of one central care district in Finland**
Heli Larjava (Central Finland Health Care District/Medical Imaging, FI)

18:30 **Welcome reception and opening of poster exhibition**

DAY 2 Friday, OCTOBER 16

ROUND TABLE 3:
How to Establish and How to Use DRLs
Moderators: Hannu Järvinen (STUK, FI), Claudio Granata (ESPR, IT)

09:00–09:20 **18 - The role of and the need for DRLs: Where they are useful**
Raija Seuri (STUK, FI)

09:20–09:40 **19 - Which paediatric examinations should have DRLs? Frequency of paediatric examinations and contribution of paediatric examinations to the collective dose**
Erich Sorantin (ESPR, AT)

09:40–10:00 **20 - Paediatric DRLs for diagnostic and interventional radiology: Establishment and application**
John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

10:00–10:20 **21 - Automatic dose data management and DRLs**
Andreas Jahnen (LIST, LU)

10:20–10:40 **22 - Improving radiation dose management using DICOM tools**
Annalisa Trianni (Udine University Hospital, DICOM Working Group 2, IT)

10:40–11:00 **23 - Methods of using DRLs**
Hilde Bosmans (EFOMP, BE)

11:00–11:30 ***Coffee break***

11:30–11:50 **24 - Impact of using DRLs in paediatric imaging**
Moderator: Shane Foley (EFRS, IE)
Speaker: Maria Perez (WHO, Member of the PiDRL Expert Advisory Panel, CH)

ABSTRACT PRESENTATIONS:
PiDRLs and Patient Doses from Paediatric Procedures
Moderators: Stephen Evans (EFOMP, UK), Dean Pekarovic (EFRS, SI)

11:50–11:58 **25 - Radiation exposure from Pediatric Cardiac Catheterization in France**
Helene Baysson (IRSN, Laboratory of Epidemiology, FR)

11:58–12:06 **26 - Improvement of Pediatric CT protocols in Dalarna County, Sweden**
Mats Stenström (Mora Hospital, SE)

12:06–12:14 **27 - A Decade of Experience towards Establishing Pediatric clinical Imaging Guidelines, Diagnostic Reference levels and Medical Exposure Control in Kenya**
Jeska Sidika Wambani (Kenyatta National Hospital, KE)

12:14–12:22 **28 - Towards the standardization of pediatric cranial CT protocols: A Belgian multicenter study**
Timo De Bondt (Antwerp University Hospital, BE)

12:22–12:30 **29 - American College of Radiology (ACR) CT Dose Index Registry: A Resource for Pediatric CT Diagnostic Reference Levels**
Donald Frush (Duke Medical Center, US)

12:30–12:38 **30 - Dose Reference Levels For Paediatric Thorax CT: Can Image Quality Be Achieved While Maintaining Dose Reduction For Different Body Mass Indices?**
Shahed Khan (University College London, Department of Physics, UK)

12:38–12:46 **31 - Diagnostic Reference Levels for paediatric conventional imaging obtained using DoseWatch: A road for optimization**
Luis Alejo (Medical Physics Department, Hospital Universitario La Paz, ES)

12:46–12:54 **32 - A review of current local dose area product levels for paediatric fluoroscopy in a South African tertiary referral hospital as compared to standard international guidelines**
Mauritz Venter (University of Witwatersrand, ZA)

12:54–13:02 **33 - Patient specific paediatric dose assessment in dental Cone Beam Computed Tomography via Monte Carlo calculations**
Andreas Stratis (Katholieke Universiteit Leuven, BE)

13:02–13:10 **34 - A three centre European study of the feasibility of establishing diagnostic reference levels in paediatric cardiac interventional radiology**
Louise Rainford (University College Dublin, IE)

13:10–13:18 **35 - A comparison of age and weight groupings for establishing local DRLs in paediatric cardiac catheterisation examinations**
Shane Foley (University College Dublin, IE)

13:18–13:26 **36 - A comparison of patient weight, age and diameter grouping/categorisation for establishing diagnostic reference levels in paediatric CT**
Shane Foley (University College Dublin, IE)

13:26–13:34 **37 - Estimation of Local Diagnostic Reference Levels for paediatric Brain CT**
Vanessa de Sousa (Serviço de Medicina Nuclear – Hospital Garcia de Orta, PT)

13:34–13:42 **38 - Orthopantomography and lateral cephalometry Diagnostic Reference Levels in paediatrics and the influence in eye lens dose**
Joana Santos (Coimbra Health School, PT)

13:45–14:30 ***Lunch break***

PROGRAMME

ROUND TABLE 4: Establishing DRLs for Paediatric Non-cardiac and Cardiac Fluoroscopically Guided Procedures
Moderator: Jenia Vassileva (IAEA, Member of the PiDRL Expert Advisory Panel, AT)

14:30–14:50 **39 - Establishing DRLs for IR paediatric non-cardiac procedures**
Peter Vock (ESR, CH)

14:50–15:10 **40 - PiDRL dose survey for paediatric cardiac procedures**
Hannu Järvinen (STUK, FI)

15:10–15:30 **Discussion**

15:30–16:00 ***Coffee break***

ROUND TABLE 5: The Role of International and National Organisations in Establishing and Promoting the Use of DRLs for Paediatric Imaging
Moderators: Hilde Bosmans (EFOMP, BE), Virginia Tsapaki (EFOMP, GR)

16:00–16:20 **41 - International Commission on Radiological Protection (ICRP)**
Eliseo Vano (ICRP, Member of the PiDRL Expert Advisory Panel, ES)

16:20–16:40 **42 - International Atomic Energy Agency (IAEA)**
Jenia Vassileva (IAEA, Member of the PiDRL Expert Advisory Panel, AT)

16:40–17:00 **43 - World Health Organization (WHO)**
Maria Perez (WHO, Member of the PiDRL Expert Advisory Panel, CH)

17:00–17:20 **44 - Heads of the European Radiological Protection Competent Authorities (HERCA)**
Jürgen Griebel (HERCA, DE)

17:20–17:40 **45 - Public Health England (PHE)**
Sue Edyvean (PHE, Member of the PiDRL Expert Advisory Panel, UK)

17:40–18:00 **46 - Image Gently (Alliance for Radiation Safety in Pediatric Imaging)**
Donald Frush (Image Gently, US)

18:00–18:20 **Discussion**

18:30–19:30 **Poster exhibition – Meet the poster authors**

DAY 3 Saturday, OCTOBER 17

ROUND TABLE 6: European Diagnostic Reference Levels for Paediatric Imaging. The View of European Societies
Moderators: Maria Perez (WHO, Member of the PiDRL Expert Advisory Panel, CH), Sue Edyvean (PHE, Member of the PiDRL Expert Advisory Panel, UK)

09:00–09:20 **47 - European Society of Radiology (ESR)**
Peter Vock (ESR, CH)

09:20–09:40 **48 - European Federation of Radiographer Societies (EFRS)**
Graciano Paulo (EFRS, PT)

09:40–10:00 **49 - European Society of Paediatric Radiology (ESPR)**
Catherine Owens (ESPR, UK)

10:00–10:20 **50 - European Federation of Organisations for Medical Physics (EFOMP)**
Stephen Evans (EFOMP, UK)

10:20–10:40 **Discussion**

10:40–11:10 ***Coffee break***

11:10–12:20 **Panel discussion**
Coordinator: John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)
Participants: Hannu Järvinen (STUK, FI), Catherine Owens (ESPR, UK), Maria Perez (WHO, CH), Graciano Paulo (EFRS, PT), Raija Seuri (STUK, FI), Georgi Simeonov (EC, LU), Jenia Vassileva (IAEA, AT)

12:20–12:30 **Summary and conclusions**
John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

POSTER EXHIBITION

P01 - Development of a valid consent policy for Radiological Imaging procedures in Irish (HSE) Hospitals
Gerard Brassil (University Hospital Limerick, IE)

P02 - Dose optimization and image quality in children's CT imaging using Adaptive Statistical Iterative Reconstruction (ASIR)
Triantafyllia Makri (Radiological Imaging Department, Children's Hospital of Athens "Agia Sofia", GR)

P03 - Impact of a chest radiography dose optimization program (DOP) in a Neonatology Department (ND)
Cláudia Martins (Faculdade de Medicina da Universidade de Lisboa, PT)

P04 - Enrollment to a Chest Radiography Dose Optimization Program in Neonatology Department
Cláudia Martins (Faculdade de Medicina da Universidade de Lisboa, PT)

P05 - Cone Beam CT radiation dose in paediatric diagnostic cardiac catheterization procedures
Eva Corredoira (Hospital Universitario La Paz, ES)

P06 - Proposal of local diagnostic reference levels based on air kerma-area product values for paediatric conventional X-ray thorax examinations
Maria Hultenmo (Department of Medical Physics and Biomedical Engineering, Sahlgrenska University Hospital, Gothenburg, SE)

P07 - Low Dose CT of the Paranasal Sinus
João Casimiro (Hospital Dona Estefânia, PT)

P08 - Diagnostic Reference Levels for Port Catheter implantation in Paediatric Patients
Paula G. Castañón (University Hospital la Princesa, Madrid, ES)

P09 - Review of Dose Reference Levels in Paediatric Multidetector Computed Tomography
Paula G. Castañón (University Hospital la Princesa, Madrid, ES)

P10 - Estimation of pediatric radiation doses from abdomen-pelvis CT examinations utilizing age-specific scanning protocols
Vasileios Syrgiamiotis (General Childrens Hospital Agia Sophia MRI-CT Department, GR)

P11 - Protocol and Size Specific DRL for pediatric CT: a local approach
Alberto Mari (SOD Fisica Sanitaria AOU Ospedali Riuniti, IT)

P12 - Dose assessment in Pediatric Head CT
João Pinheiro (University of Algarve, PT)

P13 - Dose evaluation in newborns at a Neonatal Intensive Care Unit
João Pinheiro (University of Algarve, PT)

P14 - CT scan dose reduction: An Optimization of acquisition protocols in Pediatric neuroradiology
Filomena Batalha (Radiology Department of Pediatrics D. Estefânia Hospital – CHLC, Lisbon; MSc Student at Appliyng Health Radiations Master, branch of Radiation Protection, PT)

P15 - Paediatric CT Dose survey in Andalusia
Esther Angulo (Hospital U. Puerta del Mar de Cádiz, ES)

P16 - Optimizing protocols in radiology diagnostic procedures in neonatology
Esther Angulo (Hospital U. Puerta del Mar de Cádiz, ES)

P17 - Survey of Radiation Doses in Paediatric Radiography in Estonia
Jelena Subina (Environmental Board, Radiation Safety Department, EE)

P18 - Head CT Paediatric Diagnostic Reference Levels: analysing two different methods
Joana Santos (Coimbra Health School, PT)

ABSTRACTS - THURSDAY, OCTOBER 15, 2015

WELCOME

00 - Welcome by ESR and presentation of EuroSafe Imaging context

Guy Frija (ESR, Chair of EuroSafe Imaging Steering Committee, FR)

EuroSafe Imaging is the European Society of Radiology's flagship initiative to promote quality and safety in medical imaging by strengthening medical radiation protection across Europe following a holistic, inclusive approach. It is a multi-stakeholder campaign led by a Steering Committee composed of representatives from ESR, EFOMP, EFRS, CIRSE, ESPR, ESR-PAG, and COCIR, as well as the European Commission as observer. EuroSafe Imaging's mission is embodied in its 12-point Call for Action published in September 2014. Based on the challenges outlined in the Bonn Call for Action issued by the IAEA and WHO, the ESR undertakes concrete projects for each of the 12 action items, including promoting clinical audit, developing a policy for imaging equipment update, conducting data collection surveys and improving communication with patients and carers.

Improving appropriateness in medical imaging and supporting healthcare professionals in maintaining doses within diagnostic reference levels are among EuroSafe Imaging's main objectives. To enhance appropriateness, the ESR is developing ESR iGuide, a Clinical Decision Support (CDS) system for European imaging referral guidelines to ensure that guidelines are available to referrers as part of their workflow at the point of care. The aim of ESR iGuide is to address the current situation in Europe, where the use of referral guidelines is minimal while a significant number of imaging procedures is inappropriate or unnecessary.

Diagnostic reference levels are a key tool for minimising radiation exposure. As children are especially vulnerable to radiation, the ESR is particularly proud to be leading the PiDRL European Commission tender project to establish paediatric diagnostic reference levels in order to improve the safety of paediatric patients. With EuroSafe Imaging, the ESR has created a platform ideally suited to not only disseminating the results of PiDRL, but also to ensure that its recommendations will have an impact long beyond the official end of the project at the end of 2015.

The ESR thanks all workshop participants and in particular the European Commission and consortium partners for their important contribution to the PiDRL project and the safety of paediatric patients across Europe.

ROUND TABLE 1:
PiDRL Project Presentation

Moderators: Peter Vock (ESR, CH), Graciano Paulo (EFRS, PT)

01 - Welcome - Overview of the PiDRL Project

John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

There is little information on DRLs for paediatric examinations and procedures. The main reasons for this lack of information are listed below:

- The number of examinations carried out in children is lower compared to adults
- Data need to be categorized into age/weight/body size etc subgroups
- Difficulties in conducting patient dose surveys

There is a need to establish DRLs for radiologic examinations and procedures where DRLs are not available, consolidate available information and provide guidance on what actions are needed in using DRLs to further enhance radiation protection of children. The 'European DRLs for Paediatric Imaging' project (abbreviation: PiDRL) is a new EC project aimed to a) develop a methodology for establishing and using DRLs for paediatric medical imaging and b) update and extend the European DRLs to cover as many as possible procedures. The professional organisations involved include ESR as coordinator as well as EFOMP, EFRS, and ESPR, covering the key European stakeholders and professional groups with relevance to radiation protection of paediatric patients.

The project is divided into 4 Work Packages (WPs); each work package covers specific tasks contributing to the common objective of enhancement of radiation protection of paediatric patients through the concept of DRLs. WP0, chaired by the coordinator of the project, is responsible for the management and general coordination of the project. The coordinator acts as contact person between the Consortium and the European Commission. WP1 is responsible for assessing and agreeing on a methodology for establishing and using DRLs for paediatric imaging, and for producing European guidelines including data provided by WP2. WP2 is responsible for updating and extending the existing European DRLs to cover more procedures and a wider patient age/weight range. WP3 organizes the European workshop to discuss the findings of the studies conducted under the project and to subject the draft European Guidelines to critical review and discussion. More information about this project can be found at www.pidrl.eu.

02 - The importance of European guidance for the establishment and use of DRLs for paediatric imaging

Georgi Simeonov (European Commission, LU)

It is a well-recognised fact that computed tomography (CT) and interventional radiology have experienced a tremendous growth in the last decade or so. Today CT alone contributes almost 60 per cent of the total radiation dose from all x-ray procedures in Europe. Radiological examinations of children are among the fastest growing imaging procedures.

Diagnostic Reference Levels (DRLs) have been introduced in the European radiation protection legislation in 1997 as a tool to optimise radiation protection of patients. The Medical Exposure Directive (MED) 97/43/Euratom required from the EU Member States to "promote the establishment and the use" of DRLs and made reference to European DRLs.

In 2013 the MED was replaced by the European Basic Safety Standards (BSS) Directive 2013/59/Euratom, which strengthens the DRL-related requirements, e.g. by mandating the "establishment, regular review and use" of DRLs and expanding their use to interventional radiology. The BSS Directive requires "special attention" to be paid to the medical exposure of children, e.g. through quality assurance, dose assessment and the use of appropriate equipment, techniques and protocols.

In 1999 the Commission issued "RP109: Guidance on diagnostic reference levels DRLs for medical exposure", which highlighted the importance of establishing DRLs for children but included limited paediatric DRL guidance and values. More recent international publications have brought limited progress in this area. National attempts to establish paediatric DRLs have been made with differing degree of success.

In this context, in 2014 the European Commission launched a project on DRLs in paediatric imaging (PiDRL). The PiDRL project will provide DRLs for children and promote their use, with a focus on CT and interventional radiology. The specific objectives are to (i) agree on a methodology for establishing and using DRLs for paediatric imaging, and (ii) update and extend the European DRLs to cover more procedures and a wider patient age / weight range.

One of the main outcomes of the PiDRL project, the European paediatric DRL guidance, will help Member States produce and use DRLs in practice. The guidance will cover wide range of issues, such as (i) important procedures in need of DRLs, (ii) grouping of paediatric patients according to age, weight, etc., (iii) dose quantities to be used for paediatric DRLs, (iv) methods to measure, collect and process dose data for establishing paediatric DRLs, and (v) use of DRLs and dose distribution data in optimization of protection of paediatric patients.

03 - WP1: Development of the European PiDRL guidelines

Hannu Järvinen (STUK, FI)

Introduction: Diagnostic reference levels (DRLs) have been recommended by the International Commission on Radiation Protection (ICRP) as an advisory measure to improve optimization of patient protection. The European Council Directive 2013/59/Euratom (EU BSS), requires the Member States to ensure the establishment, regular review and use of DRLs for radiodiagnostic examinations. The existing guidance on DRLs by the European Commission (EC) is no longer up to date and quotes paediatric DRLs only for plain film-screen based radiography of standard sized five-year old patients. Therefore, there has been a clear need to provide guidelines on DRLs for paediatric x-ray procedures.

Purpose: The purpose was to provide European guidelines on DRLs for paediatric x-ray procedures, including

- recommended methodology for establishing and using DRLs
- updating and extending the European DRLs where sufficient experience and data are available
- promoting the establishment and use of DRLs

Materials and Methods: The preparation of the Guidelines was organized in Work Package 1 of the EC PiDRL project.

First, a comprehensive evaluation of the status of DRLs in paediatric imaging was carried out. National DRLs set by an authoritative body in European countries were reviewed based on the EC Dose Datamed 2 (DDM2) project and verified by a questionnaire to the contact persons of 36 European countries. Furthermore, a worldwide review of literature on patient doses and DRLs for paediatric x-ray procedures was carried out.

The data obtained through the questionnaire and literature review were used to draft the Guidelines. The details of draft were extensively discussed between the experts of the PiDRL project. For consistency, the work was coordinated with the work of the ICRP. Finally, the draft was distributed for consultations to several international organizations.

Results: The resulting Guidelines provide a comprehensive review of the existing paediatric DRLs, identifies the x-ray procedures where paediatric DRLs are recommended, and introduces basic guidance for establishing paediatric DRLS: recommended quantities, patient grouping, patient dose surveys, setting of DRLs, making use of automatic dose management and the methods of using the DRLs. For a few procedures where sufficient data were available, the Guidelines give suggestion for European DRLs (EDRLs).

Conclusion: The EC Guidelines provide a basic tool for establishment and promotion of the paediatric DRLs for x-ray procedures. National DRLs (NDRLs) should be based on national dose surveys, while the EDRLs suggested should be considered only as the preliminary choice for the NDRLs.

04 - WP2: Update and expansion of European DRLs in paediatric imaging

John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

WP2 is responsible for updating and extending the existing European DRLs to cover more procedures.

A worldwide review of literature on patient doses and DRLs for children of different age groups, or other distributions, and for different examinations was carried out with an emphasis on European literature. Several different search engines were used, including PubMed, Google Scholar and Science Direct, using various terms to locate pertinent articles. For the output of this review, a database of literature was created, classified in suitable headings, using the Mendeley platform. The articles selected included studies on DRLs in general but also in dose optimisation. Subgroups were created to help facilitate the process of the literature review.

The review of DRLs has indicated that for interventional, fluoroscopy-guided cardiac procedures, no national DRLs exist but only a few local DRLs have been suggested, and for interventional non-cardiac procedures, no DRLs have been suggested at all. Efforts to establish multi-national DRLs for non-cardiac paediatric interventional procedures are in progress. A tentative list of interventional examinations and requirements for inclusion of an examination type has been distributed to 5 'external' partners from France, UK and Italy. Inclusion requirements have been set to establish DRLs for fluoroscopically-guided non-cardiac procedures. PiDRL partners have delivered paediatric patient data and radiation doses useful for DRL establishment. Preliminary DRL values have been derived for non-cardiac fluoroscopically-guided procedures. Age/weight group data from less than 20 patients were excluded from the analysis. Very large variations have been observed from center to center. Results will be presented during the PiDRL workshop.

European DRLs have been established based on current literature. For examinations in which European countries national DRLs exist (in radiography, fluoroscopy and CT), European DRLs have been derived as a median value of the relevant national DRLs. For fluoroscopically guided procedures, preliminary European DRLs are based on the surveys among centres in France, Italy and UK performed within the PiDRL project.

ABSTRACTS - THURSDAY, OCTOBER 15, 2015

ROUND TABLE 2:
Current Status in DRLs for Paediatric Imaging in European Countries

Moderators: John Damilakis (ESR, Scientific Coordinator of PiDRL, GR), Annalisa Trianni (DICOM Working Group 2, IT)

05 - Summary of DRLs in European countries for paediatric imaging based on the DDM2 data and the results of the PiDRL specific questionnaire

Hannu Järvinen (STUK, FI)

Introduction: For the purpose of preparing the European Guidelines on DRLs for paediatric x-ray procedures, information on the present status of paediatric DRLs were needed. The National DRLs (NDRLs) set by an authoritative body in European countries had been reviewed in 2010-11 in the European Commission (EC) Dose Datamed 2 (DDM2) project, including DRLs for paediatric examinations. This data stored in the DDM2 database had to be checked and updated.

Purpose: The purpose was to provide a comprehensive summary of paediatric NDRLs set by authoritative bodies in the European countries.

Materials and Methods: The DDM2 data on NDRLs for paediatric procedures was verified (confirmed and supplemented) by a questionnaire to the contact persons of 36 European countries. Further, the correspondence of any published data with the results of the questionnaire was checked and the information from the two sources combined.

Results: NDRLs are provided for some groups of examinations (radiography, fluoroscopy or CT) in 15 European countries (42 % of the European countries). In 7 countries the available NDRLs are based on own patient dose surveys and in 6 countries adopted from published values; in 5 countries adopted from the EC guidance and in one country from published values in another country. In one country, the NDRLs are either based on a survey in only one institute or adopted from another country. In one country, the NDRLs are based on protocol data or adopted from literature. For interventional radiology, no paediatric NDRLs have been set for any procedures in any European country.

For paediatric NDRLs, there seems to be reasonable agreement on the examinations where DRLs are needed and on the quantities used. The current NDRLs are based on the 3rd quartile method, but in one case for CT a 50 % level is given as supplementary information. For patient grouping, a set of age groups up to 15y of age (0, 1, 5, 10, 15 y) seems to be the most common practice. In one country, a DRL curve with patient thickness (radiography) or weight (CT) as the parameter is used to overcome the problems of poor statistics with discrete groups.

Conclusion: A rough consensus exists on the paediatric examinations for the DRLs and their parameters (quantities, percentile of dose distribution, patient grouping). However, better standardization and guidelines is needed, in particular for the patient dose surveys as the basis of setting DRLs.

06 - Radiographic and fluoroscopic paediatric DRLs: Data from the literature

Virginia Tsapaki (EFOMP, GR)

Introduction: While the benefit of a clinically appropriate X-ray imaging procedure outweighs the risk from ionizing radiation, efforts should be made to minimize this risk and optimize radiation dose. This is especially important for paediatric patients due to their higher radiosensitivity than adults as well as longer expected lifetime.

Purpose: Published scientific papers and/or reports on paediatric DRLs from various European and non-European countries were taken into account with the scope to define new, or verify proposed European DRLs.

Materials and Methods: For best evaluation of literature data, an excel file was created in order to group the information so as to better identify advantages and/or limitations of each study. The excel included information such as region, country, year of study, sample size, number of X-ray machines, clinical protocol/s, paediatric grouping, method of dose or estimation, dose quantity, DRL values, etc.

Results: Apart from the Dose Datamed II European report, there were approximately 16 studies in radiography and only 4 in fluoroscopy. Twelve of the radiographic studies were performed in a single country, mostly European. Some of them provided national DRLs for radiography. These were determined for the most common examinations such as chest, skull, abdomen and pelvis X-ray procedures for radiography and micturating cystourethrogram, barium meal, upper gastrointestinal imaging and barium swallow in fluoroscopy. The patients were grouped and analyzed according to age in most studies. Some studies used also normalization factors derived from weight and height data. Limited number of studies grouped patients according to patients' size. Entrance surface dose (ESD), Entrance Surface air Kerma and/or Kerma Area Product were either calculated or measured. There was only one radiographic study that used the quantity "Effective dose" to define DRLs.

Conclusion: It is evident from the literature that there is need for standardization of the method used for paediatric DRLs. In most of the cases insufficient data for some age groups or for a type of examination could not permit to draw rigid conclusions or permit calculation of DRLs. For fluoroscopy, recent studies concerning dose exposure are still extremely scarce.

07 - The current situation of dose and DRLs for fluoroscopically guided procedures in children

Claudio Granata (ESPR, IT)

The need for establishing a DRL is based on the collective dose to the population: all radiological procedures resulting in high collective dose should have DRLs. This can include both the most common low dose procedures and the less common high doses procedures.

FGIPs - although relatively rare – can expose children to very high radiation doses. In the literature, data on radiation dose exposure related to FGIPs in children are very limited. In particular, studies on dose exposure related to interventional cardiology procedures in children are very few in Europe and even fewer outside Europe. Neither national nor regional DRLs are available, whereas only local DRLs are provided by single studies. These studies use different methods, provide different data, and sometimes their conclusions are contradictory, making it difficult to make any comparison among them.

Even for non-cardiologic interventional procedures, there are no studies on DRLs available for children in Europe. Data published outside Europe are extremely scarce and limited to common vascular and enteric procedures. No data are available about embolization or sclerotherapy of vascular malformations, neuroradiology procedures, diagnostic arteriography, CT guided biopsies, and biliary procedures.

Actually, establishing DRLs for FGIPs can be extremely difficult. These procedures encompass a wide range of interventions, many of them without any other treatment option and with variable complexity. Some of them also require to be repeated a few times to be effective at least partially (e.g. embolizations of vascular malformations). Therefore, probably DRLs cannot be defined for these procedures. However, DRLs could be established for a few standard procedures such as diagnostic cardiac catheterization, interventional closure of cardiac septal defects, and insertion of central venous catheters.

In conclusion, further studies and dose surveys are necessary to determine the feasibility of establishing DRLs for FGIPs in children.

08 - CT paediatric DRLs: Data from the literature

Shane Foley (EFRS, IE)

Introduction: European Council directives and ICRP guidance recommend the establishment of diagnostic reference levels (DRLs) for common radiology examinations as an optimisation tool to limit unjustified high doses. DRLs are especially relevant for high dose medical examinations such as computed tomography (CT) and also for patient groups such as paediatrics who are more sensitive to radiation.

Purpose: To review the scientific literature for research into CT diagnostic reference levels for paediatric patients.

Methods and Materials: A worldwide review of literature on patient doses and DRLs for children of different age groups, or other distributions for different CT examinations was carried out with an emphasis on European literature. Several different search engines were used: PubMed, Google Scholar and Science Direct, using various terms to locate pertinent articles. A database of literature was created, classified in suitable headings, using the Mendeley (www.mendeley.com) platform. The articles selected included studies on DRLs in general but also in dose optimization. To evaluate the data found in the literature, the information was further grouped to help identify the advantages and/or limitations of each study and to more easily draw conclusions on the methodology used in the DRL determinations.

Results: The resulting database contains 40 articles which were specific to CT [*until 25 Feb 2015*] but collection remains ongoing. Most studies reported doses from single countries/regions collecting data using a variety of sample sizes (1-126 scanners) and based their calculations on either patient /phantom studies or from standard protocols. All methodologies used the standard CT dose metrics of either $CTDI_w$ / $CTDI_{vol}$ and/or DLP, with the majority basing their calculations on the 3rdquartile of dose distribution recorded. Most publications categorised patients according to age, although a variety of categories were used. The most common CT examination DRLs were for the head, chest and abdomen regions. Clinical indications for CT protocols were not always reported, nor did all articles propose national DRL values.

Conclusion: Methodological inconsistencies are noted across most published work with variations in patient categorisation, method of data collection and sampling used.

09 - Paediatric imaging and the establishment of European DRLs

Virginia Tsapaki (EFOMP, GR)

Introduction: Medical technology has taken a remarkable boost the last few decades. A huge assortment of medical equipment currently exists resulting not only on an apparent increase in the number of procedures, but also an expansion into different areas of medicine. Complex radiation-based techniques are applied not only to adults but also to paediatric patients occasionally by specialists with different levels of knowledge about radiation, dose and the risks. The Radiation Protection 109 Report by the European Commission entitled: 'Guidance on diagnostic reference levels (DRLs) for medical exposure' highlights the importance of establishing DRLs for high-dose medical examinations and especially children.

Purpose: The routine approach of establishing DRL for adults has been that of average-sized adult phantom or standard phantom. For paediatric patients a similar approach cannot be considered appropriate due to the wide variation in body size. The purpose of this work was to review the literature to collect existing information on methods used to determine European DRLs.

Materials and Methods: The European literature was identified and analyzed using an excel file to group the information.

Results: There is an obvious lack of harmonization in the methodology used by different authors for data collection, producing an evident bias when comparing values, not only of exam technical factors but also of dose exposure values, patient characterization, influence of different technology and impact on image quality. There is lack of definition for the best-recommended values and literature review does not help in identifying the most adequate factors. Important data such as use of grid and added filtration are missing in most of the articles. There is a need to build a methodology to define a standard patient that could serve the purpose of harmonizing data collection, iv) Influence of different technology: There is a lack of information regarding the way to optimize different technologies available such as CRand DR technology. Most of the papers published do not take into account image quality. For fluoroscopy and Interventional procedures, apart from DDM II Report, only local DRLs for cardiac and non cardiac IR exist with all studies reporting data from single institutions.

Conclusion: There is urgent need to standardize the method to measure, collect and process dose data for establishing paediatric DRLs. More studies are urgently needed for fluoroscopy and interventional procedures.

ABSTRACTS - THURSDAY, OCTOBER 15, 2015

INVITED PAPER

Moderator: Raija Seuri (STUK, FI)

10 - The establishment of CT DRLs in Portugal

Joana Santos (Coimbra Health School, PT)

Introduction: The volume of Computed Tomography (CT) examinations has increased with resultant increases in collective dose values over the last decade. The clinical applicability of CT for diagnosis is unquestionable, however the potential risk of high radiation exposure associated with CT should not be ignored, particularly for paediatrics due to their higher sensitivity to radiation and longer expected lifetime.

Purpose: Identify the frequency of CT examinations, current protocols and establish national diagnostic reference levels (DRLs) for commonly performed adult and paediatric CT examinations.

Materials and Methods: A national survey of practice across all CT sites was completed. Demographic data were collated, collected over a seven-month period and protocols were reviewed (including methods of paediatric age categorisation). The 75th percentiles for CT volume index (CTDIvol) and dose-length product (DLP) values of commonly performed examinations were identified. To establish paediatric CT DRL's the dose values were directly collected on the tree paediatric centres of excellence in Portugal.

Results: A 21% response rate resulted from the national survey, from which 55% were public institutions. Head (22%), thorax (10%) and abdominal (12%) CT examinations were identified as the most commonly performed. National DRLs are recommended in CTDIvol (mGy) and DLP (mGy.cm) for the head 75mGy/1010mGy.cm, thorax 14mGy/470mGy.cm and abdomen 18mGy/800mGy.cm, respectively. Specific paediatric protocols and age categorisation methods varied considerably, therefore paediatric CT DRLs were not defined based on this survey. For paediatric head and chest examinations: 48mGy and 2mGy (newborns), 50mGy and 6mGy (five years old), 70mGy and 6mGy (ten years old) and 72mGy and 7mGy for fifteen years old children, respectively.

Conclusion: Portuguese DRLs for CT examinations have been identified and recommended. The majority were higher than European recommendations. The Portuguese paediatric CT DRL's were optimised after the findings of this study.

ABSTRACT PRESENTATIONS:

National Developments of Paediatric DRLs

Moderators: Erich Sorantin (ESPR, AT), Andreas Jahnen (LIST, LU)

11 - A decade of pediatric DRLs in France: Assessment and perspectives

David Célier[1], Patrice Roch[1], Cécile Etard[1]

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Introduction: DRLs have been established in France in 2004. In pediatric imaging, only the plain radiography was then taken into account. In 2011 the scope of pediatric DRLs has been extended to computed tomography and nuclear medicine.

Purpose: As a starting point, the French DRLs in pediatric plain radiography were based on European guidance values. The pediatric DRLs in computed tomography and nuclear medicine were mostly defined from literature. According to the French regulations, these initial DRLs were supposed to be revised periodically, to reflect properly national practices.

Materials and Methods: To update the DRL values, an annual collection of dose data from all the imaging departments (radiology and nuclear medicine) has been set up in the 2004 DRL order. Annually, each diagnostic imaging department has to evaluate the doses delivered to a sample of 30 patients for 2 types of examination chosen from a list, to compare the average dose value to the DRLs and to take corrective actions if necessary. At last, they have to send their data to IRSN (Institute for Radiological Protection and Nuclear Safety), who is in charge of data analysis in order to recommend regulation updates according to the 3rd quartile method.

Results: After 10 years of data collection, IRSN is not able to propose any update of pediatric DRL values because of the lack of collected data. Several reasons can explain this fact:

professionals can choose to evaluate each year either adult or pediatric examinations;

- pediatric examinations are less frequent than adult ones;
- pediatric DRLs take the morphology into account (weight), so it is difficult to obtain a significant number of children examinations concerning a given range of weight.
- As a consequence, except for departments specialized in pediatric imaging, it is far easier to evaluate adults examinations.

Conclusion: French authorities have taken into account the assessment of IRSN concerning the lack of French data and the inefficiency of the current pediatric DRLs. An expert workgroup was created in 2014 in order to analyze the situation in France and in other countries and to propose actions which could allow to establish representative and updated DRLs in pediatrics. In this context, IRSN is implementing a new approach based on studies focused on imaging departments specialized in pediatrics in order to set representative and applicable DRLs that should be used by professionals – in particular non-specialists of pediatrics – to evaluate and optimize their practice.

12 - Implementation of Diagnostic Reference Levels for children in Dutch clinical practice

Harmen Bijwaard[1], Doreth Valk[1]

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Introduction: In the Netherlands Diagnostic Reference Levels (DRLs) have been established for eleven types of radiological examinations. Four of these DRLs pertain specifically to children: X-rays of thorax and abdomen, CT scans of the head and micturating cystourethrograms (MCUG). For a comparison of dose indications such as DLP, CTDI and DAP to the DRLs, values for 20 children per age group (0, 1, 5 and for CT head also 10 years) need to be averaged.

Purpose: The goal of this study was to find out if and how the DRLs are implemented in Dutch clinical practice. Have they been implemented in the QA systems? Are measures of dose being compared to them? What difficulties arise during practical implementation? Can differences be observed between general and children's hospitals?

Materials and Methods: Two surveys have been conducted among 20 and 29 Dutch hospitals, respectively. The first survey was aimed at the implementation of DRLs in clinical practice. The second survey was aimed at radiation protection measures for children in general and children's hospitals, but also inquired into comparisons to the DRLs.

Results: The first survey showed that general hospitals have difficulties in implementing the DRLs for children because they often do not receive enough children per age group to perform the prescribed comparison to the DRLs. The second survey indicated differences in radiological protection measures taken for children between general and children's hospitals. Apart from that, DRLs were exceeded in 20% of the cases in which comparisons had been performed according to the prescribed procedure.

Conclusion: The current procedure for comparing dose indications to DRLs that has been developed in the Netherlands does not always work well for children. It is advisable to change this procedure and take into account the differences between general and children's hospitals. With regard to radiological protection measures for children general hospitals might benefit from information exchange with children's hospitals.

13 - Impact of new national diagnostic reference levels (DRL) for pediatric CT examinations

Hannu Järvinen[1], Eero Kauppinen[2], Jyrki Ruohonen[3], Eini Niskanen[4], Raija Seuri[5]

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Introduction: Computed tomography (CT) contributes to about 60 % of the population dose from all medical use of radiation. Paediatric CT deserves special attention because children are more sensitive to ionizing radiation than adults. Diagnostic reference levels (DRLs) have been recommended by the ICRP to improve optimization. In Finland, national DRLs for paediatric CT examinations were recently established using data from over 1000 patients in four university hospitals. A new approach, DRL curve (dosimetric quantity vs. patient weight) was applied for body CT, while for head CT, DRLs were defined for four age groups. The DRLs represented the 75 % (3rd quartile) of the patient dose distributions while also a 50 % curve was introduced as an additional guidance for achievable dose.

Purpose: The purpose was to test the application of the new DRLs and their impact on the clinical practices at a few hospitals before their final issue.

Materials and Methods: Three central hospitals not specialized in paediatric imaging were asked to provide samples of patient dose data for paediatric body CT (chest, abdomen and chest+abdomen) and head CT, for the indications specified for the DRLs, i.e. routine head and ventricular size for head CT and several indications (with the same DRL) for body CT. The samples were compared with the DRLs and possible explanations for unusual dose levels were discussed with local physicists and radiologists.

Results: Except for "head routine" CT, very few data (typically less than 10 patients per year) could be collected. DRLs were exceeded with head CT for "ventricular size" in all hospitals, whereas with chest, abdomen and whole body CT only in one of the hospitals. When iterative reconstruction algorithm had been used, doses were close to or below the 50 % curve. Image quality was accepted by local radiologists. An acceptable situation was confirmed in most cases while need for further optimization was suggested in some cases.

Conclusion: The results prove the usefulness of the DRLs for improving the optimization. They provide an important reference in particular for small radiological departments where patient flow can be very small and the proper optimization is otherwise difficult. Especially for body CT, the DRL curve seems to be the only feasible method in small departments where only a few paediatric patients are examined in a year. The supplementary 50 % level curve provided helpful additional guidance on the achievable dose level.

14 - Patient radiation doses and reference levels in paediatric interventional radiology

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Introduction: Reference Levels (RLs) in paediatric interventional radiology are scarce in the literature. These data are required to enhance radiation protection of children.

Purpose: To evaluate patient radiation dose and to propose RLs in paediatric interventional radiology.

Materials and Methods: From January 2012 to March 2015, 573 children who underwent an interventional radiology procedure in two French university hospitals were included in the study. Procedures were done on two types of vascular machine: an Innova IGS 530 single plane (General Electric) and an Artis Zee biplane (Siemens). Three age groups were identified: less than 2 years (A0-2), between 3 and 7 years (A3-7) and between 8 and 18 years (A8-18). Paediatric interventional radiology procedures were divided into five groups: cerebral angiography, intracranial aneurysm embolization, brain arteriovenous malformation embolization, sclerotherapy of superficial vascular malformation and sclerotherapy of bone cyst aneurysm. Demographic (age, weight, height, head circumference for cerebral procedures) and dosimetric data (dose area product DAP for acquisition, fluoroscopy and 3D-CBCT modes separately, air kerma K,

ABSTRACTS - THURSDAY, OCTOBER 15, 2015

fluoroscopic time T, number of acquisitions N) were collected from the PACS or the dose manager software (Radiation Dose Monitor from Med[2]) or the patient clinical file.

Results: For cerebral angiography, the median weight (kg), BMI (kg.m-2) and head circumference (cm) were 8-16-44 for A0-2, 19-16-50 for A3-7, and 44-18-55 for A8-18, respectively. The 75th-percentile values of the total DAP (cGy.cm^2) were 359 for A0-2 (21 procedures), 1900 for A3-7 (38 procedures), and 2785 for A8-18 (92 procedures). In general, the DAP for acquisition mode corresponds to more than 80% of the total DAP value. The 3D-CBCT acquisitions are used in 16% of procedures only for A8-18 age group.

Conclusion: Enough data seem available in this preliminary study to propose reference levels for paediatric interventional radiology procedures.

15 - Initial paediatric LDRLs at the main public hospital in Malta for common paediatric examinations

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Introduction: European Diagnostic Reference Levels (EDRLs), National (NDRLs) and local DRLs (LDRLs) are used in medical imaging as practical tools to help manage patient radiation doses. They are used as guidelines to indicate whether the radiation dose received by a standard sample of patients during a given type of examination carried out in a given imaging facility is unusually high or low for that particular procedure when compared to that from other facilities.

Purpose: The purpose of the study was to establish paediatric LDRLs for common paediatric examinations in the largest public hospital in Malta, since the only work that has been done so far in Malta, was only done on DRLs for adult patients. The LDRLs obtained were compared with other NDRLs from other European states.

Materials and Methods: Dose data was measured for two different paediatric imaging examinations, being projection radiography of the chest and CT examinations of the head and abdomen. The study was delimited to patient ages between 0 and 15 years. In the case of chest radiographs, the doses measured on paediatric patients of non-standard size are used to calculate doses for the nearest chosen standard sizes as suggested by Hart et al., (2000). For the measurements of CT head and abdomen, a new approach was adopted. Instead of measuring the patients' weight, the head/abdomen circumference was measured.

Results: Results were evaluated using regression analysis. Scatter plots for patient thicknesses against the relevant dose measurement were drawn and analysed for any correlations. LDRLs were set by calculating mean values for KAP for chest radiographs and mean values of DLP and CTDIvol for CT scans of the head and abdomen.

The main results of the study were

a) For chest radiography, KAP data ranges were between 11 and 26 mGycm2 for different age groups.

b) For CT head, DLP ranges are between 177 and 418 mGycm and for CT abdomen DLP ranges are between 47 and 553 mGycm.

Conclusion: The new approach to measure patient head/abdomen thickness instead of weight shows that there is a linear relationship with a high coefficient of determination (R2) between age/patient thickness and CTDIvol and DLP.

Comparisons between the established LDRLs and the NDRLs from other countries show that in general dose values for the hospital under study were lower or matched the other NDRLs. This indicates good practice.

16 - Establishment of national Diagnostic Reference Levels (DRLs) for pediatric patients

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Introduction: Dose reference levels (DRLs) constitute an effective tool for the optimization of medical exposures. Their role becomes more significant in the case of pediatric patients, where the risks associated with the medical exposures, are higher than the ones for adults. The Greek Atomic Energy Commission (EEAE) has already established national DRL values for diagnostic radiology, nuclear medicine and interventional cardiology procedures, concerning adult patients.

Purpose: This study presents the results of the first national survey conducted by EEAE for the establishment of DRLs for pediatric patients undergoing diagnostic radiology, image guided interventional procedures and nuclear medicine.

Methodology: Pediatric patients' data, including age and weight, dosimetric data and radiopharmaceutical administered activities (AAs) were collected using modality specific questionnaires distributed to the medical facilities. The national DRLs were estimated by adopting the 3rd quartile method. The most frequent AAs were calculated, as well.

Diagnostic and interventional radiology: Fourteen (14) pediatric radiology departments, covering the majority of pediatric procedures countrywide, participated in the survey. ESAK values were collected for radiographic examinations, KAP and exposure time for interventional procedures and CTDIvol and DLP values for CT examinations. The data were collected by the departments' medical physicists. Dosimetric data were assessed, either directly from the X-ray systems or by performing measurements in accordance with the applied examination protocols.

Nuclear medicine: More than 90% of the nuclear medicine departments in the country responded to the respective questionnaire. The methodology used for the prescription of AAs (MBq) to pediatric patients was also requested to be reported.

Results: The DRLs for each procedure and pediatric patient groups are comparable to those from other similar studies found in the literature. Considerable variations in typical patient doses were observed among hospitals/clinics in the country, for the same procedures and pediatric patient groups. Additionally, for nuclear medicine procedures, correlation seems to exist among the reported AAs and the methodology used for their prescription e.g. European Association of Nuclear Medicine (EANM) Dosage Card.

Conclusions: This is the first attempt to establish the methodology and assess national DRLs for pediatric procedures. PiDRL project is expected to contribute to the standardization and harmonization of the applied methodology and the comparison of the national DRLs values to those from other EU countries.

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17 - PiDRLs for dental lateral cephalograph – study of one central care district in Finland

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Introduction: A lateral cephalograph is routinely required for orthodontic diagnosis and treatment planning[1]. Scientific evidence has recently been provided that exposure to routine dental X-rays appears to be associated with an increased risk of intracranial meningioma[2].

Dental radiographs are usually taken by dental assistants instead of radiographers, and the equipment is not supervised by radiologist or medical physicist. The dose reference level exists for dental panoramic radiograph, but there is none for cephalographic imaging in Europe[3]. In literature there aren't recent dose levels reported for the direct digital imaging systems.

Purpose: To create a DRL for lateral cephalogram to be used in Central Finland area.

Methods: In the beginning of the year 2014 we in Central Finland Health Care District had 7 dental panoramic and cephalographic direct digital radiography equipment, one of which is placed in central hospital and others in imaging rooms of the local health centers, and are being operated by our radiographers. During the spring 2014 there were two more equipment installed. Their number of examinations have been included from April the 1st,, 2014. Doses have been reported with varying degree in our RIS system from 6 places (central hospital and 5 health centers). Equipment is from two different vendors and represents three different models. The 3rd quartile value has been calculated for the lateral cephalographic image for children.

During the year 2014 in our medical imaging there were 1353 lateral cephalograph imaging examinations done with direct digital equipment. The dose value has been recorded in our RIS system for 434 examinations.

Results: We calculated the 3rd quartile value for the lateral cephalographic image for children: 20,8 mGycm2. Doing this we noticed a significant difference in the radiation levels with one vendor which affects to this value. Work to lower the level is under progress.

Conclusion: In our health care district these equipment are under the supervision of the medical physicist. There is need for the DRL since even in this situation the significant difference in dose levels could continue two years before being noticed.

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ABSTRACTS - FRIDAY, OCTOBER 16, 2015

ROUND TABLE 3:
How to Establish and How to Use DRLs

Moderators: Hannu Järvinen (STUK, FI), Claudio Granata (ESPR, IT)

18 - The role of and the need for DRLs: Where they are useful

Raija Seuri (STUK, FI)

Introduction: Although dose limit or constraint is not applicable to patient imaging, the dose to the patient should be as low as reasonable achievable considering the medical imaging task to be investigated. This is especially important in paediatrics because of the relative sensitivity of children to the possible harmful effects of radiation. Diagnostic reference levels were introduced by ICRP 1991 as a tool for optimization, and EC Directive 2013 requires that member states implement the use of either national or European DRLs.

Purpose: This presentation will focus on the need and practical use of DRLs in paediatric imaging, as well as the challenges faced in the practice.

Results: Looking at the literature, the published variation in dose levels for the same kind of examination still shows that some exposures may not be fully optimized. There is also a considerable variation in the few published national paediatric DRLs. The scarcity may partly be due to the time needed to collect enough data because the number of paediatric patients is much smaller than adults. The same fact emphasizes the need of guidance to optimize paediatric radiological practices and dose levels in institutions where there are relatively few paediatric patients for each radiological procedure. The challenge is even bigger because we need different imaging parameters for all the different sizes of children. For comparisons the patients have usually been divided to several groups by e.g. age or weight, but also a continuous curve can be used.

In radiological imaging the dose must always be discussed together with image quality, and the image quality needed is dependent on the medical imaging task. The DRLs can thus be applied to the most common indications of a procedure, and image quality is considered diagnostic when the median dose of a practice is compared to the DRL. If the dose level exceeds the DRL, it should always prompt detailed analysis to detect the spots in the practice, where further optimization is needed.

Conclusion: DRLs are needed to help optimization and to recognize poorly optimized practices. Reference levels can be very helpful in the optimization process where the number of patients is small and thus optimization challenging, and also when there is change of practice or equipment.

19 - Which paediatric examinations should have DRLs? Frequency of paediatric examinations and contribution of paediatric examinations to the collective dose

Erich Sorantin (ESPR, AT)

Introduction: Several countries have released „Diagnostic Reference Levels (DRL)“ for imaging procedures using ionizing radiation. Unfortunately those DRL differ in types of procedures and granularity as well as information about the proportion of paediatric patients within the different examinations are sparse.

Therefore an more evidence based approach seems to be feasible - meaning releasing DRL first for frequent and radiation burdened examinations.

Purpose: To give an overview about types and frequencies of paediatric imaging procedures as well as the contribution to the collective dose.

Material and Methods: A survey within Europe was conducted and a questionnaire was sent to key persons of the European Society of Paediatric Radiology (www.espr.org) as well to a large academic, interdisciplinary, international Network within the CEEPUS programme (Central European Exchange Program for University Studies – www.ceepus.info).

Results: Altogether 33 centres were contacted and an response was received from 18 (54.5.%). From one centre only frequencies for Interventional Radiology was sent.

Plain films: most frequent procedures are extremities (48.5%), followed by chest films (31.4%) - both account together for more than ¾.

Flouroscopy: voding cysto urethrography (VCU) 37.2%, followed by upper gastro intestinal (GI) series with 32.1% - again representing 2/3 of those examinations.

Computed Tomography: head & neck 46.8%, chest 27.8%, abdomen 13.7% - together almost 90%.

Interventional Radiology and cardiac interventions: only limited data available and procedures quite hardly standardize and comparable. It seems advisable, that only a few procedures are suitable for DRL like peripheral insertion of vascular lines, occlusion of Ductus Arteriosus botalli or stent implantation for coarctation.

In order to estimate the contribution to the relative collective dose all values were normalized to a chest x-rays (1.0) and the following numbers could be calculated: abdominal plain film 0.1, skull 0.01, CT Head 2.6, CT chest 10.2, CT Abdomen 4.5.

Conclusions: The most frequent imaging procedures based on ionizing radiation are in plain films extremities and chest x-rays, in flouroscopy VCU and upper GI series and in CT head, chest and abdomen and therefore EU wide DRL should be released for those examinations. Interventional radiology and cardiac interventions vary considerable and only a few are suitable for DRL definition. As it could be expected chest CT is the main contributor to the collective dose.

20 - Paediatric DRLs for diagnostic and interventional radiology: Establishment and application

John Damilakis (ESR, Scientific Coordinator of PiDRL, GR)

Among the main objectives of the PiDRL project are to agree on a methodology for establishing and using DRLs for paediatric imaging covering plain radiography, fluoroscopy, fluoroscopically guided interventional procedures and draft relevant European guidelines. DRLs should be established primarily for paediatric examinations that significantly contribute to the collective effective dose of the paediatric patient population. A list of the most important procedures and/or clinical indications for which paediatric DRLs should be defined is included in the PiDRL guidelines. Recommendations on the appropriate dose quantities to be used for defining paediatric DRLs, taking into account international standards and technological capabilities are also included in the guidelines. DRLs should be based on appropriate patient dose surveys. In general, it is recommended that from each institution a representative sample of at least 10 patients per procedure type and per patient group is needed for non-complex examinations such as radiography and CT and at least 20 patients per procedure type and per patient group for complex procedures such as fluoroscopy and fluoroscopically

guided procedures. For all body examinations, weight should be used as a parameter for patient grouping. The recommended weight groups are < 5 kg, 5-<15 kg, 15-<30 kg, 30-<50 kg and 50-<80 kg. For head examinations, age is recommended as the grouping parameter. The recommended age groups are 0-<4 weeks, 4 weeks-<1y, 1-<6y and ≥ 6 y. Patient dose data should be collected from a representative sample of various types of equipment and practices in the geographical area concerned. Dose management solutions can play a very important role in the establishment and use of DRLs. For national or local DRLs the 3rd quartile (the 75thpercentile) should be used. However, the full dose distribution should be exploited for optimization in addition to DRLs.

The median values of patient dose distributions from representative samples of examinations, obtained from each radiology department within the hospital or group of hospitals, should regularly be compared with local DRLs whenever these have been defined for the hospital or group of hospitals. Institutions that have their own local DRLs must carry out regular comparison of the local DRLs with national RDLs to ensure they are not higher. The national DRLs, when not adopted from the European DRLs, should be compared with the European DRLs.

21 - Automatic dose data management and DRLs

Andreas Jahnen (LIST, LU)

Introduction: New medical imaging equipment uses digital representations of the image data and provide dose descriptors in electronic format. Those available data is a useful source to support DRL studies. With the availability of the data, dose data management systems have been developed that support the collection and evaluation of data.

Purpose: This talk reviews the dose descriptors and give an overview of dose data management systems with a focus on their utility for paediatric DRL studies.

Materials and Methods: Dose descriptors are accessible in the DICOM headers of medical images, or more recently, as DICOM Radiation Dose Structured Report (RDSR) with more comprehensive description. As the images are stored in the PACS systems, this data is not easily available. Dose management system collect this specific information and make evaluation tools available to the user.

In the framework of the PiDRL project a review of available dose management systems has been performed with the focus on dedicated paediatric features. The talk will show illustrative examples on how dose management system can support the PiDRL guideline.

Results: Modern dose management systems provide good support for DRL studies and are a useful a tool in managing paediatric DRLs. Each product, provide export features in order to allow further analysis. Currently, dedicated paediatric modules are in development, that will even improve the situation.

Conclusion: A automatic dose management system can be a useful tool to support the establishment, optimisation and the control of paediatric DRLs as proposed by the PiDRL project.

22 - Improving radiation dose management using DICOM tools

Annalisa Trianni (Udine University Hospital, DICOM Working Group 2, IT)

There has been an increase in public awareness about the radiation dose used to acquire images in diagnostic imaging examinations. Recently, the new Basic Safety Standard, published in 2013, introduced new requirements for monitoring and recording patient exposure.

Several tools have been developed to extract, collect, store and analyze data regarding the exposure involved during radiologic procedures. This information is communicated using specific standards such as the *non-image information object definitions* DICOM objects.

More specifically, there are three DICOM objects in the standard that can be used to transport exposure information: the DICOM header, the DICOM Modality Performed Procedure Step (MPPS) and the DICOM Radiation Dose Structured Report (RDSR). These objects have several advantages and some limitations. For example, the DICOM header cannot be decoupled from the image. Therefore, if an image is not stored for any reason (e.g. fluoroscopy sequences), the exposure data is lost, resulting in an underestimation of the exposure. On the other hand, it could result in an overestimation of the exposure if an image is duplicated for any reason (e.g. storage of an additional CT reconstruction).

The most complete of the three objects previously mentioned is the DICOM RDSR, which was added to the Standard in 2005. This object transports all the information related to the equipment output along with information about the patient and the procedure that could be used to estimate the exposure to the patient. Due to the information it provides, the RDSR can be used for a wide range of applications: e.g., it could be used in the optimization process; to directly inform national dose registries; and to provide the clinical medical physicist with the information necessary to perform patient and/or fetal dose estimates.

All the mentioned objects are carrying information about equipment output and do not provide any information on patient dose. Although they can include (especially the RDSR) some of the information needed to estimate patient dose, unfortunately this information is not complete. And moreover none of these objects includes a template for patient-specific dose data to be recorded after estimation. For this reason a new DICOM object, the Patient Radiation Dose Structured Report (P-RDSR) is being developed. The P-RDSR will include some of the information lacking in the RDSR necessary for estimating patient-specific dose and will provide the archival tool to record the results of the estimations and the methodology used to achieve this estimate.

ABSTRACTS - FRIDAY, OCTOBER 16, 2015

23 - Methods of using DRLs

Hilde Bosmans (EFOMP, BE)

Diagnostic reference levels (DRLs) are established in a growing number of EC Member States and provide data for local use in the hospitals when optimizing their radiological practice as well as to the decision makers supporting their role in supervision and steering. More and more Member States collect also data of paediatric exams. Establishment of paediatric DRLs may be more difficult as the number of contributing cases or centers may be small. Data pooling from regions larger than a single Member State may be indicated. Practices may also be very different between larger specialized centers and regional hospitals, leading to a spread in collected data. Finally, a single value may not summarize the DRL of a particular standard X-ray exam in children, due to the relatively large range in age/weight among these patients. As explained in the PiDRL document, curves can be a good alternative for a single value. Member States should promote the use of the DRL-curve.

In this presentation, we will discuss practical uses of DRLs in adult versus children. Paediatric DRLs will also be used at different levels, from the European or international authorities down to the local users in the hospital. Whereas the first group may strive to international harmonization and work towards obtaining such a situation, the local user may have a very different interest related with the specificities of his installation. A typical example happens at the purchase of a new system, where the user may want to see the effect of an investment into lower dose acquisitions. He may be very satisfied with his data points far below and therefore deviating from the national averages. Most local users may welcome a first dose benchmark and follow up scheme. International authorities and local users have at least one point in common: there is a huge demand to learn from these data. The global and local use of the DRLs may show an enormous potential into dose reduction and safety increases.

INVITED PAPER

Moderator: Shane Foley (EFRS, IE)

24 - Impact of using DRLs in paediatric imaging

Maria Perez (WHO, Member of the PiDRL Expert Advisory Panel, CH)

The medical use of ionizing radiation has expanded worldwide. Advanced imaging technology has opened new horizons to diagnostics and improved patient care. Managing the risks of medical radiation exposures demands policies that both recognize the multiple health benefits that can be obtained, while addressing and minimizing potential health risks. Indeed, maximizing benefits and minimizing risks is the ultimate purpose radiation protection in medicine, based on the two principles of: justification of procedures and optimization of protection to manage the radiation dose commensurate with the medical purpose. For an individual patient the risk-benefit balance favours the benefit when the exam is appropriately prescribed ("to do the right procedure") and properly performed (" to do the procedure right"). However, this risk/benefit balance does no more favour the benefit if a medical imaging procedure is performed without a clinical indication or if the patient receives a higher dose than necessary to obtain an image of diagnostic quality. Diagnostic reference levels (DRLs) have proven to be an effective tool for optimisation of protection in medical imaging. The availability of paediatric DRLs and their use in the daily practice are still very limited, and this applies to diagnostic radiology procedures as well as image-guided interventional procedures. Taking into account the higher vulnerability of children, prevention of unnecessary radiation exposure is critical in paediatric health care. This calls for policies to support implementation of paediatric DRLs at regional, national, local and facility levels. These policies should address challenges such as selection of the methodology for establishing DRLs for children, criteria and intervals for their review and update, clarification of concepts, harmonization of terminology, approaches for different modalities, considerations for new technologies, consensus about quantities and units to express DRL values, development of patient dose surveys, data collection and interpretation, among others. Effective strategies to encourage the use of DRL values at the point of care need to be developed and implemented. These strategies should be tailored to local conditions and integrated in the more general concept of safety and quality of health care, keeping in mind that good medical practice encompasses radiation safety. This presentation provides an overview on these issues, highlighting that the promotion of the use of DRLs in paediatric imaging can significant reduce unnecessary radiation exposure and related risks, thus improving safety and quality of paediatric health care.

ABSTRACT PRESENTATIONS:
PiDRLs and Patient Doses from Paediatric Procedures

Moderators: Stephen Evans (EFOMP, UK), Dean Pekarovic (EFRS, SI)

25 - Radiation exposure from Pediatric Cardiac Catheterization in France

Helene Baysson[1], Serge Dreuil[1], Younes Boudjemline[2], Damien Bonnet[2], Cécile Etard[1], Marie Odile Bernier[1]

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Introduction: The justification as well as the benefit–risk ratio of cardiac catheterization procedures (CCP) is well established. However, the assessment of radiation exposure during such procedures and the evaluation of carcinogenic effects of ionizing radiation remain of great concern especially for children.

Purpose: The present study aims at evaluating radiation dose levels for the most frequent CCP performed at the Necker hospital, French reference center for complex congenital heart disease (CHD). A total of 540 Diagnostic CCP and 1267 Therapeutic CCP performed among pediatric patients (< 16 years old) over the period 2010-2012 were analysed.

Materials and Methods: Diagnostic procedures consisted mainly of hemodynamic measures and/or imaging of heart structures. The main therapeutic procedures investigated were: Patent Ductus Arterious closure (PDA), Atrial Septal Defects closure (ASD) and Pulmonary Valve dilatation (PV). For each of these procedures, the date of procedure, the age and weight of the patient were collected. Dose area product (DAP) and fluoroscopy time (FT) were retrieved retrospectively from automatic dose recording. The mean, median, standard deviation, minimum and maximum values of DAP and FT were calculated. Organ doses to lung, thyroid, breast and bone marrow will be calculated using PCXMC software.

Results: For diagnostic procedures, the mean value of DAP was 5.2 ± 7.3 Gy.cm2. For therapeutic procedures, the mean value of DAP was 6.9 ± 14.7 Gy.cm2. For diagnostic procedures, the mean FT value was 9.2 ± 11.9 minutes. For therapeutic procedures, the mean FT value was 9.6 ± 11.9 minutes. Among therapeutic procedures, a large variability in doses was observed. For PDA, the mean DAP value was 2.93 ± 7.07 Gy.cm2; for ASD the mean DAP value was 2.15 ± 6.30 Gy.cm2; for PV the mean DAP value was 2.15 ± 6.30 Gy.cm2. This variability was expected because there was no standard technique with which to perform a CCP. The radiological exposure parameters and the duration of the procedure depend strongly on the patient's characteristics and the complexity of the CHD.

Conclusion: This is the first study in France to focus on children undergoing CCP. In order to have a better evaluation of current practices in pediatric CCP at national level, the study will be extended to the whole French network for CHD. The present work is included in the framework of an epidemiological cohort study, named "Coccinelle" ("Ladybird" in French), specifically designed to evaluate the incidence of cancer and leukaemia after CCP during childhood.

26 - Improvement of Pediatric CT protocols in Dalarna County, Sweden

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Introduction: Dalarna County Council has six CT scanners and performs approximately 30,000 CT examinations annually of which 500 are performed on children aged 0-16 years. A proportion of the studies are trauma scans of children following accidents in connection with mountain and ski tourism in the region. In 2013 a project was initiated to improve our pediatric CT examinations in the light of a rising demand for computed tomography.

Purpose: Increase the number of examinations on our CT systems performed with age or weight adjusted protocols. The impact of fixation device on CT dose modulation and automatic exposure control has been analyzed.

We have in this study looked at the effect of education of radiographers, division of protocols for children, protocol parameters, dose comparison between our CT systems and comparison with national DRLs.

Materials and Methods: All pediatric CT protocols has been reviewed and divided according to age or weight. All staff has been introduced in the process and specific training has been carried out for those how operate the CT. Every examination has been identified and protocol parameters have been collected. Specific examinations have been discussed in a conference with technologies, radiologist and physicist. Focus were absorbed dose and image quality.

Result: At the starting point 20% of the examinations were performed using pediatric protocols. After the introduction of age/weight-adjusted protocols and following training, the percentage raised to 70%. Fixation of the patient affects dose modulation and increases the absorbed dose with 22%. Use of iterative reconstruction algorithms, adjusted protocol parameters including kV, has reduced the absorbed dose with 30%.

Conclusion: Our local reference levels are higher compared to the levels at the dedicated children´s hospital but have reached an acceptable level. The work now continues to reach a level where every child is examined using an aged or weight adjusted protocol. There is a need for refined DRLs for children for comparison.

27 - A Decade of Experience towards Establishing Pediatric clinical Imaging Guidelines, Diagnostic Reference levels and Medical Exposure Control in Kenya

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Introduction: Pediatric disease diagnosis and imaging poses a great challenge to clinicians and the radiologists in Africa, Kenya included. There is a large disease burden, malnutrition, inadequate skilled manpower, poor infrastructure, deficit health financing and accessibility to quality healthcare. The use of ionizing radiation in pediatric imaging has technologically

ABSTRACTS - FRIDAY, OCTOBER 16, 2015

advanced and has become valuable and relevant tool in clinical practice ensuing broader usage. The elevated use compounded with lack of appropriate clinical imaging criteria, justification of practice and optimal imaging techniques has created a public health concern.

Purpose: The purpose of the paper is to demonstrate how Kenya benchmarked and extended the establishment of pediatric DRLs in general radiography; fluoroscopy; computed tomography and Interventional Procedures.

Materials and Methods: A structured questionnaire-type form was developed for recording examination frequency, imaging techniques and patient radiation dose exposure during imaging in fully equipped medical facilities across the country. A radiologist and physicist from the national hospital visited the participating facilities to make QA presentations, observe the procedures of radiological examinations, QC measurements, patient dose assessment, interact with hospital staff, encourage participation in the survey, which ultimately led to a QA evaluation report with recommendations.

Results: The national annual number of pediatric patient was over 1 million constituting 32% of all radiological examinations done in Kenya. One in every twenty pediatric patients underwent a radiological Imaging. The national pediatric patient annual examination frequencies in decreasing order were as follows: general radiography 1,017,618 (95%); fluoroscopy 30,047 (3%); CT 22,141 (2%) and IPs 241 (<1%). The pediatric patient dose, NDRLs and effective dose were determined for 30 types of pediatric examinations distributed as follows; general radiography 16 (53%); fluoroscopy 5 (17%); CT 6 (20%) and IPs 3 (10%). Additionally, the annual collective effective dose and effective dose per capita were approximated.

Conclusion: The pediatric radiation exposure was broadly distributed between the examination types indicating the need to develop and implement local diagnostic reference levels as a standardization and optimization tool for the radiological protection of patients at institutional level.

28 - Towards the standardization of pediatric cranial CT protocols: A Belgian multicenter study

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Introduction: Standardization of pediatric CT protocols has lagged behind greatly and is of capital importance for reducing radiation induced side effects.

Purpose: To benchmark regional standard practice for cranial CT procedures on pediatric patients in terms of clinical indication and radiation dose.

Materials and Methods: Pediatric population cranial CT dose data was retrospectively collected during a 1 year period, at 3 Belgian hospitals. A commercially available dose-tracking system, DoseWatch (GE Healthcare) was used to automatically gather demographic and scan information. Data was stratified by age and clinical indication; appropriate use of child-tailored protocols was assessed.

Results: A total of 296 pediatric cranial CT procedures were collected. The main clinical indication was head trauma (around 80%) for all three sites. Adult protocols were erroneously used for children to a larger extent in one institution. All institutions used automatic tube current modulation and iterative reconstruction algorithms to reduce the delivered dose. Despite the fact that all institutions have a median CTDIvol below the national P75 reference level of 44.5 mGy, major differences were noted between institutions in delivered dose.

Conclusion: After internal dose-benchmarking, sharing dose data between hospitals is a necessary next step to take, in order to put everyday practice in a broader perspective. Pediatric CT examinations represent only a small percentage of everyday work in a radiology department, and they are therefore susceptible to standardization issues. Inappropriate use of protocols and scan parameters in CT procedures on pediatric patients is still an issue that needs attention in the near future.

29 - American College of Radiology (ACR) CT Dose Index Registry: A Resource for Pediatric CT Diagnostic Reference Levels

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Introduction: Diagnostic reference levels (DRLs) provide guidance for radiation dose management. DRLs for CT should be based on data from broad contemporary practice that is population-specific, such as for age.

Purpose: Our purpose was to use the ACR CT Dose Index Registry (DIR) as there is little generic information in the U.S. on wide-ranging demographics and dose estimates for pediatric CT.

Materials and Methods: DIR data for 3.5 yrs mos. (7/11-12/14) was reviewed for 3 common CT examinations: head/brain without IV contrast media (contrast) (head), chest with contrast (chest), and abdomen/pelvis with contrast (AP) by age (>0-<¬3, 3-<7, 7-<11, 11-<15, 15-18). Dose parameters included CTDIvol (mGy, 16 cm head, 32 cm body) and size-specific dose estimate (SSDE, mGy). Analysis included gender, practice geography and type (e.g., community, pediatric specialty centers).

Results: For 5,387,120 total head, chest, and AP examinations for all ages, 5.8% (309,807) were pediatric (99.6% from U.S. sites): 7% head, 5% AP, and 2% chest. 69% of all pediatric examinations were head. 72% of AP, 61% of chest, and 56% of brain examinations were performed in 11-18 yr old children, with the highest frequency in the oldest age category. For all examination types across all ages, the majority (53-62%) was performed in males (exceptions were the 11-<15, and 15-18 yr group for AP CT where 52% and 61% were performed in females). Ranges across all age categories included mean CTDIvol of 4.9-13.5 and mean SSDE of 8.8-17.7 for AP, and mean CTDIvol of 3.4-15.5 with mean SSDE of 6.3-18.1 SSDE for chest CT; higher dose estimates positively correlated with increasing age group. The range of mean head CTDIvol was 32.9-60, increasing with age with the largest increases in the two oldest age groups. The mean AP CT SSDE and CTDIvol were higher than the chest dose estimates for every age group, except for the 15-18 group. SSDE values were always greater than CTDIvol for each age category. 51% of scans were from community and 45% from centers with pediatric expertise (children's hospitals, university-based academic programs).

Conclusion: The ACR Dose Index Registry affords an efficient and effective opportunity to establish and update pediatric DRLs in the U.S. for a large number and variety of age-based CT examinations and from a broad representation of practice types.

30 - Dose Reference Levels For Paediatric Thorax CT: Can Image Quality Be Achieved While Maintaining Dose Reduction For Different Body Mass Indices?

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The current DRLs are mean values for standard body sizes, which are generally adapted for paediatric patients. In practice, DRLs are higher than necessary in most European countries and there is a wide variation depending on equipment and training. One of the main reasons for this is the complexity of the dose optimization process, while maintaining diagnostic image quality for patients with BMIs different from the standard. It is accepted that radiation dose must decrease for younger children due to risk of radiation-induced cancers, especially leukaemia arising from biological mechanisms such as high cellularity; image quality requiring larger doses for larger BMIs within age groups. Since individual organ sizes vary with changes in body size, this is a key issue in countries with a high prevalence of obesity among children. Nevertheless, thorax is an anatomic region where the radiation dose can be significantly reduced due to high contrast between the natural structures such as mediastinal fat and air in the lungs.

However, studies that calculate dose as a function of patient size typically use a phantom of 32 cm and, therefore, the availability of studies using real body size data is scarce.

This is the first study that estimates both contributions of age and BMI to the amount of organ doses for diagnostic thorax CT accounting for body sizes of 573 male Bangladeshi children from 0 to 10 years old.

We use the ImPACT calculator based on Monte Carlo simulations to compute organ doses for an average male adult (170cm*70kg) undergoing a thorax CT examination.

Using a tube voltage of 120 kV for Siemens 64 slice CT scanner, we construct ratios of organ dose to CTDIvol as a function of location of organs in the thorax. In addition, different BMIs are modelled as different diameter water cylinders in order to obtain the correspondent factors for organ doses in paediatric patients undergoing thorax examinations relative to the organ doses received by a reference adult.

Results show that age operates a reduction in absorbed dose by a factor ranging 0.33 to 0.79, which are consistent with the results of other reference studies. Conversely, an increase of 1 BMI unit implies an increase in absorbed dose up to 13% in order to maintain the quality standards of diagnostic imaging. These findings encourage the construction of dosimetry tables for body mass indices within age groups.

31 - Diagnostic Reference Levels for paediatric conventional imaging obtained using DoseWatch: A road for optimization

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Introduction: The new Euratom Directive 2013/59 (ED) requires the registration of individual radiation doses received by patients in paediatric diagnostic imaging. Therefore, automatic dose data management software is needed, and local Diagnostic Reference Levels (DRLs) can be obtained.

Purpose: In application of ED, we have used the dose management software DoseWatch® (General Electric) and we have obtained local DRLs for the most common examinations performed in a paediatric conventional radiology room, for different age ranges. Since in some cases the local DRL exceeds that proposed by the European Commission (EC), 1996, a dosimetric optimization procedure has been performed to reduce patient doses, taking care of not compromising the quality of diagnostic images.

Materials and Methods:
a) Reference state establishment. During ten months of 2014, 11495 studies were performed in a conventional radiology digital equipment Definium 8000 (General Electric). All dosimetric and demographic data were registered by DoseWatch®. The studies were classified according to the different age ranges commonly used in paediatrics. For children under 1 year, dosimetric data were obtained for three additional age ranges: [0, 3), [3, 6) and [6, 12) months. The dosimetric information provided by the equipment, in terms of entrance surface air kerma (Ka,e, ICRU 2005), was verified in phantom with an ionization chamber. Local DRLs were obtained for Abdomen, Chest PA/AP and AP Pelvis exams in the age ranges mentioned, using the 75th percentile of the population data, and compared with the DRLs proposed by EC. The uncertainties of the percentiles were obtained using the bootstrap method.

b) Optimization procedure. To perform the optimization, an analysis of the causes of the high doses observed was made using data provided by DoseWatch®. The consequent reduction of doses was performed improving exploration protocols in terms of kV and mA, and activating the automatic exposure control. The post-processing of the images was adjusted to ensure that the image quality was not compromised.

Results: Local DRLs in terms of Ka,e, with their uncertainties, for the most common explorations and age ranges of paediatric conventional radiology, have been obtained. For the age range [0,1) and Chest PA/AP exploration, the local DRL exceeded the proposed by EC (160%). The dosimetric optimization procedure performed has reduced the patient doses necessary (below EC's DRL) without significant detriment of diagnostic imaging quality.

Conclusions: Automatic dose data management software like DoseWacth® is needed to accomplish the new Euratom Directive 2013/59, and it is useful to establish DRLs and perform dosimetric optimization procedures.

32 - A review of current local dose area product levels for paediatric fluoroscopy in a South African tertiary referral hospital as compared to standard international guidelines

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Introduction: As there is an increased risk of developing malignancy compared to adults, it is important to reduce radiation exposure in children. Published data on the current range of dosages in paediatric fluoroscopy is extremely limited in the Sub Saharan clinical setting.

Aim: To determine the dose area product (DAP) values in children, undergoing the most common fluoroscopic examinations over a period of three years and comparing these values to international standards. Secondly, to use our values to set standard local diagnostic reference levels.

Method: A retrospective single- center study has been conducted at the Charlotte Maxeke General Academic Hospital in

Johannesburg South Africa, to determine the dose area product (DAP) in children undergoing fluoroscopic examinations over three years. Preliminary data collected over a year from 1 January 2014 to 31 March 2015 of 126 studies done in a single dedicated fluoroscopy unit was collected retrospectively.

All examinations were performed using the single fluoroscopy unit in our dedicated paediatric fluoroscopy suite. In our institution, we aim to follow the Radiological society of South Africa/ South African Paediatric Imaging's guidelines. However technique is tailored to specific patient profile and clinical question, to obtain optimal medical imaging quality, while minimizing radiation exposure. This includes restricted anatomical views, collimation and "image grab". The third quartile and mean DAP values were collected on individual basis for each study performed, categorized into 5 age groups (0-1, 2-5, 6-10 and 11- 16 years) and stratified by our 2 major examinations. The data were compared to literature from the National UK Radiological Protection Board.

Results: Preliminary results are based on a years data collection.

The two most common examinations were further analyzed and compared to international standards (30 VCU/MCUG studies and 96 contrasted swallows).

DAP's (median and third quartile) for upper gastrointestinal studies were significantly lower than the National UK Radiological Protection Board's (NRPB) 2010 review diagnostic reference levels.

DAP's for VCU were significantly lower for the 0-1 and 11-16 years age group, however higher for the remaining age groups, compared to NRPB's diagnostic reference levels.

Conclusion: Since the risk of ionizing radiation is higher in children, it is crucial to strive for the lowest possible DAP, while maintaining diagnostic accuracy. By following the Radiological society of South Africa/ South African Paediatric Imaging's guidelines, we achieved a significant lower DAP in upper gastrointestinal studies and in most of our VCU's, compared to current international standard references. Since there are no known published South African DAP reference values for paediatric fluoroscopy, local paediatric centers are encouraged to follow our technique and use our DAP levels as reference to keep the radiation dose to a minimum. Follow up studies are recommended to compare future DAP values for the specific examinations analyzed and to extend the research to include the other subset of fluoroscopic examinations done less frequently.

33 - Patient specific paediatric dose assessment in dental Cone Beam Computed Tomography via Monte Carlo calculations

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Introduction: Dose assessment in paediatric dental CBCT imaging is crucial due to the increasing use of CBCTs in dentomaxillofacial radiology and the higher effective doses (ED) compared to intraoral and panoramic modalities. Monte Carlo (MC) calculations in voxelised phantoms provide a software dosimetric approach which overcomes the limitations of using TLDs loaded in anthropomorphic phantoms.

Purpose: To calculate organ doses and estimate the ED for three patients (5, 8 and 12 years old), for a range of clinical protocols and reconstruction settings in a Promax 3D MAX (Planmeca-Helsinki-Finland) scanner via MC simulations.

Materials and Methods: Head-neck multislice CT datasets were used to design three voxel phantoms (5 years old (yo) -male, 8 yo-male, 12 yo-female). Each phantom consists of 22 organs and includes the radiosensitive organs provided by ICRP except for lymph nodes whose dose was estimated from substitute organ doses. Each phantom was employed to a fully validated, EGSnrc-based, MC framework. It is adjusted to different tubes by generating equivalent source models, requiring HVL and bow-tie filter measurements. Doses were calculated for six different combinations of exposure settings and reconstructions (from Ultra low dose mode (ULD)/low dose (LDR) reconstruction (96kV,6mAs) to Normal dose (ND) mode/HD reconstruction (96kV,105mAs)) and each of them for four different FOV protocols (teeth: 100x55mm2, 100x90 mm2, face: 100x130mm2, skull: 160x230mm2).

Results: The teeth 100x55mm^2 protocol resulted in EDs of 28.8 (ULD-LDR) to 503.3 μSv (ND-HD) for the 5 yo, 25.1 to 438.8 μSv (8 yo) and 18.5 to 323.0 μSv (12 yo) patients. The range of EDs for the 100x90mm^2 protocol was 44.7 to 782 μSv (5 yo), 41.8 to 731.1 μSv (8 yo) and 34.8 to 609.2 μSv (12 yo) patients. The face protocol resulted in EDs of 62.3 to 1089.8 μSv (5 yo), 56.5 to 989.1 μSv (8 yo) and 46.2 to 809.2 μSv (12 yo) patients. The EDs of the skull protocol were 72.5 to 1268.1 μSv (5 yo), 70.3 to 1230.9 μSv (8 yo) and 63.2 to 1105.7 μSv (12 yo) patients. The dose to the eye lens ranged from 31.4 μSv (12 yo, 100x55 mm^2, ULD/LDR) to 12.7mGy (8 yo, 230x160mm2, ND/HD).

Conclusions: Younger patients received higher calculated EDs given the same exposure conditions. The highest doses were associated with the largest FOVs and exposure settings. Furthermore, the largest contribution to EDs originated from bone marrow equivalent doses. Finally, the highest dose to the eye lens was well below the threshold for radiation induced cataract.

34 - A three centre European study of the feasibility of establishing diagnostic reference levels in paediatric cardiac interventional radiology

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Introduction: Diagnostic reference levels (DRLs) are a useful optimisation tool in radiology and help to identify doses that are either too high or too low. Cardiac interventional radiology is an area of increasing use in radiology due to its minimal invasiveness, but is associated with relatively large radiation doses, hence the desire for optimisation within the modality. There is currently little published data on DRLs in this area, likely due to the fact that the complexity of cases can lead to a large variation in examination techniques, but also due to the difficulty in acquiring enough data for each paediatric sub category (age or weight).

Purpose: To collect cardiac interventional data from three European centres to establish the most appropriate examinations in which to establish DRLs.

Methods and Materials: Institutional permission was granted to access imaging records. Retrospective data (n=36 months) was collated in the Irish national centre for paediatric cardiac

imaging, performed on a Siemens Bicor unit. Data was age categorised: 0 -<1 years, 1-<5 years, 5-<10 years, 10-<15 years, and >15-18 years. Italian and UK prospective data (n=18 months) was collated for eight matching cardiac interventional examinations performed using Philips Integris Allura and Siemens Artis equipment respectively: aortic coarctations; aortic and pulmonary valvuloplasty, pulmonary angiography, pulmonary valve replacement, septal defects, closure of patent ductos arteriosus and cardiac catheterisation. Protocol details capture and total examination dose area product (DAP) were recorded. A minimum of 10 examinations in each paediatric category was deemed essential to establish DRLs.

Results: Data from 1092 examinations was collated, with cardiac catheterisation (n=294), patent ductus arteriosus (n=280) and septal defects (n=128) proving the most common examinations performed. The most common age group being 1-<5 year category and typically reduced in frequency with increasing age. It was not possible to establish DRLs for all age categories in any single examination, with cardiac catheterisation (4/5) having the most complete dataset. Large differences in DRL (79%, p<0.001) were noted between centres, highlighting the importance of setting DRLs specific to local equipment and techniques.

Conclusion: Establishing DRLs in paediatric cardiac interventional radiology is difficult due to the limited number of patients presenting in each age category and should be restricted to the most common examinations.

35 - A comparison of age and weight groupings for establishing local DRLs in paediatric cardiac catheterisation examinations

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Introduction: European Council directives and ICRP guidance recommend the establishment of diagnostic reference levels (DRLs) for common radiology examinations and for paediatric patients these should be defined according to age / size / weight categories, due to the variation that exists in sizes amongst the paediatric population. Published data mostly uses patient age as this is easily collected, but weight is likely a more accurate grouping.

Purpose: To compare DRLs calculated when patients are grouped according to both age and weight bands for the most common paediatric cardiac interventional examination.

Methods and Materials: Institutional permission was granted to access imaging records. Retrospective data (n=36 months) was manually collated in the Irish national centre for paediatric cardiac imaging, performed on a Siemens Bicor unit. Data was categorised according to both age (0 -<1 years, 1-<5 years, 5-<10 years, 10-<15 years, and >15-18 years) and weight ranges (0-<5kg, 5-<15kg, 15-<30kg, 30-<50kg, 50-<80kg). Protocol details including total examination times and dose area product (DAP) were recorded. A minimum of 10 examinations in each paediatric category was needed to establish DRLs, which were calculated based on the third quartile of the dose distribution of the DAP. Independent samples t-testing was used to compare DAP values between age and weight groupings.

Results: Data from 215 examinations with both age and weight data was collated, with the largest groups being <1 year (n=75) and 1-<5year groups (n=79) while the smallest was 15-18 (n=7). When patients were grouped according to weight <5kg (n=55) and 5-<15kg (n=80) had the greatest numbers, with 30-<50kg the smallest (n=11). Mean ages and ranges for the five respective weight groups was 0 (0-1), 1.5 (0-5), 5.3 (2-11), 10.5 (8-13) and 13.7 (6-17) years, while mean weight and range for the age categories was 4.4(2-8), 12.7(4-23), 22.8(13-54), 49.5 (23-73) and 63.5(52-74)kg. DRLs were calculated to be 440, 565, 960, 1705 and 2005 cGycm2 when categorised according to weight and 440, 676, 1260, 1922cGycm2 according to age, with a maximal 31% difference between corresponding groups. Although weight ranges had corresponding age ranges, significant differences in DAP values were found (p<0.05) when compared using independent measures t-tests.

Conclusion: Grouping paediatric patients by either age or weight results in significantly different mean DAP values and thus DRLs.

36 - A comparison of patient weight, age and diameter grouping/categorisation for establishing diagnostic reference levels in paediatric CT

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Introduction: Diagnostic reference levels (DRLs) are a useful optimisation tool as they can help identify excessive dose levels either locally or nationally. Establishing paediatric DRLs however is not straightforward as dose depends on the patients' body size and paediatrics vary dramatically in size, thus requiring the development of multiple different DRL categories. DRLs have typically been established according to patient age, although patient weight is thought to be a much better predictor of size. Patient diameter also has potential to act as a surrogate for patient size and it can be measured accurately using CT.

Purpose: To compare local paediatric CT diagnostic reference levels in a single national centre, when calculated according to either patient age, weight or diameter.

Materials and Method: Data was collected retrospectively for the 2014 calender year from a single national tertiary referral paediatric hospital with a single Philips Brilliance 128 slice CT scanner. The displayed CT dose metrics (CTDIvol and DLP) were checked for accuracy and data was collected using automatic dose management software (eXposure, Radimetrics, Bayer Healthcare) connected to the PACS for the most common CT examinations – axial head, routine chest and thorax-abdomen-pelvis (TAP). Local CT protocols are based on either patient weight (body: <10kg, 10-<30kg, 30-<50kg, 50-<70kg, >70kg) or age (head: 0-<12months, 1-<6years, 6-14years, >14years) as well as clinical indication. The 75th percentile of the local dose distribution was used for DRL calculation and was calculated according to patient age, weight and patient diameter (8-<10, 10-<12, 12-<14, 14-<16, 16-<18cm). Multiple regression analysis was performed to compare the grouping categories with patient dose for each examination.

Results: A total of 1319 CT dose reports were available for the year (head:199, chest:86, TAP: 65). DRL calculation demonstrated differences of X, Y and Z across the age, weight and diameter categories. As expected DLP values had moderate to strong linear relationships with all patient groupings (patient age/ weight/diameter) and variations were noted between DRLs calculated for each of the groupings. Grouping by patient diameter resulted in the inclusion of large ranges of patient age within specific categories.

Conclusion: Automated dose management software facilitates relatively easy review of CT doses and calculation of DRLs based on a variety of patient groupings.

ABSTRACTS - FRIDAY, OCTOBER 16, 2015

37 - Estimation of Local Diagnostic Reference Levels for paediatric Brain CT

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Introduction: Computed Tomography is currently one of the diagnostic procedures that expose patients to higher radiation dose, corresponding to about 47% of the radiation that is used in medical diagnosis. Continuous evolution of TC, like the increase of the number of detectors and procedures, resulted in an extra concern about public exposure, especially when performed in paediatric patients.

Thus, there is a need to optimize the procedures in order to obtain good image quality and also ensuring the lowest radiation dose.

Purpose: The present study was performed in a Portuguese Hospital and aims to establish local diagnostic reference levels (DRL) for the most common paediatric procedure - Brain CT – using two different CT scans. These DRL were then compared with paediatric DRL available in literature.

Materials and Methods: A retrospective study between May 2014 and April 2015 was performed, collecting DLP values (mGy.cm) and patients age and gender, in order to establish local paediatric DRL for the two CT scans available (TC Lightspeed and TC Brightspeed 16, both from G.E.).

The paediatric patients were divided according to age into four groups, namely 0-1 years, 2-5 years and 6-10 years.

The local paediatric DRL, calculated based on 75 percentile, were then analysed and compared with international published DRL.

Results: For TC Lightspeed we obtained the following results:

- 0-1 years (4 patients) – 869.59 [95.76, 883.70] mGy.cm
- 2-5 years (1 patients) – 1051.48 mGy.cm
- 6-10 years (9 patients) – 949.37 [415.62, 1479.23] mGy.cm

For TC Brightspeed 16 we obtained the following results:

- years (7 patients) – 389.80 [241.01, 941.43] mGy.cm
- 2-5 years (15 patients) – 941.43 [158.42, 1478.18] mGy.cm
- 6-10 years (11 patients) – 977.80 [313.31, 1109.8] mGy.cm

After comparing local DRL and values available in literature, we obtained deviations between 0.29% and 107.04%.

Conclusion: We can verify that local DRL are relatively high when compared with those in literature. There are certain factors that influence radiation dose, for example, the use of immobilization equipment in case of rooms responding to emergency requests, the body mass, anatomical structure, age and gender of the patient, experience of the technical team or complexity of the procedure. It is important to have in mind that this study did not account the weight of patients.

After this audit, it is necessary to implement optimization practices that may involve changes in protocols and sensibilization of the technical team.

38 - Orthopantomography and lateral cephalometry Diagnostic Reference Levels in paediatrics and the influence in eye lens dose

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Introduction: Oral imaging studies are frequent performed in paediatrics in order to diagnose dental pathologies, monitoring dental-facial development and analyse therapy progress in children. Children possess an increased number of dividing cells at a sensitive neoplastic transformation phase compared to adults, their organs are more sensitive to radiation damage and they have a longer lifetime during which radiation-related cancers may occur.

Purpose: Establish local Diagnostic Reference Levels (DRLs) for orthopantomographic and lateral cephalometric radiographies per age categorisation.

Materials and Methods: Orthopantomography and Lateral cephalometry and Digital Imaging and Communications in Medicine (DICOM) headers, available on Picture Archiving and Communication System (PACS), performed in 2014, were retrospectively analysed by age groups (5, 10, 15, 18 and 30 years old); In order to analyse exposure parameters and dose values. DRL's were calculate based on the 75th percentile value of Dose Area product (DAP) and compared with literature. Eye lens dose was measure during orthopantomography radiographies in anthropomorphic phantoms, correspondent to 5 and 15 years old patients.

Results: The tube voltage was 66kV and the tube current increased from 7 to 12mA with the age for orthopantomography examinations. For lateral cephalometry the exposure parameters were similar across the ages. The obtained DRL's for orthopantomography were 43, 47, 69, 79, e 65 mGy.cm2 for 5, 10, 15, 18 and 30 years old, respectively. The eye lens dose for orthopantomography was 4.3 μsv and 5.9 μsv and for 5 and 15 years old anthropomorphic phantoms. For lateral cephalometry is was not possible to calculate DRLS's for specific ages and range age categorisation of [5-10[, [10-15[and [15-18] was used; the obtained DRL's were respectively 7, 7 and 8 mGy.cm2.

Conclusion: The obtained DRLs were similar to the literature however the orthopantomography value for 30 years old was higher than for 15 years old patients, indicating the possibility of procedures optimisation. The eye lens dose values for anthropomorphic phantoms were approximately 5 times less than the described for a head CT examination in literature.

ROUND TABLE 4:
Establishing DRLs for Paediatric Non-cardiac and Cardiac Fluoroscopically Guided Procedures

Moderator: Jenia Vassileva (IAEA, Member of the PiDRL Expert Advisory Panel, AT)

39 - Establishing DRLs for IR paediatric non-cardiac procedures

Peter Vock (ESR, CH)

Introduction: The literature does not offer much information on radiation exposure in paediatric non-cardiac interventions. The PiDRL project performed a limited survey among highly specialised paediatric interventional university units.

Purpose: The purpose of this survey was to get an idea of the types of non-cardiac interventions performed in a few European centres, to calculate local DRLs and – potentially – to combine these in order to establish tentative European DRLs

Material and Methods: Five cooperating centres located in 3 European countries retrospectively extracted demographic information, exposure data and information about the types of intervention of the last 1-4 years and their anatomical location. DAP values were the primary exposure parameter, and body size was characterised by the age (5 centres) and the weight (2 centres).

The following interventions were performed most often: embolization of the head/neck/spine, general embolization in other locations, sclerotherapy of venous malformations/cysts/lymph-angiomas, arteriography, peripheral insertion of central venous catheters and ports, and biliary interventions.

Weight grouping (< 5kg; 5-<15kg; 15-<30kg; 30-<50kg; 50-<80kg) and age grouping (<1m; 1m-<4y; 4-<10y; 10-<14y; 14-<18y) included 5 ranges each. To decrease statistical variation, a minimal number of 20 interventions per type and group was required for each centre. For each group, the 75th percentile of DAP was considered as local DRL.

Results: While one specialised centre contributed 80 biliary interventions, the others collected 173, 235, 463 and 640 different interventions respectively; the number of 20 interventions per centre was reached only for a minority of weight/age groups.

Variation was huge between intervention types, groups and centres, with lowest exposure of 0.02-2 Gycm^2 for the insertion of venous catheters and highest of 47.8-132 Gycm^2 for embolisations of the head/neck/spine. Depending on the anatomical location and the group, angiography had the widest range (0.5-265 Gycm^2); correlation between weight and DAP was poor but became good when only interventions of the trunk at one centre were considered.

Discussion: Variation of exposure during different paediatric non-cardiac interventions is huge, most probably due to the high number of factors influencing it. These include the growing patient (body size, region), technical aspects (equipment, local protocols, optimisation, technical skills) and disease aspects (population, case mix, clinical question, diagnosis/treatment, complexity). As some factors are constant within a centre, we suggest to determine local DRLs in a first step before standardisation will allow defining European DRLs.

40 - PiDRL dose survey for paediatric cardiac procedures

Hannu Järvinen (STUK, FI)

Introduction: According to USCEAR data, 4 % of all cardiac angiography is carried out for paediatric patients. Dramatic increase of number and type of procedures has been reported in literature, while also cone beam computed tomography (CBCT) has been increasingly used for these procedures. Paediatric cardiac procedures can result in high patient doses, including sometimes high skin exposure. Complex congenital heart diseases are often catheterized several times leading to high cumulative doses to patients. Therefore, the need to establish DRLs for paediatric diagnostic or interventional cardiac procedures has become evident. However, no NDRLs have been established but only a few local DRLs (LDRLs) have been published.

Purpose: The purpose was collect a sample of patient dose data from a few cardiac centers, for a few selected paediatric cardiac procedures, and compare the results with the data from the recent literature in order to propose preliminary DRLs.

Materials and Methods: Eight recent studies (2007-2015) on paediatric cardiac procedures were reviewed. Patient dose data from two cardiac centres was collected. Atrial septal defect (ASD) occlusion, patent ductus arteriosus (PDA) occlusion and pulmonary valve dilatation was selected as the procedures of interest.

Results: Only a few patient dose data could be collected during the PiDRL project. For PDA, data for 13 and 7 patients were obtained from the two centers, while for ASD, data for 8 patients was obtained from one center. The results were not sufficient to make any firm conclusions on the patient dose levels or DRLs. However, for PDA, comparison of the results with a few recent publications indicated that the patient dose level in the two hospitals was of the same order of magnitude but significantly (up to 4 times) lower than other published values. Several of the published papers concluded that patient weight is the main contributor to DAP value and reported good or reasonable correlation of DAP and patient weight. On the contrary, screening time (fluoroscopy time) seemed to have poor correlation with weight and to be a poor indicator for dose level.

Conclusion: No sufficient data is available to suggest DRLs for paediatric cardiac procedures which could be more generally applicable. There seems to be significant differences between dose levels in various centers. DAP per patient weight seems to be a convenient quantity for setting the DRLs. More data from several cardiac centers should be collected in order to provide better basis for setting the DRLs.

ABSTRACTS - FRIDAY, OCTOBER 16, 2015

ROUND TABLE 5:
The Role of International and National Organisations in Establishing and Promoting the Use of DRLs for Paediatric Imaging

Moderators: Hilde Bosmans (EFOMP, BE), Virginia Tsapaki (EFOMP, GR)

41 - International Commission on Radiological Protection (ICRP)

Eliseo Vano (ICRP, Member of the PiDRL Expert Advisory Panel, ES)

Committee 3 of the International Commission on Radiological Protection (ICRP) develops recommendations and guidance for protection of patients, staff, and the public regarding radiation exposure in medicine. While preparing its recommendations, ICRP is in contact with other organizations working on similar topics and coordinates the work. ICRP is finalizing a document on "Diagnostic Reference Levels (DRLs) in Medical Imaging" and one example of good cooperation is the interaction of ICRP with the European Consortium developing the "European Guidelines on Paediatric DRLs".

ICRP introduced the term 'Diagnostic Reference Level' in 1996. The concept was subsequently further developed, and practical advice was provided in 2001. DRLs have proven to be an effective tool for optimisation of protection in medical exposures of patients. As time went by, it became evident that additional advice was needed: for instance, in issues related to definitions of terms used in previous guidance, determination of values for DRLs, appropriate interval for re-evaluating and updating these values, appropriate use of DRLs in clinical practice, methods for practical application especially to certain newer imaging technologies.

The new document of ICRP updates and refines the recommendations of 2001. It highlights that the application of DRLs by itself is not sufficient for optimization of protection. Image quality or, more generally, the diagnostic information provided by the examination (including the effects of post-processing), must be evaluated. Quantities used for DRLs should be appropriate to the imaging modality being evaluated, assess the amount of ionizing radiation applied to perform a medical imaging task, and be measured directly. For interventional procedures, complexity of the procedure may be considered in setting DRLs. National and regional DRLs should be revised at regular intervals (3-5 years) or more frequently when substantial changes in technology, new imaging protocols or post-processing of images become available. DRLs shall not be used for individual patients or as trigger (alert or alarm) levels for individual patients or individual examinations. The radiation doses for examinations of children vary tremendously according to the great variation in patient weight. Variation in patient dose is appropriate when related to patient weight. Variation in patient dose as the result of inappropriate technique or technical failure to child-size the imaging protocol is not. Appropriate weight bands (generally with 5 or 10 kg intervals) are recommended for establishing paediatric DRLs and should be promoted in paediatrics.

42 - International Atomic Energy Agency (IAEA)

Jenia Vassileva (IAEA, Member of the PiDRL Expert Advisory Panel, AT)

In 2014, the revised International Basic Safety Standards on Radiation Protection and Safety of Radiation Sources (the BSS) were published, jointly sponsored by the International Atomic Energy Agency (IAEA) and seven other international organizations. Diagnostic reference levels (DRLs) are recognized in the BSS as an important tool for optimization of radiation protection and safety. The BSS set to the government responsibilities for the establishment of DRLs, in consultation between the health authority, relevant professional bodies and the regulatory body. In setting such DRLs, account shall be taken of the need for adequate image quality. Such DRLs shall be based, as far as possible, on wide scale surveys or on published values that are appropriate for the local circumstances. The imaging procedures, for which DRLs are to be established, should be decided upon at national or regional level. They should also reflect the typical practice in the country.

The IAEA is in the process of development of a Safety Guide on Radiation Protection and Safety in Medical Uses of Ionizing Radiation, to provide guidance on fulfilling the requirements of the BSS with respect to medical uses of ionizing radiation. It is aimed primarily at end-users in medical radiation facilities, but also provides recommendations and guidance to referring physicians; to manufacturers and suppliers of medical radiological equipment; as well as to regulatory bodies, health authorities, and professional bodies. The Safety Guide will provide guidelines on establishment and use of DRLs. Special focus is made on optimization of procedures for paediatric patients subject to medical exposure.

IAEA is supporting countries/regions to establish and utilise their national DRLs, based on the equipment and practice in their country. This is particularly done through the Technical Cooperation (TC) program. The largest IAEA survey of paediatric CT practice and doses in 40 countries demonstrated large variation in doses and potential for optimization, and established international DRLs for paediatric CT, to be used by less-resourced countries. The current TC projects includes tasks relevant to the PiDRL project, aimed to support Member States in development of references doses at clinically acceptable image quality in diagnostic imaging, and to take actions on radiation protection of children.

It is expected that the PiDRL project outcomes will provide important contribution for the practical implementations of the international requirements on establishment and use of paediatric DRLs.

43 - World Health Organization (WHO)

Maria Perez (WHO, Member of the PiDRL Expert Advisory Panel, CH)

The new international radiation basic safety standards (BSS) are cosponsored by six UN organizations (IAEA, ILO, WHO, FAO, PAHO, UNEP) and two intergovernmental organizations (OECD/NEA and EC).

The new international BSS, as well as the new Euratom BSS, include a robust framework of safety requirements for medical exposures that explicitly addresses the establishment of diagnostic reference levels (DRLs) as a requirement for optimization of protection and safety of medical exposures. The international BSS identify roles and responsibilities concerning establishment and use of DRLs for medical imaging, including

governments, regulatory bodies, health authorities, professional bodies, registrants, licensees and other relevant parties. As part of the operational considerations for optimization of protection and safety, the new BSS require that the particular aspects of the optimization process for paediatric patients are considered. The international organizations that cosponsor the BSS are working to support the implementation of the new BSS in their Member States. In this context, the WHO is conducting a Global Initiative on Radiation Safety in Health Care Settings (RSHCS) aimed to engage the medical community towards the implementation of the BSS in medicine. This initiative brings together health authorities, international organizations, professional and scientific societies, patient associations and other stakeholders in concerted action to improve safety and quality in the medical uses of ionizing radiation. Under the areas of risk assessment, management and communication this initiative is currently focused on the implementation of ten priority actions identified in the so-called a "Bonn Call for Action". The action number 2 refers to enhancing implementation of optimization of protection and safety. It explicitly addresses the need to "ensure establishment, use of, and regular update of DRLs for radiological procedures, including interventional procedures, in particular for children". Under its Global Initiative on RSHCS, WHO fosters the establishment and use of paediatric DRLs worldwide, advocates for the inclusion of DRLs in the education and training programs for health professionals and incorporates the concept of DRLs in information products and communication tools to support risk benefit dialogue in paediatric imaging involving health care providers, patients, parents and general public. Promoting the use of paediatric DRLs is part of WHO's commitment to collaborate with relevant stakeholders and build global, regional and national partnerships to improve radiation safety culture in paediatric health care.

44 - Heads of the European Radiological Protection Competent Authorities (HERCA)

Jürgen Griebel (HERCA, DE)

Introduction: For the purposes of radiation protection regulation, it is assumed that there is no dose threshold below which radiation-induced risk does not exist and that any exposure, however small, gives rise to a probability of cancer later in life. For children, the concerns are even stronger due to their higher radio-sensitivity and their longer life expectancy. A further concern is that paediatric doses will exceed adult doses if the same exposure settings are used.

This calls for a specific approach in medical radiation protection. The cornerstones are the principles of justification and optimization. Within optimization, diagnostic reference levels (DRL) play a pivotal role. This is in particular valid for radio-sensitive groups of the population such as children.

The recently revised Euratom Basic Safety Standards Directive explicitly underlines the importance of DRLs by requiring the establishment, regular review and use of DRLs for radio-diagnostic examinations, as well as appropriate local reviews whenever DRLs are consistently exceeded. Finally, it states that special attention shall be given to medical exposures of children, and for procedures involving high doses to the patient, such as interventional procedures and computed tomography (CT).

The Role of HERCA: HERCA, the *Heads of European Radiological protection Competent Authorities*, was founded in 2007. It is a voluntary association in which the heads of the Radiation Protection Authorities work together in order to identify and discuss common interests in significant regulatory issues. The *HERCA Working Group on Medical Applications* (WGMA) covers all radiation protection issues concerning the medical applications of ionising radiation. Its activities include discussions, surveys, hosting stakeholder meetings and publishing position papers on key issues.

HERCA has no statutory role in relation to medical radiation protection in Europe. Nevertheless, HERCA can be a positive force in this field by:

- raising awareness on radiation protection issues,
- acting as a platform to identify such issues, to develop a common understanding and to explore common approaches,
- promoting good practices among its member countries,
- facilitating the involvement of important stakeholders,
- providing guidance where appropriate and feasible,
- being a resource for competent authorities in its member countries,
- acting as an interested stakeholder with the European Commission, and
- adding value to areas involving trans-boundary processes.

Conclusion: HERCA highly appreciates the PiDRL Project and, via its WGMA, is willing to support the important objectives of the project within the framework described above.

45 - Public Health England (PHE)

Sue Edyvean (PHE, Member of the PiDRL Expert Advisory Panel, UK)

Public Health England (and its predecessor organisations HPA and NRPB) has undertaken national audits of patient radiation doses over three decades. The results form national diagnostic reference levels (NDRLS) to aid in optimisation and protection of the patient.

Since 1985 five national dose audits in general diagnostic radiology, including interventional and dental, have been undertaken, falling into a regular pattern of 5 yearly intervals from 1995. Three audits in computed tomography (CT) have been carried out since 1989, with the latest published in 2014. Consistently run surveys at appropriate intervals enable a review of national trends over time.

Special attention to paediatric doses at PHE/HPA/NRPB began in the mid-1990s, resulting in the inclusion of paediatric dose data in the national audits, for CT in 2003 and for general radiology in 2005, continuing in subsequent surveys. Audits are based on examinations with regard to both clinical indication and body region. Values are collected within age classifications, however this is not without recognition of associated size variation with within age categories, and therefore size details were also requested.

Since the late 1980s implementation of UK legislation, from successive European Directives, has been embraced to the extent that every radiology department is associated with a medical physics service providing radiation protection and medical physics expertise for optimisation and local DRLs. Collaboration of radiology professional bodies (radiologists, physicists and radiographers) with PHE/HPA/NRPB has been key in establishing a national approach, with a protocol for dose audits, guidance for legislation implementation, and

for establishing and implementing local DRLs, thus ensuring ownership of process and outcomes.

This collaboration now continues with a new working party, consisting of PHE, radiology professional bodies, the UK Department of Health and key experts, brought together to address current issues and future strategies. Topics include priorities for future audits, protocol naming, use of dose data collection systems, and also standards for specialist audits to enable a process for establishment of NRDLs in these areas. Two such (adult) studies are already underway, and a further initiative is planned for the next national paediatric dose audit.

The value of a long term and consistent approach to national dose audits undertaken, overseen or co-ordinated, by a national body such as PHE, should not be underestimated. In addition, audits are facilitated, enhanced and enabled, by a collaborative approach with relevant - in this instance with paediatric specialisation - radiology professionals and professional bodies.

46 - Image Gently (Alliance for Radiation Safety in Pediatric Imaging)

Donald Frush (Image Gently, US)

Introduction: The Image Gently Alliance was created in 2007 and consists of both a consensus group of founding professional imaging organizations and, currently, nearly 100 professional medical and dental organizations/societies globally, representing over 1,000,000 health care professionals. The mission of the Alliance is *"...through advocacy, to improve safe and effective imaging care of children worldwide". Before that time efforts at education for radiation protection in imaging and image guided interventions for children were largely "local" (e.g., practice, regional, national, society), created by and intended for subgroups of relevant stakeholders using a variety of strategies.*

Purpose: the purpose of the Alliance was to create an infrastructure and marketing strategy that would provide for a successful, sustainable, and adaptable model.

Materials and Methods: The founding organizations consisted of the major stakeholders in diagnostic imaging: radiologists, technologists and medical physicists (SPR, AAPM, ACR, ASRT). Information is delivered through a website, other social media, through 6 modality-based campaigns (e.g., CT, nuclear medicine), presentations, document review, scientific publications, and media engagements. Information is intended for other imaging professionals, healthcare providers and patients, parents/caregivers. The Alliance governance is independent, and founding organizations have an equivalent voice. All individuals are volunteers, and funding is primarily from the founding organizations, based on organizational resources. No industry support is accepted (there was one unrestricted industry educational startup grant). The Alliance controls branding and has a program for presentations for Alliance activities. Alliance organizations pledge to uphold Alliance missions, support dissemination of information through their organizational communications, and help with relevant expertise when appropriate (e.g., publications, campaigns, response to inquiries). There are no Alliance membership fees. There is an annual Alliance meeting for all members held at the RSNA meeting.

Results: The Image Gently Alliance has, with the above strategy, attained national and international recognition and acclaim evidenced through presence at conferences, publications, and cooperation with developing and reviewing documents from regulatory and other guiding (e.g., accrediting) bodies such as the FDA, MITA, EPA, The Joint Commission, WHO, and IAEA. The Image Gently model is also a successful business model, and the model has served as a template for other organizations with similar missions (e.g., Image Wisely). There has been measurable impact on use, such as consensus guidelines for nuclear imaging in children through harmonization of multinational practices, for example.

Conclusions: The Image Gently Alliance has developed a successful and adaptable model for dissemination of information relevant to medical radiation protection for children, which can include DRLs.

ROUND TABLE 6:
European Diagnostic Reference Levels for Paediatric Imaging. The View of European Societies

Moderators: Maria Perez (WHO, Member of the PiDRL Expert Advisory Panel, CH), Sue Edyvean (PHE, Member of the PiDRL Expert Advisory Panel, UK)

47 - European Society of Radiology (ESR)

Peter Vock (ESR, CH)

Introduction: As consortium partner and coordinator of the project, the ESR fully supports the initiative of the EC to update existing values, to describe the methodology, and to derive new DRLs for paediatric imaging.

Purpose: While there is a general lack of up-to-date European imaging DRLs, this deficit is even more severe for children, due to the growth-induced variability and the delay in defining children-specific examination protocols. The ESR wants to improve this situation both during and after the PiDRL project.

Material and Methods: Radiation protection activities of the ESR follow the Bonn Call for Action of the IAEA and WHO as well as the EuroSafe Imaging Call for Action, a 12-point action plan. Both calls underline the importance of a holistic approach to radiation protection by promoting appropriateness in radiological imaging, maintaining radiation doses within diagnostic reference levels, using the ALARA principle, promoting the use of up-to-date equipment, strengthening research, empowering patients, and joining forces with various stakeholders, as practised during the PiDRL project.

Results: The joint efforts of the PiDRL project have collected existing scientific data on paediatric DRLs, defined the methodology for establishing paediatric European and shown the current deficits. Based on the methodological consensus reached through the project, it will be easier to collect representative samples even for rare examinations and the different paediatric growth stages and body habitus types. Paediatric European DRLs can be suggested for a rather small range of examinations, and often local or national DRLs have to substitute for representative European values. The growing support by dose management software solutions will technically enhance prospective data collections for DRLs.

Discussion: Defining paediatric European DRLs remains a major challenge, and methodological differences currently limit the generation of multinational data. The methodological consensus reached through the project will significantly improve this situation. The ESR has a strong commitment to making a further step by defining DRLs appropriate for specific frequent clinical indications, as purely anatomical modality-specific DRLs neglect the variable image quality levels required for different indications.

48 - European Federation of Radiographer Societies (EFRS)

Graciano Paulo (EFRS, PT)

The European Federation of Radiographer Societies (EFRS) represents 38 national societies from European Countries (100.000 radiographers) and 49 Universities (8000 radiography students). The role of EFRS is to represent, promote and develop the profession of radiography in Europe, within the whole range of medical imaging, nuclear medicine and radiotherapy.

In daily practice Radiographers play a key role in medical imaging procedures, acting as the interface between patient and technology. Radiographers are the pivot between referrers, patients, radiologists and therefore a key player in justification and optimisation. By being the final point of contact for the patient, they have the responsibility to guarantee the correct procedure to the right patient, while ensuring maximum optimisation and effective use of equipment.

Radiographers must keep to a minimum the radiation exposure to the patient, itself and other persons present at the time of the examination or treatment (EFRS Code of Ethics).

The European Union Council Directive 2013/59/Euratom, laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, gives to each Member State the responsibility to ensure that all doses due to medical exposure for radiodiagnostic, interventional radiology, planning, guiding and verification purposes are kept as low as reasonably achievable consistent with obtaining the required medical information (article 56.1). To achieve that desideratum Member States must establish, regularly review and use Diagnostic Reference Levels (DRLs) (article 56.2).

Establishing, regularly reviewing and using DRLs in all clinical practice settings is a challenging task for health care systems in general and medical imaging departments in particular, specially for the paediatric population, due to their anthropomorphic characteristics differences. Therefore EFRS strongly supports the initiative of the EU Commission in providing such an important tool as the European Guidelines on DRLs for Paediatric Imaging.

EFRS will strongly encourage their members (National Societies and Universities) to commit themselves in promoting the establishment, review and use DRLs in daily practice in each Member State, according to the referred Directive and Guidelines, with the firm objective to contribute to a harmonisation of good clinical practice in Europe.

49 - European Society of Paediatric Radiology (ESPR)

Catherine Owens (ESPR, UK)

The PiDRL project outlines the vital requirements for the use of new and updated DRLs within childrens' imaging, and the need for a novel, shared methodology across Europe in order to define them.

Consequently ESPR has participated in this project as a major stakeholder.

This project also underscores the special role of the paediatric radiologist, who has a pivotal role in optimization and best practice of all radiologic studies and procedures in children. Therefore ESPR is committed to play a pivotal leading role in creating awareness among all radiologists through education, to promote new surveys on dose exposure in children, and to propose optimized protocols and guidelines for usage across Europe.

There is an increasing public fear of adverse effects occurring as consequence of exposure to radiologic studies most especially among the parents of young children.

Therefore ESPR should also make evidence based information easily available for parents, to reassure them about the beneficial effects of justified and optimized examinations which are essential in the clinical care pathways in their children's health.

In conclusion commitment, awareness and clinical excellence should be the keywords and the goals for ESPR on this subject.

50 - European Federation of Organisations for Medical Physics (EFOMP)

Stephen Evans (EFOMP, UK)

The European Federation of Organisations for Medical Physics (EFOMP) was founded to foster and coordinate the activities of the professional medical physics organisations in Europe. The current membership (2015) includes 35 national organisations which together represent around 7,500 medical physicists and clinical engineers.

The European Union Council Directive 2013/59/Euratom (the Directive) identifies, with regards to patient exposures, that the medical physicist must have a high level of competence and a clear definition of responsibilities and tasks. The Directive also requires (Article 56.2) that, "Member States shall ensure the establishment, regular review and use of diagnostic reference levels for radiodiagnostic examinations, having regard to the recommended European diagnostic reference levels where available, and where appropriate, for interventional radiology procedures, and the availability of guidance for this purpose', and that the Medical Physics Expert (senior medical physicist) must contribute, in particular, to the process of optimisation of patient doses and the application and use of DRLs.

Due to the difficulty in establishing paediatric diagnostic reference levels (DRLs), these are only found in a relatively small number of countries and for a relatively small number of procedures. EFOMP believes the establishment of paediatric EDRLs is therefore extremely important and that medical physics organisations should adopt and encourage the use of the current proposals in the PiDRL consortium document by their members. In particular, medical physics organisations should encourage their members to: identify the paediatric examinations within their hospitals that should be included in the dose assessments for comparisons with the National and European DRLs; discuss and support the implementation of paediatric dose assessments with their radiology colleagues; and, provide data on dose assessments to a national database so that, where practical, National DRLs are developed and where this is not practical, compare patient dose assessments with the EDRLs.

The PiDRL document recommends that patient weights rather than age are used as the primary parameter for banding paediatric DRLs. EFOMP supports this initiative but also recognises the difficulty this may pose for some hospitals that currently do not weigh paediatrics nor have the facility for recording weights in their patient database. EFOMP therefore calls on the national member organisations to help drive through changes in radiology information systems to incorporate paediatric patient weights. Until such changes are made, it is recommended that medical physicists should encourage their radiology departments to manually record paediatric patient weights and then take responsibility for gathering and analysing such information.

Where it is found that the median doses measured are significantly greater than the corresponding EDRLs, the medical physicist should be closely involved in the optimisation process to reduce the paediatric doses in their hospital, taking into account the overriding need for the clinical information to be uncompromised.

P01 - Development of a valid consent policy for Radiological Imaging procedures in Irish (HSE) Hospitals

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Purpose: The issue of informed consent for examinations that expose individuals to ionising radiation stirs ethical, moral, legal and medical debate amongst professionals. In May 2013, a National Consent Policy (NCP) to guide staff in relation to implementation of consent was launched by the HSE. The principal objective of the study was to propose solutions to the problems, particular to, that of consent in radiology. These could be used to generate a comprehensive and cohesive consent policy. A single, standardised protocol would ensure a harmonised approach to the consent process. Findings of the study would have relevance outside the jurisdiction of the HSE.

Methodology: A comprehensive review of the literature and research relevant to this study was performed using a number of resources including Science Direct, Pub Med and Google Scholar. Areas of relevance identified in NCP particular to ionising radiation were thoroughly examined. From the literature the author identified key issues, namely: the lack of professional guidance to consent for radiology procedures, difficulties with communicating radiation risk, disseminating risk/benefit information and seeking consent is problematic, the type of consent to be sought is a complex concept, documentation of and responsibility for consent were frequently identified as issues of concern.

Results: Findings from the literature informed the design of protocol for informed consent in radiology. A standardised radiology consent policy was proposed and recommendations included, the need to form an alliance of professional bodies to meet the demands of consent. A "Risk Matrix" and "look-up-table" were designed as communication tools. A two-step process, for seeking consent involving prescriber and radiology professional was proposed. A "checkbox" system and "consent forms" for documenting consent were designed. Due to the ambiguity surrounding responsibility for consent, it was identified that legislative and litigious definitions are lacking and clarity is needed. In the interim, local classification of responsibilities is suggested.

Conclusion: The gaps between ideal theory and existing everyday practice in informed consent in radiology are evident. Further research in the field of consent to ionising radiation is recommended. In order to maintain respect for patient autonomy, preserve trust in our profession and to uphold moral, ethical, legal and professional high standards, effective communication with patients is key.

Keywords: Informed Consent, Risk Communication, Risk Ionising, and Consent Radiology.

P02 - Dose optimization and image quality in children's CT imaging using Adaptive Statistical Iterative Reconstruction (ASIR)

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Introduction: A new reconstruction algorithm, adaptive statistical iterative reconstruction (ASIR), has been introduced that effectively increases image quality by reducing noise and lowers radiation doses by up to 80%, depending on the imaging protocol and patient-specific factors.

Purpose: To evaluate dose reduction in pediatric head, chest and abdomen CT examinations, using different percentages of ASIR and assess the image quality.

Method and Materials: A GE BrightSpeed Elite 16CT scanner was used. A study with phantom took place, in order to investigate the effect of ASIR on dose and image quality A hundred and forty two patients from 0,5 to 15 years old (9,1± 4,6) underwent head, chest or abdominal CT examinations, according to age-based examination protocols, using Auto mA. During pre-scan protocol management, varying degrees of ASIR were applied to the same CT data set, such as 0%, 20%, 40%, 60%, and 80% ASIR, in order to record CTDIvol values from each set. Low dose protocols using 60% ASIR for head, (instead of the standard protocol 40%) and 80% ASIR for chest and abdomen (instead of the standard protocols 60%), were used and the effect of high ASIR setting on image quality was studied. The obtained anatomical images were assessed by physicians for: Image noise, Image sharpness and Diagnostic utility

Results: The average value of CTDIvol for different ASIR settings was estimated. A significant reduction of dose was found, according to the degree of ASIR and the protocol, from 21,2 to 82,3 %. For head examination, the use of 60% instead of 40% ASIR leads to an average dose reduction of 28,7%, while for chest and abdomen examinations the use of 80% instead of 60% ASIR, leads to an average dose reduction of 22,3 and 27,3 % respectively. Regarding image quality, the opinion of the physicians was that no qualitative differences were indentified. Election of high levels of ASIR, grater than 60%, gives the images an "artificial" look.

Conclusion: The high ASIR settings lead to dose reduction up to 80%. A reduction of the DRLs is also achievable. Settings in the range of 20-60% are generally used for most CT examinations, with the higher values used for young patients, who may be at higher risk from radiation exposure, for returning patients who require frequent imaging, and for low-dose protocols.

P03 - Impact of a chest radiography dose optimization program (DOP) in a Neonatology Department (ND)

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Introduction: Hospitalized newborns in a ND are often subjected to radiological examinations in order to diagnose diseases or to assess the positioning of medical devices. Being this group more sensitive to the harmful effects of the X-ray (XR), is of utmost importance to assess the effective dose (ED) of the radiological examinations performed and to optimize procedures.

ABSTRACTS - POSTER EXHIBITION

Objectives: To compare the ED of (1) radiographic procedures in male/female infants and premature/non-premature newborns, and (2) chest radiographs in hospitalized infants before and after DOP implementation.

To assess the impact of the chest radiographs DOP.

Materials and Methods: An epidemiological study has been conducted in a population of infants admitted to a ND of a general hospital for 12 nonconsecutive months. Data were collected before (P1) and after (P2) the implementation of a DOP. Aspects such as the position, exposure, collimation and recommendations for the use of lead shields were addressed. A total of 159 hospitalized infants were enrolled in the study (138 in P1; 21 in P2). For each radiographic examination applied potential (kV), current-time product (mAs), focus-detector distance (cm), FOV, gender, gestational age and infant weight were recorded. The resultant ED was estimated using PCXMC, a PC-based Monte Carlo program.

Results: 476 radiographs (thorax, abdomen and babygram) were registered in P1 with a mean ED of 51 ± 36μSv per examination (3-233) [50±31 (6-197) μSv in female infants; 56±43 (3-233) μSv in males; 49 ± 33 (2-233) μSv in premature; 57 ± 44 (10-233) μSv in non-premature].

There were 56 radiographs assessed in P2 [Mean ED=43 ± 41 μSv (4-272)].

The chest examination was the most common. 308 chest examinations were assessed (278 in P1; 30 in P2). The mean ED of chest radiographs was of 49 ± 33μSv (6-233) in P1 and 38 ± 47 (4-272) Sv, in P2. A reduction of 22.5% was observed.

Conclusion: Although a reduction in the ED in the chest examinations has been observed, the mean values of the ED remain high (as per the ACR Radiation Dose Assessment Introduction guideline) after the DOP implementation. This study results suggest a level 2 risk when the chest exam risk in children is quantified as 1 (below 30 μSv).

P04 - Enrollment to a Chest Radiography Dose Optimization Program in Neonatology Department

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Introduction: Hospitalized newborns in a ND are often subjected to radiological examinations so its optimization is of utmost importance. A DOP was developed to address aspects such as the position, exposure, collimation and recommendations for the use of lead shields.

Objectives: To compare the exposure parameters, the use of lead shields and collimation in hospitalized infants undergoing chest radiographs before and after DOP implementation in a NS.

To assess the adherence to the DOP by the radiology technicians.

Materials and Methods: An epidemiological study has been conducted in a population of infants admitted to a NS of a general hospital for 12 nonconsecutive months. Radiographic data [e.g. applied potential (kV), current-time product (mAs), focus-detector distance (cm), FOV, and the use of lead shields] were collected before (P1) and after (P2) the implementation of a DOP. DOP was presented to the target population (radiologic technicians) in four sessions and aimed to give guidance on positioning, exposure parameters, the use of lead shields and collimation.

The collimation of chest radiographs was assessed by two observers according to the exclusion of anatomical structures (1) of the skull; (2) below the 12th rib; (3) beyond the 1/3 proximal of the humerus. The assessment was performed quarterly. The chest exams were randomly selected to be assessed in one month of the quarter (one in, one out).

Results: 308 chest X-ray were assessed (278 in P1; 30 in P2).

A decrease in the variability of exposure parameters was observed after DOP implementation. The chest X-ray protocol compliance was of 50% (15/30) for mAs and 90% (27/30) for kV. The use of lead protection was only observed in 40% of the exams (12/30).

Regarding the collimation, 34 chest x-rays were evaluated (12 in P1; 22 in P2). A compliance increase was observed in all parameters, being the most evident the exclusion of the upper limbs (compliance increased from 20.1% to 45.5%) and abdomen (compliance increased from 8.3% to 34.1%).

Conclusion: Although the adherence to the DOP by the radiology technicians was considered reasonable some program compliance aspects were challenging, namely the decrease of the mAs, and more careful collimation.

P05 - Cone Beam CT radiation dose in paediatric diagnostic cardiac catheterization procedures

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Introduction: Cone Beam CT (CBCT) uses the flat_panel detector to acquire X-ray projections around the patient and get a volumetric image. In paediatric cardiology offers the ability to acquire high resolution 3D images of vascular volumes and the option of visualising complex spatial relationships from any angle. This option can have clinical benefits in planning and guiding surgical and non-surgical interventions. In some circumstances can even replace multidetector CT acquisition. Paediatric cardiologist need to know the radiation dose patient received when CBCT is used, in order to justify the use of this new imaging technique and optimise protocols.

Purpose: To establish local dose reference levels in paediatric diagnostic cardiac catheterization procedures with cone beam CT acquisitions

Material and Methods: During 2009-2014 radiation dose data were collected for 68 paediatric patients who were undergoing diagnostic catheterization procedures with CBCT acquisition. Air Kerma-area product (Pka), reference air kerma at the patient entrance reference point (ka,i,rp), number of cine frames and duration of fluoroscopy were recorded.

Results: Proposed local reference values for diagnostic cardiac procedures with CBCT acquisitions are provided by age and weight ranges and the contribution of the CBCT is studied. The percentage increase in the 75th percentile value of Pka and Ka,i,rp due to CBCT were 19% and 8,3%.

Conclusions: The associated radiation dose due to CBCT should be considered. The local reference dose levels presented can contribute to the establishment of paediatric reference levels for cardiac fluoroscopically guided procedures.

P06 - Proposal of local diagnostic reference levels based on air kerma-area product values for paediatric conventional X-ray thorax examinations

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Introduction: Conventional X-ray examination of the thorax is a common paediatric examination and there are follow-up patients who undergoes several thorax examinations during childhood. Since radiosensitive organs such as the lungs are exposed it is important to analyse patient doses and introduce diagnostic reference levels (DRLs).

Purpose: The aim of the study was to analyse air kerma-area product (KAP) values from paediatric conventional X-ray examinations of the thorax in order to establish DRLs.

Materials and Methods: Examination data from 55 paediatric conventional X-ray examinations of the thorax at the Queen Silvia Children's Hospital in Gothenburg, Sweden, were collected retrospectively. Each standard examination included a frontal and a lateral projection, and the total KAP-value was registered. The scan protocols were age-dependent and in total there were 12 patients in the group of 2-5 years-old, 16 patients in group 6-10 years-old, 20 patients in group 11-15 years-old and 7 patients in group 16-18 years-old. The examinations were performed on three different conventional X-ray units during 2012 to 2014: Arcoma (Mediel, Sweden), Adora (Mediel, Sweden) and Triathlon (Mediel, Sweden). All examinations were performed with automatic exposure control, either in a wall stand or on a radiographic table. Digital Canon CXDI detectors with either GOS (Gd_2O_2S:Tb) or caesium iodide (CsI) as scintillator materials were used. The exposure parameters differed between the three X-ray units.

Results: The average total KAP-value of the standard thorax examinations in the different age groups were: 25±13 mGycm2 (mean±1 standard deviation) for the 2-5 years-old with mean body weight of 16 kg, 48±25 mGycm2 for the 6-10 years-old (mean weight 30 kg), 83±46 mGycm2 for 11-15 years-old (mean weight 49 kg), and 165±41 mGycm2 for 16-18 years-old (mean weight 71 kg). The third quartile of the total KAP-values were: 32 mGycm2 for the 2-5 years-old, 58 mGycm2 for the 6-10 years-old, 98 mGycm2 for the 11-15 years-old and 165 mGycm2 for the 16-18 years-old. The KAP-values from the Triathlon equipment were generally lower compared to the two others.

Conclusions: Since the KAP-values increased with patient size the DRLs must be specified for different sub groups, preferably based on age. The KAP-values varied depending on the choice of equipment and protocol, and they also varied between patients with similar body weight examined on the same X-ray unit. Due to these variations, the third quartile of the KAP-values in each age group is proposed as paediatric DRL for conventional X-ray thorax examinations.

P07 - Low Dose CT of the Paranasal Sinus

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Introduction: Sinusitis is a well known pathology that affects between 10% and 30% of the population in both U.S. and Europe. In the pediatric population is often a consequence of an upper tract respiratory infection and it can origin orbital complications. Computed Tomography (CT) is the most reliable test on identifying and staging the inflammatory disease of the paranasal sinus. Because of its reliability CT is commonly used both in the diagnostic and staging of acute and chronic sinusitis, leading to a significant exposure to the patient. Performing CT scans repeatedly within a short interval of time in a pediatric patient increases the risk of both deterministic effects of radiation (eg. falls) as the stochastic effects of radiation (eg. cancer). Therefore it is of high relevance to adopt low-dose protocols for carrying out such monitoring evolving over time in order to achieve the diagnosis/clinical objective, and minimize exposure to x-radiation to which children are submitted. For this reason the implementation of a low dose ct protocol is mandatory when scanning pediatric patients.

Purpose: The aim of this paper is to evaluate the implementation of the low dose ct protocol for evaluation the pediatric population in Hospital D. Estefânia, and to determine where it can be improved.

Materials and Methods: For this study we reviewed 6 months of our PACS system and analyse all the Sinus CT exams in order to determine indications, image quality and radiation exposure. With these data, we have carried out a comparison of the radiation dose results delivered to the patients in order to identify the contribution of the application of the low dose Sinus CT protocols.

Results: The data obtained provided us a general panorama of our sinus ct exams and by analysing DLP values we can compare it with European DRL's. Images from the low dose protocol show more noise but retain diagnostic value.

Conclusion: Sinus CT is currently the gold standard for diagnose and stage the acute and chronic sinusitis. The images obtained with low dose protocol Low Dose Sinus CT represents a evolution that can add to the diagnostic value, the savings in radiation exposure to sensitive organs, such as the eye, particularly in pediatric patients.

P08 - Diagnostic Reference Levels for Port Catheter Implantation in Paediatric Patients

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Introduction: Long-term central venous access is increasingly demanded in order to meet the requirements of more complex intravenous therapy, especially in oncological patients. Port catheter implantation was regarded in the beginning as a surgical procedure, but it has become nowadays a common practice in interventional radiology departments, thus reducing procedural complications in comparison to the standard surgical procedure.

This practice has been established at a paediatric hospital in 2010. Despite the procedure is simple and implies low radiation dose to the patient, it is by far the interventional procedure

ABSTRACTS - POSTER EXHIBITION

most frequently performed at this facility, so it is mandatory to estimate paediatric patient doses.

According to Directive 2013/59 Euratom, interventional and paediatric procedures are considered special practices, where optimization is even more critical. Member States shall ensure, especially on those procedures, the establishment, review and use of diagnostic reference levels (DRLs). Low-complexity interventional procedures are generally neglected and there are no published DRLs in paediatric patients.

Purpose: The aim of the study is to estimate paediatric patient doses in port catheter implantations, in order to establish diagnostic reference levels (DRLs) as a tool of optimization in radiation protection.

Materials and Methods: The study has been performed at a paediatric hospital. Procedures are conducted at a Toshiba Ultimax-i unit, focused mainly on low –complexity interventional procedures. Procedures are performed in posteroanterior (PA) projection at the thoracic region. Dosimetric and patient information of the patients have been recorded, including dose area product (DAP), fluoroscopy time and age.

Median DAP and percentile 75 in cGy.cm2 have been calculated for four different standard ages: 1 year, 5 years, 10 years and 15 years. Provisional DRLs have been proposed for these ages median of the DAP (mGy.cm2).

Results: Data analyzed show that there are no significant differences in fluoroscopy time for different age groups, showing that time spent depends more on radiologist's skills than on patient size. DAP increases with patient age as expected, for it depends strongly on the imaged area and patient thickness.

DRLs proposed for port catheter implantation are: 115 mGy.cm2 for 1 year, 315 mGy.cm2 for 5 years, 350 mGy.cm2 for 10 years and 715 mGy.cm2 for 15 years.

Conclusion: Although registered DAPs are low compared to other fluoroscopically guided procedures in children, these values must be reviewed regularly, as new Directive states, in order to optimize medical and occupational exposures in paediatric x-ray examinations.

P09 - Review of Dose Reference Levels in Paediatric Multidetector Computed Tomography

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Introduction: Computed Tomography (CT) represents the greatest contribution to collective effective dose due to medical examinations. Multidetector CT (MDCT) units have supposed a great advance, nevertheless this technology could imply an increase in patient doses although they incorporate new strategies to reduce them. Radiation dose assessment is especially important in paediatric patients, due to their long life expectancy and great radiosensitivity. New Directive Euratom 2013/59 considers CT procedures as high-dose practices, which require especial attention in radiation protection optimization. Review of diagnostic reference levels (DRLs) is a key tool in MDCT dose optimization, particularly on paediatric patients.

Purpose: The aim of this study is to review existing DRLs in a paediatric facility after installation of a multidetector computed tomography unit.

Materials and Methods: The study has been performed at a paediatric CT facility, with Philips Brilliance CT of 64 detector rows. Protocols are adapted for paediatric patients based on an optimization of diagnostic image quality. The most frequent examinations performed have been included in the study: spiral chest CT and axial head CT.

DRLs proposed have been calculated as the median Dose Length Product (DLP) and the median volumetric Computed Tomography Dose Index (CTDIvol) for four different standard ages: 1, 5, 10 and 15 years.

Results: The proposed DRLs for head CT are, in terms of CTDIvol: 35 mGy for all ages. In terms of DLP, proposed values are 415 mGy.cm for 1 year and 450 mGy.cm for the rest age groups. These results reflect that head sizes are almost the same for children above 2 years.

For spiral chest CT, proposed DRLs are 2.4, 2.5, 2.7 and 4 mGy in terms of CTDIvol; 54, 58, 75 and 124 mGy.cm in terms of DLP.

The estimated data have been compared with previous established DRLs (EU 2000) for axial head CT and spiral chest CT protocols. A stable behaviour has been observed in head CT DRLs, since sequential protocols used have not suffered noteworthy changes. On the other hand, chest CT DRLs have experienced a significant reduction in a factor that ranges from 4 to 8 depending on the age group. This reduction is strongly linked to dose-saving technology implemented in modern MDCT.

Conclusion: MDCT Technology has allowed a significant dose reduction in helical CT procedures. Dose optimization in axial procedures would require new strategies such as Iterative Reconstruction Algorithms.

P10 - Estimation of pediatric radiation doses from abdomen-pelvis CT examinations utilizing age-specific scanning protocols

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Introduction: CT scan is the examination of choice for the detection and the follow up of various paediatric diseases. However the radiation burden involved to the CT examinations should be seriously taken into account for this patient group as they are more susceptible to radiation-induced risks than the adults owing to their more rapidly growing tissues, their wider and increased cellular distribution of skeletal active marrow, and their greater post-exposure life expectancy. For that reason, calculation of paediatric radiation doses is vital in order to better understand the potential radiation risks of this modality.

Purpose: The purpose of this study is to calculate the radiation doses from pediatric patients underwent upper abdomen -pelvis CT examinations using a 16-slice multi-detector CT and to estimate the associated cancer risk.

Materials and Methods: A cohort of 35 pediatric patients scanned with abdomen-pelvis CT protocol using an iterative reconstruction algorithm (IR) at the Ag. Sofia General Pediatric Hospital was included in this study. The patients were categorized into 4 age groups: 0-1 yr, 1-5 yr, 5-10 yr and 10-15 yr. For each patient, the somatometric characteristics, the exposure settings, and the dosimetric data as displayed in the console (CTDI and DLP) were recorded. The effective diameter of each patient was also measured at the level of umbilicus. Then, the Size specific dose estimator (SSDE) was calculated taking into account the different diameters of the pediatric patients. Effective dose was

also estimated using the age-dependent DLP conversion factors and the radiation risk was calculated as well.

Results: The mean effective doses from the abdomen-pelvis CT procedures for the 0-1 yr, 1-5 yr, 5-10 yr and 10-15 yr age groups were 3.79±1.16 mSv, 3.30±1.91 mSv, 2.57±1.31 mSv, and 5.01±2.04 mSv, respectively corresponding to lifetime cancer mortality risks of 0.048%, 0.039%, 0.031% and 0.047%. The SSDE values were 6.65±1.10 mGy for the first, 4.74±1.64 mGy for the second, 5.28±1.65 mGy for the third, and 8.02±2.30 mGy for the last age group.

Conclusion: The study concluded that the use of IR algorithm enabled significant dose reductions compared to that reported in literature. Furthermore, especially for the newborns (0-1y group) the received dose was underestimated as it seemed from the SSDE results.

P11 - Protocol and Size Specific DRL for pediatric CT: a local approach

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Introduction: The extreme variability of size and radiosensibility of pediatric patients, including local approach to explain examination, are the mean limitations to the definition of DRL in pediatric radiology

Purpose: We tried to individuate useful DRL for pediatrics giving also a more "real" pre-exam indicator of patient dose (SSDE).

Materials and Methods: We analyzed 3 years of pediatric CTs collected by Dosewatch (GE Medical Systems) individuating homogeneous groups for age and size. We analyzed CTDI, DLP, SSDE factor; age range (0-5, 6-10, 11-16yr). Using average and SD of above parameters we selected subgroups considering body part scan (head, thorax, abdomen, thorax-abdomen) and protocol (surrogate of clinical indication). We extracted also the SSDE factor for each sub-group analyzed.

Results: Head scans are homogeneous, with an average CTDI of 17mGy with SD of 3mGy, SSDE factor is 1.09 (0.12 SD) with difference only for neonatal protocol (CTDI 7.41 SSDE f 1.27). For the thorax average CTDI is 2.5mGy and SD 1.3mGy, analyzing for age the average varies lightly and SD decrease to 0.5mGy, for the SSDE f average is 1.50 and SD 0.5 regardless of age. Considering a sub division of age range, excluding oncologic protocols (higher in dose: 5mGy) mean values are less than 2mGy for smaller patients and more than 2.5mGy for bigger; CTDI SD decrease to 15% for 0-5y range and SSDE SD to 4%. For the abdomen we found the same feature, the global analysis gives a SD of 30%, splitting categories as above we reached the same values of the thorax for SD, the final average CTDIs are 3.5mGy for 0-5y patients and 3mGy for 6-10y; SSDEf SD is 5% for smallers but remains 30% for biggers. Thorax-abdomen exams have a mixed feature of the two specific protocol groups.

Conclusions: Dose levels in our clinical context are low but depends on clinical issue. To be really useful the DRL must be strictly close to the patient age/size and to the clinical indication, as said by results. Considering the low values of dosimetric index we chosen the 75% percentile as DRL. The huge size variability request a smart tool to individuate the correct dose level of each patient before the exam execution, the SSDEfactor per protocol/age results the smart (and reliable, considering the low SD) tool to get the correct dose level for each exam/patient in order to apply efficiently the pediatric DRL.

P12 - Dose assessment in Pediatric Head CT

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Introduction: The theme discussed in this paper relates the evaluation of pediatric dose in head computed tomography examinations.

The study aimed to determine if the doses used in head computed tomography scan in pediatric patients are appropriate in view of Reference Dose Levels applied in other countries.

Methodology: This study was conducted in the Department of Radiology of a public distrital hospital, using a sample of 535 patients under 15 years of age. These exams were performed with an equipment of 2, 6, and 16 cuts.

Results: As a result it was obtained mean values of Dose Length-product: <1 year, 469 mGy.cm; 1 to 5 years, 590 mGy.cm; 6 to 10 years, 720 mGy.cm and from 11 to 15 years old, 807 mGy.cm. Getting also the medium values from effective dose: <1 year, 4,04 mSv; 1 to 5 years, 3,48 mSv; de 6 to 10 years, 2,74 mSv and from 11 to 15 anos, of 2,58 mSv.

The values of dose-length product obtained from some groups are beneath the reference dose levels (6-10 and 11-15 years), however, until 5 years the values were above the recommendations. With these results we conclude that is very important to adjust the parameters of acquisition about the children age.

Conclusion: This theme is very important since the children have higher radiosensitivity. Therefore, this work identifies possible gaps and allows us to make a set of recommendations to optimize the dose in this type of examinations.

P13 - Dose evaluation in newborns at a Neonatal Intensive Care Unit

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Methodology: Over 3 months we collected data on exposure parameters of chest radiographs in the Neonatal Intensive Care Unit providing a sample of 24 elements. A total of 25 Radiographers were also questioned about who performed the exams and which technical parameters (kVp and mAs) were used depending on the weight of the baby.

Results: We calculated the values of Entrance Surface Doses resulting from the 75th percentile of the sample collected over 3 months (23.35 μGy) and from the Radiographers sample (28.12 μGy), did not exceeded the international limits. Meanwhile, it was found that the Entrance Surface Dose increased with the increase in the weight of children.

Conclusion: The results of this study were also compared with three previous studies. The values of the Entrance Surface Dose resulted from the average of this study (23.8 μGy and 24.38 μGy) only exceeded the results of a study which the Entrance Surface Dose was 20.0 μGy. We we can conclude that ESD in newborns is dependent on several factors including, changes in technical

parameters used, the focus-film distance and the attenuation of the x-ray beam exerted by the incubator.

P14 - CT scan dose reduction: An Optimization of acquisition protocols in Pediatric neuroradiology

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Introduction: The number of expositions have been increased due the growth of CT examinations performed annually in children, increasing the non desired potential effects of ionizing radiation. Especially in this population is imperative the optimization of examination protocols regarding the reduce of exposure.

Purpose: In radiological protection field the optimization of pediatric neuroradiology protocols, is needed, applying the best practices in patient safety which aimed an effective dose reduction while maintaining image quality.

Materials and Methods: In a Pediatric Hospital, using a multidetector scanner Emotion 6 (Siemens Medical Systems; Erlangen, Germany) this study aimed to assess if there was, or not, a dose reduction in pediatrics neuroradiology examinations through the comparison the dose descriptors (CTIvol and DLP) and technical parametrs (Kvp, mAs, exposure time and slice thickness), before (2012) and after (2013) of protocol's optimization.In this assessment were included.

In this assessment were included 1212 valid cases in 2012 and 1395 in the year of 2013 in children, range [0-18] years old. The examination types included were, CT brain, temporal bone, paranasl sinus, orbits and maxilloafcial. The database of department was checked.

Results: Through of ANOVA results there was differences, with Ps<0.05, between the two years regarding the CTDIvol reaching a 17,6% in dose reduction. The same result was obtained to DLP with a reduction of 12,4%. Concerning the acquisition time, there was changes between years. The results are statistically significant, Ps=0,001 having however a difference between of mean values (¬=130,7 mAs and 123,8 mAs) in 2012 and 2013 respectively.

For slice thickness, the results shown the mean differences at level of Ps=0,007. Regarding the kVp of tube, and comparing the two years, has differences with Ps=0,000 having been the mean values of 122,41 kVp to 2012 and 118,65 kVp to 2013. Applying the analysis by gender the differences were no significant regarding the CTDIvol. The nonparametric Spearman test shown correlations, however weak, between all variables and age range.

Conclusion: As a conclusion was very important to staff know what was the impact of the radiation protection practices and the dose reduction, in order to decrease the risk of radio-induce pathology in children. This study revealed an effective reduction in the CT dose levels in the neuroradiological studies.

P15 - Paediatric CT Dose survey in Andalusia

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Establishing protocols for children, after justification of the study, is the first step for dose reduction in paediatric CT. This Protocol Management and Review of Practice are clearly stated as essential activities in ensuring patient safety and acceptable image quality in the first AAPM Medical Physics Practice Guideline.

We intend to obtain a current status of CT procedures used in paediatrics in the autonomous region of Andalusia. We analyze the techniques available in the different systems of several public hospitals in Andalusia and conduct a comparative study of dose indicators in order to establish in a near future local reference levels for common procedures: head, chest, abdomen.

Technical data on regional paediatric CT practice in Andalusia are being collected in a significant number of public hospitals using a survey that includes the main protocol details and the CTDIvol and DLP for different examinations following that protocol. The mean, median, 75th percentile and standard deviation were calculated for the Radiation Dose Indices collected for each scenario and hospital and these values were compared among us and with published data.

No universal CT technique can be used with a variety of vendors CT scanners for either an adult or a given size paediatric patient. Protocols from one scanner to the next are not transferable unless the scanner's design, configuration and software revision are identical. We found that wide variations in technique and radiation dose exist for different hospitals in similar examinations. As expected, the CT protocol used dramatically affects the radiation dose received.

This study highlights that we have a clear deficit of structures work (monitoring working group Dose / Dose Indicators) to allow us to work continuously on record, analysis, monitoring of alert levels, and of course in the optimization of the procedures.

P16 - Optimizing protocols in radiology diagnostic procedures in neonatology

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For a patient admitted in a Neonatal Intensive Care Unit (NICU), it is very usual receive X-radiation (XR) during the admission. The mean number of studies that a newborn receives in this period is 5-10. This population is especially in risk of developing X ray related cancer. For this reason, we want to revise the technical parameters used aiming to reduce the dose level that we need to obtain these complementary exams to our Newborns.

A recording sheet was designed to record the technical data by technicians and to evaluate the image quality by pediatricians.

Entrance surface dose (ESD) for patient was measured indirectly by entrance surface dose measured in a phantom in all kV range with an ionization chamber. The population included all neonates admitted for a diagnostic radiography, in our hospital NICU. The

mean, median, 75th percentile and standard deviation were calculated for ESD for chest and abdomen and the results were 54,4 µGy and 58,5 approximately.

We obtain that DRLs for neonates in our hospital were lower than values reported by other studies such as European national diagnostic reference levels and similar than NRPB reference dose. But we observed that we can improve them using a high kVp and better collimation that also affected some exams in the NICUs.

P17 - Survey of Radiation Doses in Paediatric Radiography in Estonia

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Introduction: Medical exposure examinations are performed on the basis of patient's interests and the principles of radiation protection – the benefits must outweigh the radiation risk. This survey is based on the EC COUNCIL DIRECTIVE 2013/59/EURATOM, UNSCEAR report 2013 (Volume II) and supported by the statistic database.

Purpose: Present paediatric doses from conventional radiology for patients divided into different age groups and compare them with generally accepted practice.

Method and Materials: The study included retrospectively and prospectively selected DAP values for 644 young patients from two children hospitals. The radiation doses were collected during October 2014 to March 2015. The survey contains assessment of the paediatric doses using the DAP from the chest (AP/PA, LAT), skull (AP/PA, LAT), pelvis and lumbar spine (AP, LAT). The medical exposure examinations were performed using two DR and two CR devices. In one of the hospitals the collection of patient doses was performed retrospectively using the (PACS). During the examinations with one radiography the record form was fulfilled with the children weight/height data that allowed facilitating calculation ESD

Results: Adjusted examination settings for four radiography devices were different. Applied tube voltage potentials (kV), tube loading (mAs) and FDD (100-180 cm) for thorax PA/AP examination are greatly varied in all age groups. For patients < 1y, a tube voltage differed from 56,9 kV (median) in radiography 1 to 90 kV (median). During the survey the quality of image was also evaluated by responsible radiologist and all images were accepted, except one. The estimated 3rd quartile in terms of DAP in comparison with the European DRL for skull LAT projection the doses for both hospitals are lower than European DRL but for skull PA the DAP value exceeds European DRL up to 4 times. Measured DAP for thorax examination for all radiographies are greater than proposed in European countries up to 4 times. During the survey the radiography 2 was upgraded and flat-panel detector was replaced by a more sensitive that eventually affected to the dose results.

Discussion: The results show that the DAP is useful tools for a patient dose assessment and convenient to assess quality and optimization of a medical procedure. Estimated 3rd quartile for DAP very clear identify inadequate use of technique and needs for appropriate corrective action. Establishment of a program for collection and analysis of patient doses in a hospital give an good opportunity to raise an awareness about the optimization of medical exposure through the personal.

Conclusion: It is important to perform patient dose measurement in hospital, to increase awareness of medical staff about patient doses and their responsibility for optimisation of medical exposure.

P18 - Head CT Paediatric Diagnostic Reference Levels: analysing two different methods

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Introduction: Head CT examinations have been highlighted as the most frequent pediatric CT examination in several countries. Some studies have indicated that younger children are being exposed to similar CT dose index (CTDIvol - mGy) and dose length product (DLP - mGy.cm) values as older children, and adult's dose levels in cases where imaging protocols are not modified according to the patient size.

Purpose: Establish and compare local Diagnostic Reference Levels (DRLs) for head CT examinations for two different age categorisations: the traditional (0, 5, 10 and 15 years old) and the new guidelines age categorisation suggestion (less than 4 weeks, 4weeks to 1 year, 1 to 6 years old, more than 6 years old).

Materials and Methods: Digital Imaging and Communications in Medicine (DICOM) headers of 132 head CT examinations available on Picture Archiving and Communication System (PACS) were retrospective analysed. Diagnostic Reference Levels (DRLs) were established based on the 75th percentile CT values.

Results: The obtained DRL's values in terms of CTDIvol for the traditional method were 48, 45, 50 and 60mGy, respectively for 0, 5, 10 and 15 years old. For the new guidelines categorisation the obtained values were 48, 48, 48, 49 and 57mGy for children with less than 4 week, 4weeks to 1 year, 1 to 6 years old, more than 6 years old).

Conclusion: The obtained values were similar for both categorisations indicating the need of optimisation of this procedure in order to obtained different dose values across that new age categorisation. The new method gives more detail for small children dose values however older children and adolescent dose values are analysed in the same categorisation.

LIST OF PRESENTERS