UDC 616-053.2:615.849.11
DOI: https://doi.org/10.17721/3041-1491/2024.11-10

Birutė GRICIENĖ[1,2], PhD, Assoc. Prof.
ORCID ID: 0000-0002-9224-6512
e-mail: birute.griciene@santa.lt

Leonid KRYNKE[1]
ORCID ID: 0009-0006-1580-6981
e-mail: leonid.krynke@santa.lt

Milda BAREIKĖ[1]
ORCID ID: 0009-0001-7676-4125
e-mail: milda.petkelyte@santa.lt

Antonio JREIJE[1], PhD Student
ORCID ID: 0000-0001-9774-9461
e-mail: antonio.jreije@santa.lt

Kirill SKOVORODKO[1], PhD
ORCID ID: 0000-0001-7517-4767
e-mail: kirill.skov@gmail.com

[1]Vilnius University Hospital Santaros Klinikos, Vilnius, Lithuania
[2] Vilnius University, Vilnius, Lithuania

TOWARDS GOOD PRACTICE IN PATIENT DOSE MANAGEMENT IN PAEDIATRICRADIOLOGY

Introduction. ***Diagnostic and interventional X-rays represent a substantial portion of radiation exposure from artificial sources, with pediatric patients being particularly vulnerable due to their increased sensitivity to ionizing radiation. This study aimed at assessing radiation exposure in children undergoing interventional radiology (IR) procedures and computer tomography (CT) scans at Vilnius University Hospital Santaros Klinikos (VUHSK), Lithuania's second-largest hospital, and to establish local Diagnostic Reference Levels (DRLs) to ensure optimized dose management.***

Methods. ***Data from pediatric IR and CT procedures conducted between 2021 and 2023 were analyzed, with local DRLs set at the 75th percentile of dose-related parameters such as Dose Area Product (DAP), Dose Length Product (DLP), Entrance Surface Dose (ESD), and Fluoroscopy Time (FT).***

Results. ***The findings reveal that pediatric CT doses at VUHSK are consistently below European DRLs, with reductions of up to 25 %, largely due to over a decade of ongoing patient exposure assessment and protocol optimization. Optimization efforts included adjustments to acquisition parameters. Despite the challenges of establishing separate local DRLs for each IR procedure due to limited sample sizes, age-based DRLs were developed to address the absence of routinely recorded patient weight.***

Conclusions. ***This study highlights the importance of continuous research in dose optimization and the need for local DRLs, especially for pediatric interventional radiology. The findings demonstrate that individualized optimization is crucial for maintaining low radiation doses without compromising diagnostic quality, and that establishing local DRLs is an essential step in ensuring patient safety.***

Keywords: ***DRL's, Radiation patient dose, Patient dose assessment, Pediatric Computed Tomography, Pediatric interventional radiology, Pediatric radiology.***

© Gricienė Birutė, Krynke Leonid, Bareikė Milda, Jreije Antonio, Skovorodko Kirill, 2024

Introduction

Diagnostic and interventional X-rays account for the largest portion of radiation exposure from artificial sources to the general population. Over the past two decades, the number of radiological examinations has risen significantly, leading to increased radiation exposure among patients (*United Nations Scientific Committee on the Effects of Atomic Radiation*, UNSCEAR) (UNSCEAR 2020/2021, 2021). Children are especially vulnerable to the effects of ionizing radiation due to their developing tissues and longer life expectancy, which increases their lifetime risk of cancer. As a result, it is crucial to carefully monitor and optimize radiation exposure during pediatric radiology, particularly in high-dose procedures including interventional radiology and computer tomography scans (European Council Directive 2013/59/Euratom, 2013). The heightened sensitivity of children to ionizing radiation makes dose management a priority in ensuring the safety and efficacy of diagnostic imaging.

Dose optimization strategies in pediatric radiology are essential for minimizing radiation exposure while maintaining diagnostic accuracy. These strategies include using age- and size-specific protocols, employing advanced imaging technologies that reduce dose (such as automatic exposure control and iterative reconstruction), and ensuring that exams are clinically justified. Additionally, careful collimation, and limiting repeat scans can further enhance dose reduction efforts. The integration of these methods ensures that each pediatric patient receives the lowest possible radiation dose while obtaining high-quality diagnostic images (European Council Directive 2013/59/Euratom, 2013). Moreover, Diagnostic Reference Levels (DRLs) have been introduced as an invaluable tool for monitoring and optimizing patient radiation exposure. DRLs are not strict dose limits but rather upper reference values that guide healthcare providers in optimizing patient doses without compromising diagnostic image quality (European Council Directive 2013/59/Euratom, 2013). By comparing administered doses to established DRLs, healthcare professionals can make informed decisions to reduce unnecessary radiation exposure, thus mitigating the risks of potential adverse effects.

However, effective dose monitoring remains a challenge for many healthcare facilities. Despite the critical importance of managing pediatric radiation exposure, only a limited number of hospitals have published comprehensive data on patient dose evaluations and the establishment of local DRLs. Many countries still lack DRLs for a basic set of common pediatric examinations, leaving gaps in radiation protection practices. In Lithuania, for example, despite legal requirements, there is an absence of national DRLs addressing Pediatric Interventional Radiology (PIR) procedures. This lack of national guidelines further complicates efforts to standardize dose optimization and safeguard young patients from unnecessary radiation exposure.

At Vilnius University Hospital Santaros Klinikos (VUHSK), Lithuania's second-largest hospital, a wide array of diagnostic, interventional, and nuclear medicine procedures are performed annually. Given the significant volume of pediatric radiology cases at VUHSK, implementing effective dose management strategies is essential to safeguard the health of pediatric patients.

The aim of this study was to evaluate radiation exposure doses in children undergoing interventional radiology procedures and CT investigations, set up local DRLs and check compliance with national diagnostic reference levels (DRLs) when available.

Methods

Data collection was conducted for computed tomography (CT) and interventional radiology (IR) procedures performed between 2021 and 2023. Retrospective CT datasets from head, thoracic, and abdominal-pelvic CT scans performed on children aged 0–17 years were analyzed. CT dose data was categorized by weight interval for thoracic and abdominal-pelvic procedures into the following groups: 5–14 kg, 15–29 kg, 30–49 kg, and 50–79 kg. While for head CT, data was grouped into age groups following two different intervals: < 1, 1 – < 5, 5 –< 10, 10 – < 15 and 15 – < 18 years as well as 0 – < 3 month, 3 month – < 1 year, 1 – < 6 year, 6 – < 18 years.

IR procedures were carried out using two angiography systems: the Shimadzu Trinias B12 and the Philips Allura Xper FD20. The following IR procedures were evaluated: Patent Ductus Arteriosus (PDA) closure (32 %), Pulmonary Artery (PA) balloon angioplasty and/or stenting (21 %), Coarctation of the Aorta (CoA) balloon angioplasty and/or stenting (19 %), Atrial Septal Defect (ASD) closure (14 %), Transcatheter Pulmonary Valve Replacement (TPVR) (5 %), Percutaneous Balloon Aortic Valvuloplasty (BAV) (5 %), and Percutaneous Balloon Pulmonary Valvuloplasty (BPV) (4 %). The dose data for these procedures were grouped by patient age into the following intervals: < 1 year, 1 – < 5 years, 5 – < 10 years, and 10 – < 18 years.

Local DRLs were established as the 75^{th} percentile of the distribution of dose-related parameters, depending on the type of diagnostic procedure. These parameters included Dose Area Product (DAP), Dose Length Product (DLP), Entrance Surface Dose (ESD), and Fluoroscopy Time (FT), in accordance with recommendations from the European Commission and the Radiation Protection Centre in Lithuania.

Results

It is recommended to compare established local DRLs against both national and European DRLs to assess the level of patient radiation protection at each hospital. However, Lithuania DRLs are not currently established for all radiological procedures included in this study, such as interventional procedures. While for some procedures, like thorax and pelvis CT, Lithuanian DRLs are categorized by age groups rather than weigh groups, further complicating direct comparisons. Despite these challenges, CT dose for head, thorax and pelvis-abdoman procedures were established (Table 1) and the data indicates that pediatric CT doses are generally low, with most falling well below European DRLs (Fig. 1) (European Commission, 2018).

The results can be attributed to over a decade of continuous efforts in patient exposure assessment and dose optimization at the hospital. Optimization measures included adjusting acquisition protocols for various procedures, such as reducing the X-ray source voltage, adjusting tube current time product (mAs), modifying pitch, and implementing iterative reconstruction techniques. For example, in routine CT head exams and thorax imaging for deformities, the X-ray tube voltage was reduced from 120 kVp to 100 kVp, and the tube current time product was optimized for each specific indication. As a result of these efforts, CT doses have steadily decreased, with head CT doses for the youngest patients reduced by approximately threefold

since 2010. Additionally, continuous training of practitioners and technicians in radiation protection has been instrumental in achieving these dose reductions and ensuring ongoing optimization of patient safety.

Table 1

CT doses reported as maximum, median, 3rd quartile values of DLP (mGy·cm)

Weightgroup	Numberofscans	Max	Median	Q3
Head				
<1	27	–	119	158
1–<5	55		215	265
5–<10	55	–	232	280
10–<15	51	–	275	327
15–<18	25	–	297	335
0–<3m	6		111	117
3m–<1y	21	–	140	175
1–<6y	75	–	228	270
6–<18y	111	–	269	323
Thorax				
5–14kg	13	58.7	34.7	38
15–29kg	43	91.4	49.3	60
30–49kg	71	163.3	85.9	107
50–79kg	75	420.1	139.1	153
Abdomen–Pelvis				
5–14kg	21	100.6	51.5	80
15–29kg	33	239.7	131.6	159
30–49kg	21	358.5	97.7	201
50–79kg	30	595.5	261.8	353

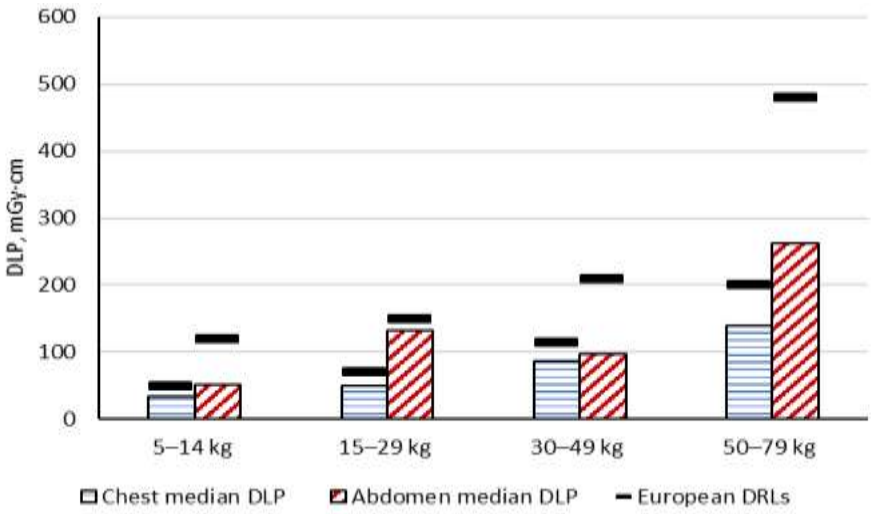


Fig. 1. Comparison of median DLPs with European DRLs

Due to limited number of pediatric IR procedures, it was challenging to establish separate local DRLs for each procedure since European Guidelines on DRL for pediatric imaging recommend a sample of ≥ 20 patients. Nevertheless, this issue is common across healthcare facilities and countries, contributing to the scarcity of published DRL data in pediatric interventional radiology and cardiology, making comparisons difficult (Fig. 1). To address this, all available data were combined to obtain a more representative sample. Radiation dose-related parameter reported as median, minimum and maximum value of ESD (mGy), DAP (Gy. cm^2) and FT (min) for each procedure are summarized in Table 2. In this study, pediatric IR DRLs were stratified by age rather than weight, as patient weight and height are not routinely recorded at the hospital. It should be noted that ICRP Publication 135 recommend categorizing pediatric DRL by weight, while suggesting the use of age-based categorization as an acceptable alternative when weight data are unavailable (Vañó et al., 2017).

Table 2

Dose indicators for combined IR procedures stated as the median, minimum and maximum value

Procedures	Patient Number	ESD(mGy)			DAP(Gy.cm^2)			FT(min)		
		Median	Min	Max	Median	Min	Max	Median	Min	Max
Total	168	66.21	3.17	3341.6	4.40	0.26	326.0	8.25	1.90	79.2
<1	35	31.00	9.30	415.1	1.35	0.26	17.3	9.09	2.75	79.2
1–<5	59	72.40	11.55	526.8	4.57	0.70	29.3	10.12	1.90	58.9
5–<10	32	59.12	9.50	224.8	3.70	0.58	12.8	7.18	2.21	34.1
10–<18	42	241.19	3.17	3341.6	13.00	0.30	326.0	7.46	2.20	68.4

Discussion and conclusions

Setting DRL can be a complex and time-consuming process, as it requires covering a wide range of diagnostic procedures across different hospital departments. At the European level, there are relatively few publications on pediatric DRLs, highlighting the pressing need for the establishment of national and local DRLs. These benchmarks are essential for identifying inconsistencies in radiation exposure between different equipment and ensuring that patient doses are kept as low as reasonably achievable. The radiation exposure values obtained from CT imaging in this study showed that optimization practices resulted in doses up to 25 % lower than European DRLs. This underscores the importance of individualized optimization for each piece of equipment and procedure type. For interventional radiology, the results revealed greater variation between procedures due to differences in case complexity and physicians experience, thus further complicating the task of dose monitoring and optimization. Overall, our findings demonstrate the critical role of continuous research in patient dose optimization. Establishing new national DRLs for Lithuania and developing local DRLs within hospitals should be an ongoing effort to ensure patient safety and maintain consistent radiation protection practices.

Authors' contribution. All authors participated in the study design, original text writing and performing the measurements. Birutė Griciene is the first corresponding author, she was responsible for methodology, data analysis, writing and reviewing the manuscript. Leonid Krynke was responsible for the methodology, data analysis, writing the manuscript. Milda Bareike contributed to the methodology, conceptualization, formal analysis and writing the manuscript. Antonio Jreije participated in data interpretation as well as writing the manuscript. Kirill Skovorodko edited the manuscript and provided useful comments and suggestions. All authors read and approved the final version of the manuscript.

References

European Commission. (2018). European Guidelines on Diagnostic Reference Levels for Paediatric Imaging. *Radiation Protection*, 185. http://www.eurosafeimaging.org/wp/wpcontent/uploads /2018/09/rp_185.pdf

European Council Directive 2013/59/Euratom. (2013). On basic safety standards for protection against the dangers arising from exposure to ionizing radiation and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/ Euratom. OJ of the EU. 2014; L13; 57: 1–73.

UNSCEAR 2020/2021. (2021). Sources, Effects and Risks of Ionizing Radiation. *Report to gneral assembly*, Vol. I.

Vañó, E., Miller, D.L., Martin, C.J. et al. (2017). ICRP Publication 135: Diagnostic Reference Levels in Medical Imaging. *Ann ICRP*, 46(1), 1–144. https://doi.org/10.1177/0146645317717209

Отримано редакцією збірника / Received: 11.09.24
Прорецензовано / Revised: 25.09.24
Схвалено до друку / Accepted: 23.10.24

Біруте ГРІЦІЕНЕ[1,2], д-р філософії, доц.
ORCID ID: 0000-0002-9224-6512
e-mail: birute.griciene@santa.lt

Леонід КРИНКЕ[1]
ORCID ID: 0009-0006-1580-6981
e-mail: leonid.krynke@santa.lt

Мілда БАРЕІКЕ[1]
ORCID ID: 0009-0001-7676-4125
e-mail: milda.petkelyte@santa.lt

Антоніо ЙРЕІЄ[1], асп.
ORCID ID: 0000-0001-9774-9461
e-mail: antonio.jreije@santa.lt

Кірілл СКОВОРОДКО[1]
ORCID ID: 0000-0001-7517-4767
e-mail: kirill.skov@gmail.com

[1]Лікарня Вільнюського університету Santaros Klinikos, Вільнюс, Литва
[2] Вільнюський університет, Вільнюс, Литва

ДО ПЕРЕВІРЕНОЇ ПРАКТИКИ УПРАВЛІННЯ ДОЗАМИ ОПРОМІНЕННЯ ПАЦІЄНТІВ У ПЕДІАТРИЧНІЙ РАДІОЛОГІЇ

Вступ. ***Рентгенівське опромінення під час діагностичних та інтервенційних процедур становить значну частину радіаційного опромінення від штучних джерел, при цьому педіатричні пацієнти є особливо вразливими через їхню***

підвищену чутливість до іонізуючого випромінювання. Це дослідження було спрямоване на оцінювання радіаційного опромінення дітей, які проходять процедури інтервенційної радіології (ІР) та комп'ютерну томографію (КТ) у лікарні Вільнюського університету Сантарос Клінікос (ЛВУСК), яка є другою за величиною лікарнею Литви, а також встановити місцеві діагностичні референтні рівні (ДРР) для забезпечення оптимізації дози.

Методи. ***Було проаналізовано дані педіатричних ІР та КТ процедур, проведених з 2021 по 2023 роки, з місцевими ДРР, встановленими на 75-му процентилі параметрів, пов'язаних з дозою, таких як добуток площа-доза, добуток довжина-доза, вхідна поверхнева доза і час флюороскопії.***

Результати. ***Отримані результати показують, що педіатричні дози КТ у ЛВУСК стабільно нижчі за європейські ДРР, зі зниженням до 25 %, головним чином через десятиліття постійної оцінки опромінення пацієнтів та оптимізації протоколу. Зусилля з оптимізації включали коригування параметрів накопичення. Незважаючи на труднощі встановлення окремих місцевих ДРР для кожної процедури ІР через обмежені розміри вибірки, були розроблені ДРР на основі віку, що усунуло відсутність регулярних записів ваги пацієнта.***

Висновки. ***Це дослідження вказує на важливість постійних досліджень з оптимізації дози та потребу в локальних ДРР, особливо для дитячої інтервенційної радіології. Результати демонструють, що індивідуальна оптимізація має вирішальне значення для забезпечення низьких доз опромінення без шкоди для якості діагностики, а встановлення локальних ДРР є важливим кроком у забезпеченні безпеки пацієнтів.***

Ключові слова: ***DRL, доза опромінення пацієнта, оцінювання дози пацієнта, дитяча комп'ютерна томографія, дитяча інтервенційна радіологія, дитяча радіологія.***

Автори Б. Гріціене, Л. Кринке, М. Бареіке, А. Йреіє та К. Сковородко заявляють про відсутність конфлікту інтересів. Спонсори не брали участі в розробленні дослідження; у зборі, аналізі чи інтерпретації даних; у написанні рукопису; в рішенні про публікацію результатів.

The authors B. Gricienė, L. Krynke, M. Bareikė, A. Jreije and K. Skovorodko declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; in the decision to publish the results.